Farm power availability for sustainable agriculture development in Punjab state of India

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Abstract: It has transforming from subsistence farming which was dependent on human and animals, to mechanized farming using inanimate power sources like tractors, diesel engines and electric motors. In Punjab agriculture, the human and animal power has substantially reduced from 7.5% to 0.69% and 73% to 0.61% respectively due to increase in mechanical power from 17% to 76 % and electrical power from 1.7% to 23.5% from 1960-61 to 2012-13. The intensity of farm power availability has increased from 0.37 to 5.68 kW/ha during the same period. Correspondingly there has been an increase in the cropping intensity (112% to 196%), production (3.16 to 28.58 mt) and productivity (668 to 3638 kg/ha) of total food grains.

Keywords: Farm power, farm energy, agricultural production, Punjab, India

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1 Introduction

The technological improvements in Indian agriculture since mid-sixties have brought about revolutionary increase in agricultural production. India's food grain productivity particularly in case of wheat and rice has also been increased with the increase in mechanization thus it is a good example for developing countries. The end objective of farm mechanization is to enhance the overall productivity, production and human comfort with the lowest cost of production.The contribution of agricultural mechanization has been well recognized in enhancing the production together with irrigation, biological and chemical inputs of high yielding seed varieties, fertilizers, pesticides and mechanical energy. The farm mechanization is dependent mainly upon the size of land holding, sources and availability of farm power. The pattern of farm size distribution in Punjab has been changing differently than in India mainly because of the differences in the mechanization of agriculture and the development of custom hiring services (Singh et al. 2013). The total land holdings declined from 13.75 lakh in 1970-71 to 10.52 lakh in 2010-11. Over the years, promotion of agricultural mechanization has been directed towards the promotion of eco-friendly and selective agricultural implements and machines with the aims of optimal utilization of the available sources of human, animal and mechanical/electrical power, removing the discomfort/fatigue associated with various agricultural operations. There has been a progressive shift from draught animal power to mechanical power in Punjab agriculture because animal power and manual labor were not sufficient to cope with the work load of intensive agriculture. Modest changes also occurred within each power source in terms of the quality and diversity of the tools and implements in use. Appropriate machinery has been adopted by the farmers to ensure timely field operations and effective application of various crop production inputs utilizing mechanical and human power sources.

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Proper use of mechanized inputs in agriculture has a direct and significant effect on production, productivity and profitability on agricultural farms along with labor productivity and quality of life of people engaged in agriculture (Clarke, 2000; Singh et al., 2003; Singh et al, 2006; Yadav and Lohan, 2006). Empirical evidence confirms that there is strong correlation between farm mechanization and agricultural productivity. Power availability per hectare is an indicator of mechanization. The growth in irrigated areas and tractor density has direct bearing on the productivity and cropping intensity. Findings of the studies conducted in the past highlighted the contribution of mechanization in enhancing the cropping intensity.

An effort was made to study the present status and trends of availability of farm power sources and productivity of Punjab state. This paper also discuss the relevant background information on population dynamics, status of availability of farm power sources, agricultural machines and equipment,correlation with production, productivity and cropping intensity.

2 Materials and methods

A concept of farm power availability per hectare basis was used to indicate the level of farm mechanization. The sum of manual and machine work has been considered to estimate the level of mechanization. Since 1960, time series growth pattern of farm power sources and their unit power of the state were determined. Farm power availability calculated from different sources of power, i.e. agricultural workers, animals, diesel engines, tractors, self-propelled combines. Total estimated power availability (kW/ha) was determined by multiplying the numbers to the power equivalents of particular power source per unit of net sown area of the state (Singh et al., 2002; Singh, 2006; Singh et al., 2012). The correlation between the farm power availability with the food grain production, productivity and cropping intensity was also determined from 1960-61 to 2012-13.

3 Results and discussion

3.1 Sources of farm power

3.1.1 Human power

Human and animal power, the two renewable energy sources have been used traditionally for crop production in Punjab as well as in Indian agriculture. Field preparation, sowing, transplanting, and fertilizer application, intercultural, spraying, harvesting and threshing operations are performed by agricultural workers. The percentage of agricultural workers to the total workers was 55.89% in 1960-61 and 62.67 % in 1970-71, which reduced to 35.96% in 2011-12 (Figure 1). But in absolute term, due to increase in population, the agricultural workers has increased from 1.93 million (516 per thousand ha) in 1960 to 3.55 million (835 per thousand ha) in 2000-01 and then further reduced to 3.04 million (731 per thousand ha) in 2012-13 (Table 1), however the percent of female agricultural workers has been increased from 11.4% to 29.0% from 1981 to 2011 (Figure 1).

