COUNTRY REPORT: INDIA

INDIAN AGRICULTURE – AN INTRODUCTION

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By

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Indian Agriculture – an introduction

Agriculture has been the backbone of the Indian economy and it will continue to remain so for a long time. It has to support almost 17 per cent of world population from 2.3 per cent of world geographical area and 4.2 per cent of world's water resources. The economic reforms, initiated in the country during the early 1990s, have put the economy on a higher growth trajectory. Annual growth rate in GDP has accelerated from below 6 percent during the initial years of reforms to more than 8 percent in recent years. This happened mainly due to rapid growth in non-agriculture sector. The workforce engaged in agriculture between 1980-81 and 2006-07 witnessed a very small decline; from 60.5 percent to 52 percent.

The present cropping intensity of 137 per cent has registered an increase of only 26 per cent since 1950-51. The net sown area is 142 Mha. The net irrigated area was 58.87 Mha in 2004-05. Presently, the total net irrigated area covers 45.5 per cent of the net sown area, the remaining 54.5 per cent is rainfed. The degradation of land and surface as well as ground water resources results in fast deterioration of soil health. Losses due to biotic (insect-pests, diseases, weeds) and abiotic (drought, salinity, heat