Table 1 Population density of farm power sources in Punjab

Year	Agricultural workers		Draught animals		Tractors		Diesel engines		Self-propelled combine harvesters		Electric motors	
	Numbers, 000	Density, per thou and hectare	Numbers, 000	Density, per thousand hectare	Numbers, 000	Density, per thousand hectare	Numbers, 000	Density, per thousand hectare	Numbers, 000	Density, per thousand hectare	Numbers, 000	Density, per thousand hectare
1960-61	1937	516	2685	714.7	7.9	0.2	7	1.9	0.0	0	7	2
1965-66	2194	577	2685	706.0	10.6	3.0	26	6.7	0.0	0	20	5
1970-71	2452	605	1636	403.7	22.3	10.0	101	24.9	0.0	0	102	25
1975-76	3218	774	1670	401.6	67.7	16.0	304	73.1	0.0	0	196	47
1980-81	2859	688	1649	396.5	118.8	29.0	320	76.9	0.0	0	280	67
1985-86	3114	741	1649	392.4	173.1	41.0	221	52.6	1.0	0.2	441	105
1990-91	3370	800	1585	376.0	213.5	51.0	182	43.2	1.9	0.5	600	142
1995-96	3463	820	1521	360.2	320.5	83.0	175	41.4	2.2	0.5	750	178
2000-01	3555	836	436	102.5	407.1	96.0	288	67.7	3.0	0.7	845	199
2005-06	3647	872	436	104.2	420.4	100.0	275	65.7	8.0	1.9	971	232
2010-11	3555	835	382	89.7	443.3	104.0	226	53.1	8.1	1.9	1157	272
2012-13	3039	731	382	91.9	476.8	115.0	194	46.5	8.5	2.0	1191	287

Note: (Source: Statistical abstract of Punjab, 1975, 1981, 1995, 1997 and 2012, Statistical abstract of India, 1975, 1995, 2010; Census of India, 2011; Singh et al, 2002; Statistical profile on women labour, 2012; Dikshit et al. 2010; Chaudhary et al, 2012; Agricultural statistics at a glance, 2012)

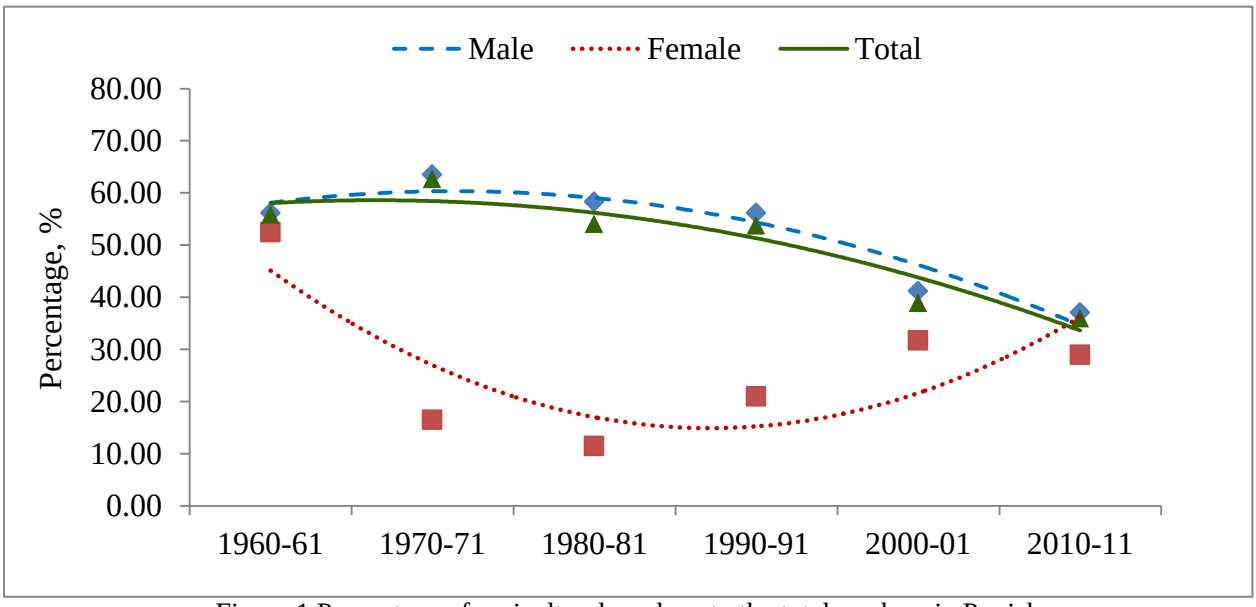

Figure 1 Percentage of agricultural workers to the total workers in Punjab

Several studies also indicated that net human labor displacement in agricultural operations was not significant and it was more than compensated by increased demand for human labor due to multiple cropping, more cropping intensity and higher productivity (Dixit et al, 2014;Sharma et al, 2014). The non-farm employment generated by mechanization provides employment through manufacturing of farm machinery, sale and purchase of spare parts, fuel and lubricants, repair and maintenance of tractors, engines and other machines. Thus, the marginal loss in direct farm employment resulting from farm mechanization was more than offset by non-farm employment in agro industrial activities, secondary and tertiary sectors of the economy.

3.1.2 Animal power

Draught animal power is a reliable and popular source of farm power in most developing countries. Bullocks, buffaloes, camels, horses, mules and donkeys are the major draught animal traction sources. Over the years, the contribution of draught animals has been going down. Before 1960-61, draught animals are the major source of motive power (tractive and rotary) and extensively used for crop production, water lifting, rural

transport, oil extraction, sugarcane crushing, chaff cutting and transportation. Tillage, irrigation and threshing operations are arduous to perform; these are gradually performed by mechanical power (Singh, 1992; 1996). They are born and reared in the village system and maintained on the feed and fodder available locally. Their dung and urine were also used as indirect source of energy as farmyard manure and biogas production.They also help in maintaining ecological balance. However, despite its growing popularity, farmers face several constraints such as rapid plough/share wear, high draught force and poor design of harness and other implements (Phaniraja and Panchasara, 2009). With the development of concrete roads connecting village and availability of electricity in the rural areas, most of the jobs are now being done using other convenient and cheaper options.

In Punjab, the population of working animals reduced in the last three decades. There had a continuous decline in the number of draught animals from 2.68 million (715 per thousand ha) in 1960-61 to 0.38 million (92 per thousand ha) in 2012-13 (Table1).But, the draught animal intensity or command area per pair animal of Punjab has been increased from 2.8 ha to 21.8 ha from 1960-61 to 2012-13. To ensure the timeliness in field operations, usually 1.5-2.5 ha per animal-pair is considered reasonable command area on net area basis. On all India average basis, the average command area was computed to 3.67 ha per animal-pair (Singh, 1999). This is because the need of timely and precisely application of crop production inputs are important factors to maximize return on input investments, increased cropping intensity and less availability of time between successive crops. In addition, more fatigue and increased cost of maintenance of draught animals has been a main cause of this trend.The contribution of animatepower has substantially reduced from 73% to 0.76% in the last 50 years (Figure 2).This shows that the additional need of farm power is being met through other sources of power, i.e. mechanical and electrical.

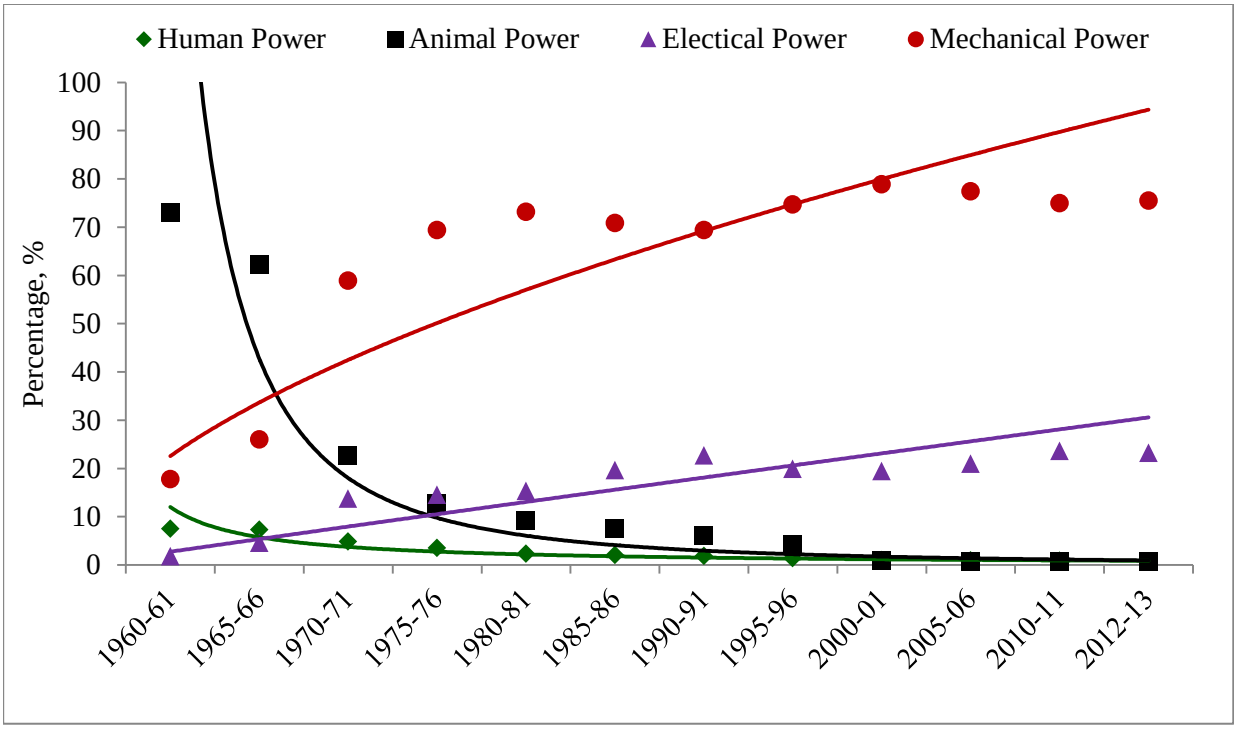

Figure 2 Percent contribution of various sources of farm power in Punjab

3.1.3 Mechanical power

Mechanical power is becoming indispensable for making an optimal use of other resources and in-time completion of various farm operations under intensive agriculture. Punjab agriculture transformed from subsistence farming to mechanized farming using mainly inanimate power sources like tractors, diesel engines, electric motors and self-propelled machines. A large number of farm machineries and equipments have been designed, developed, evaluated and tested by the Department of Farm Machinery and Power Engineering, Punjab Agricultural University (PAU), Ludhiana to meet the challenges of farm mechanization. The number of all types of farm machinery brought structural changes in the state (Table 2). In terms of gross cropped area, Punjab state has the highest density of tractors in India. In 2012-13, about 4.76 lakh tractors are being used on the cultivable land of 4.15 million ha as compared to only 79 tractors on 3.75 million ha in 1960-61. Alternatively, the net sown area per tractor was 447 ha in 1960-61 which was reduced to 8.7 ha in 2012-13.

Table 2 Time series growth of farm machines and equipments in Punjab

	1960-61	1970-71	1980-81	1990-91	1995-96	2000-01	2005-06	2010-11	2012-13
Tractors, 000	7.9	22.3	118.8	213.0	320.0	407.0	420.0	443.0	476.8
Disc harrows, 000	4.0	6.2	70.6	215.0	295.0	255.0	215.0	224.0	201.1
Rotavators,000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	8.7
Cultivators,000	0.0	18.2	95.0	195.0	235.0	285.0	290.0	380.0	460.0
Laser levellers, 000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	7.2
Seed cum fertilizer Drills, 000	0.0	18.0	45.8	100.0	130.0	180.0	160.0	183.4	175.3
Spray pumps, 000	0.0	60.0	125.4	435.0	485.0	555.0	600.0	655.0	625.0
Combine harvestors, 000	0.0	0.0	0.2	5.0	6.6	9.2	14.3	14.2	13.8
Reapers, 000	0.0	0.0	0.2	3.1	3.5	4.1	5.5	5.5	5.5
Straw reapers, 000	0.0	0.0	0.0	0.0	0.0	0.0	21.8	33.7	38.7
Threshers,000	0.0	76.0	245.0	297.0	305.0	350.0	350.0	740.0	660.3
Maize shellers, 000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.9
Potato planters,000	0.0	0.3	0.8	1.9	2.0	2.4	3.2	5.3	5.6

Note: (Source: Singh, 2006; Sharma et al, 2006; Statistical abstract of India 2010; Singh et al, 2013)

The tractor with higher horse power has the potential for maximum growth and will be the future requirement as the government's intention to encourage contract farming and custom hiring. The percent distribution of horsepower segment has been changed during the last one decade (Bector et al., 2008; Mandal, 2013). The percentage of tractors with 21-30hp and 31-40 hp categories has been reduced from 22% to 15% and 58% to 46% respectively during the year 1998-99 to 2007-08. Whereas, the category of 41-60 hp and >60 hp has increased from 19.5% to 37.5% and 0.2% to 1.6 % during the same period (Bhalla, 2010; Singh et al, 2013). Custom hiring of tractors by co-operative societies and individual farmers has been becoming popular for tillage, sowing, planting, harvesting, threshing and transport. Diesel engines which are used for stationary operations especially for lifting water for irrigation and operating grain mills, oil expellers, sugar cane crushers, power threshers and chaff cutters has been increased from seven thousand to 0.19 million during the last 50 years. Earlier, farmers used to spread chemical manually which caused several health hazards as well as ecological and environmental hazard. To minimize these hazards, and to make efficient use of chemicals, sprayers were developed. The estimated population of sprayers and dusters during 1970-71 was 6.0 thousand and has increased to 0.61 million in 2012-13.

The participation of farm women in agriculture is mainly for cutting the crop with the help of sickle and making bundles of the cut wheat plants. Hammer mill

and dummy thresher were the first type of thresher developed in 1970s, whereas for obtaining high capacity for threshing of wheat crop, chaff cutter type haramba thresher was developed in 1980.For paddy threshing, an axial flow thresher with cylinder having spike tooth was developed in 1984.Crop specific threshers, viz. Groundnut thresher, Moong thresher, Sunflower thresher, Maize sheller, Maize de-husker cum thresher were also developed.In 1970-71 the populations of threshers were about 76 thousand, which have tremendously increased up to 0.66 million in 2012-13. In 1970, PAU designed a tractor operated combine harvester suited to Punjab condition for cutting, threshing, separating and cleaning unit (Batta, 1970). During 1980, another milestone was achieved with the introduction of self-propelled combines (Randhawa, 1986). The number of combine harvesters (both tractor and self-propelled) increased from 200 in 1980-81 to 13,300 in 2012-13. Similarly, the number of other machines and implements has increased during the last two-three decades.

3.1.4 Electrical power

Electrical motors are the primary source of stationary power for irrigation, threshing and various post harvesting operations. Over the years, due to rural electrification, majority of the irrigation pumps are powered by electric motors and their size has increased due to decline of water table in many areas. As the electricity to rural areas for agricultural purposes in India is subsidized, most farmers either individually or jointly have installed tube-wells wherever ground water is available. The number of electric motor operated pumps increased from 6600 (1.75 per thousand ha) in 1960-61 to 0.119 million (287 per thousand ha) in 2012-13 (Table1). The trendsabove shows a substantially faster growth of electric motors which is due to higher efficiency, low maintenance and spread of rural electrification coupled with preferential power tariffs to the farmers.The government supports through financial incentives for irrigation hardware have played an important role in their popularization. Also decline in groundwater and higher horsepower motors for pumping water by submersible pumps has increased the power demand.

3.2 Trends of farm power availability and mechanization

Many researchers have studied the status of farm mechanization and power availability with reference to the intensity and its impact on increasing agricultural and labor productivity of the state and country. The farm power input per unit cultivated land in India is still very low as compared to South Korea (7 kW/ha), Japan (14 kW/ha) and United states of America (6 kW/ha) (Singh, 2006). The farm power availability of India was 0.22 kW/ha in 1960-61, which was increased to 0.73 kW/ha in 1990-91 and further increased up to 1.84 kW/ha in 2012-13 (Singh, 1999; Lohan et al, 2000; Srivastva, 2006; Singh, 2010; Singh et al., 2011; Sharma and Mukesh, 2013; Verma, 2006).In 1997, the highest farm power availability among the states of India was of Punjab state, i.e. 3.5 kW/ha (Singh et al., 2002; Singh, 2006; Mehta et al., 2014). Later in 2012-13 the power availability of Punjab state had reached upto 5.68 kW/ha due to which this Punjab state becomes the highly mechanized state in the country followed by Haryana, Uttar Pradesh, Andhra Pradesh and Tamilnadu states.

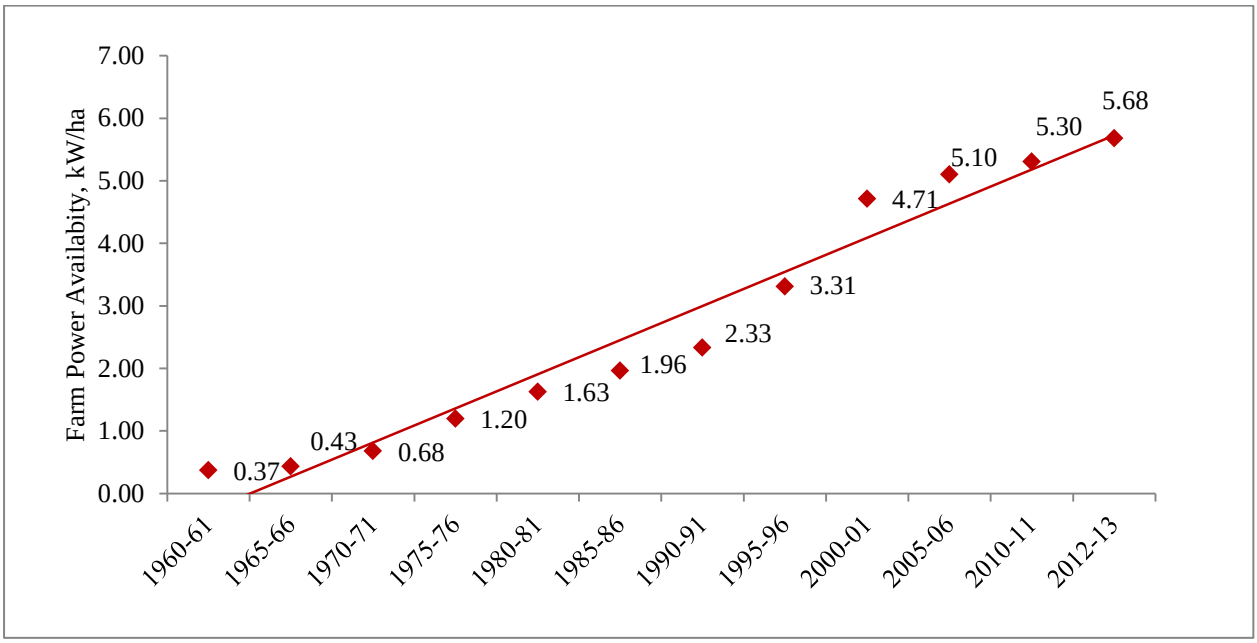

Figure 3 Increasing trends of farm power availability in Punjab state

The potential of power availability was used as the measure and could not reflect critical consistent of farm power availability during peak requirements or the actual level of use. Time series power availability of various farm power sources, i.e human, animal, mechanical and electrical power in Punjab state during the period 1960-61 to 2012-13 is presented in Table.3.

Table 3 Farm power availability of various sources in Punjab

Year	Human Power, 000 kW	Animal Power, 000 kW	Mechanical power, 000 kW)			Electric power,000 kW	Total power, 000 kW	Farm power availability, kW/ha
			Tractors	Diesel engines	Self-propelled combine harvesters			
1960-61	105	1020	208	39	0	24	1397	0.37
1965-66	119	1020	282	144	0	75	1639	0.43
1970-71	132	622	1054	566	0	377	2751	0.68
1975-76	174	635	1766	1702	0	725	4972	1.20
1980-81	154	627	3147	1792	6	1036	6762	1.63
1985-86	168	627	4581	1238	78	1632	8323	1.98
1990-91	182	602	5640	1019	149	2220	9812	2.33
1995-96	187	578	9268	980	172	2775	13960	3.31
2000-01	192	166	13431	2131	239	3887	20046	4.71
2005-06	197	166	13860	2035	618	4467	21343	5.10
2010-11	192	145	14619	1672	636	5322	22587	5.30
2012-13	164	145	15736	0.34	663	5480	23624	5.68

The contribution of human and animal power was 7.5% and 73% of the total farm power and mechanical and electrical contributed only 17.71% and 1.74% respectively in 1960-61. In 2012-13, the contribution from human and animal power reduced to 0.69% and 0.61% while the mechanical and electrical power increased to 75.5% and 23.2% (Figure 2).

The time series trends of power availability since 1960-61 were estimated (Figure 3) by linear function, with highly value of coefficient of determination (R^2) as following:

$Y = 0.546 X - 0.825$; $R^2 = 0.956$

Where, Y=Farm power availability (kW/ha); X=No. of 5 year interval after year 1960. Through this linear relationship, it is expected that the power availability

will reach to 6.68 kW/ha by the year 2020.

3.3 Impact of farm mechanization on food grain production, productivity and cropping intensity

Out of the total 5036 thousand hectare geographical area, the net sown area has been increased from 3.75 to 4.25 million ha during the last 50 years. The gross cropped area has also increased from 4732 to 7882 thousand ha during the same period. Farm mechanization has made significant contributions in enhancing agricultural productivity and cropping intensity.

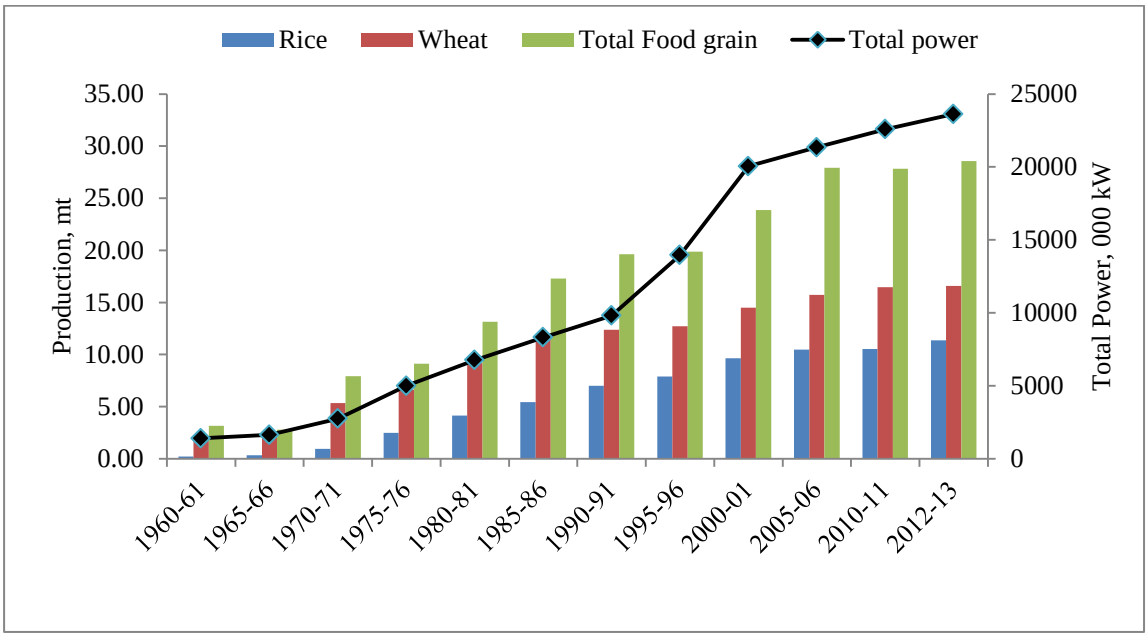

Figure 4 Trends of food grain production and total farm power available in Punjab

The productivity of farms depends mainly on the availability and judicious use of farm power by the farmers. As depicted from Figure 4, due to the increase in farm power availability (1397 to 23624 thousand kW), it has led to increase in the production of rice (0.23 to 11.37 mt), wheat (1.76 to 16.59 mt) and total food grains (3.16 to 28.58 mt).

The increase in farm power per hectare from 0.37 to 5.68 kW/ha led to increase in cropping intensity from 112% to 196% and total food grain productivity from 668 to 3638 kg/ha, especially in rice from 1009 to 3998 kg/ha and for wheat from 1230 to 5097 kg/ha respectively during the period 1960-61 to 2012-13.The relationship between farm power availability, total food grain productivity and cropping intensity for the period 1960-61 to 2012-13 were estimated by log linear function (Figure 5), with highly value of coefficient of determination (R^2) as following Equation 1 and Equation 2:

$$Y = 1074 \ln(X) + 1595; R^2 = 0.959 \quad \ldots (1)$$

Where, *Y*= Av. food grain productivity (kg/ha); *X*= Farm power availability (kW/ha)

$$Y = 27.12 \ln(X) + 147.5; R^2 = 0.948 \ldots (2)$$

Where, *Y*= cropping intensity (%); *X*= farm power availability (kW/ha)

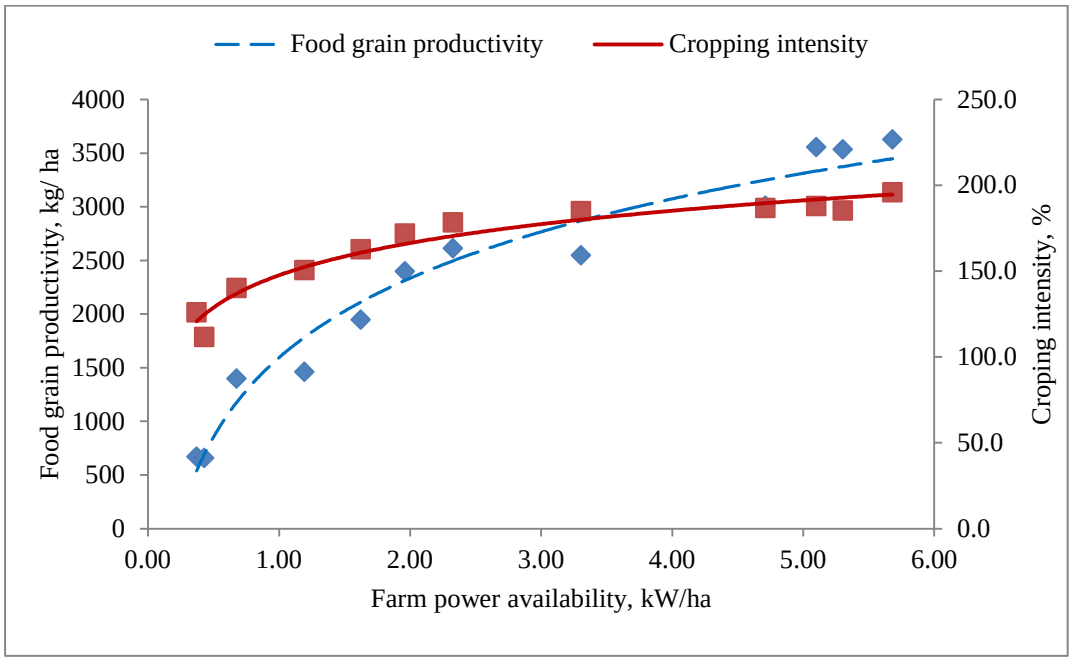

Figure5 Relationship between farm power availability and average food grain productivity

linearly. It also shows that farm power input has to increase further to achieve higher food grain production, the composition of farm power from various sources to be optimized to meet its timely requirement for various operations. As discussed in the previous section, by the year 2020 the estimated power availability will reach up to 6.68 kW/ha and correspondingly the total food grain production of 36.60 mt, with the productivity of 4306 kg/ha and cropping intensity of 212%.

3.4 Strengths, weaknesses, opportunities and threats (SWOT) analysis of farm mechanization programme in Punjab state

The SWOT analysis of farm mechanization program me in Punjab state has been presented in Table 4.

Table 4 SWOT analysis of farm mechanization in Punjab state

Items	Content
Strengths	• Assured irrigation facilities • High farm power availability, cropping intensity and productivity • Manufacturing hub in the state • Good liaison with farm machinery manufacturers • Eagerness of farmers to adopt new technologies
Weaknesses	• Degradation of natural resources (soil, water andenvironment) • Stagnation in the crop yield • Lack of standardization and quality control of equipments • Lack of mechanization in horticultural, vegetable crops
Opportunities	• Global market for need/farm size based machinery/technology • Decrease inflow of migrant labor • Liberal policy of government regarding subsidyand employmentgeneration • Capacity building of scientists/ engineers/manufactures/farmers • Eco-friendly environment
Threats	• Adequate exposure to farm machines • Poor quality of farm machines • Scarcity of farm labor • Climate change andSustainability of agriculture

The factors for strengthening of farm mechanization in the country may be numerous. Agricultural machinery and equipment industry comprises of a large number of segments even in the organized sector. Tractor industry is one of the most capital intensive industries in agricultural machinery with more than a half dozen major players in Punjab*viz. Standard, Swaraj, Sonalika and Preet Tractors.* More than 100 (95%) combine manufacturing industries of India are in Punjab. The other major parts of the industry are reapers, straw reapers, threshers, sprayers, sowing, planting and transplanting machines, rotavators, laser land levelers, disc harrows, cultivators, ploughs, horticultural equipments, diesel engines, irrigation pumps, chaff cutters and hand tools. PAU, Ludhiana has also established a large number of entrepreneurs and agro industries through product development and trainings, catering to whole of the country. Punjab State Agricultural Implements Manufacturers Association (PSAIMA) at state level and Tractors and Agricultural Machinery Manufacturers Association (TAMMA) of India were launched in 1989 and 2010 respectively.

There is a paradigm shift in agricultural policy to realize the goal of eco-friendly sustainable agriculture with reduced cost of production and high quality of produce. The time taken to perform sequence of operations is a factor determining the cropping intensity. So, considering timeliness of various farm operations, it is quite inevitable to use such mechanical equipments which have higher output capacity and cut down the number of operations to be performed. This will help in increasing cropping intensity, higher land productivity and reduced labor requirement. Development of resource conserving technologies (RCTs) with innovations in residue management to avoid straw burning, improving soil organic carbon, and having potential to reduce GHG emissions are required. Major bottlenecks in the current technology that needs attention are placement of seed at proper depth to facilitate germination in the no-tilled plots with residue retained on the soil surface is still a problem. Although a lot of improvement has been done in the zero-till seed-cum-fertilizer drill machinery, happy seeder technology, there is still a scope for further improvement to give farmers a hassle-free technology.

For diversification of agriculture by introducing new crops and cropping systems, there are ample opportunities to develop and introduction of new state-of-art farm tools and machinery for new crops and ventures especially for horticulture, floriculture and rain-fed. The equipments for operations are needed, i.e. cotton picking, sugarcane harvesting and vegetable harvesting. Establishing hi-tech an d high productive equipment hub for custom hiring is another opportunity for promotion and strengthening of agricultural mechanization in the state. This will also resultin providing employment opportunities, especially entrepreneurship for the farmers to improve their socio-economic status. Due attention towards the design of the tools/equipment/ work place using anthropometric data of farm women workers and other ergonomically principles for reduced fatigue, better human machine system efficiency and enhanced safety is also needed.

4 Conclusions

In order to make agricultural production competitive and cost effective, the use of mechanical and electrical sources of power will increase in future and the use of draught animals and human power will slowly be going down. There had been tremendous increase in the number of tractors, disc harrows, seed cum fertilizer drill, reaper, thresher, tractor operated combine and self-propelled combines since last 50 years. In 1960-61 major contribution (80.56%) in farm power was from animate power (human + draught animal), whereas in 2012-13 the major share was that of mechanical and electrical power (75.8%). Food grain productivity of Punjab state particularly in case of wheat and rice has been increased from 1230 to 5097 kg/ha and 1009 to 3998 kg/ha respectively along with the cropping intensity (112% to 196%) with the increase in the farm

power availability from 0.37 to 5.68 kW/ha during the last 50 years. The prioritized area of research with direct relevance to sustainability and diversification of agriculture in the state are precision and timeliness farming, resource conservation technologies, machinery for crop diversification, design of gender friendly machines and equipment, safety and comfort to the farm workers to reduce the hazards and fatigue.

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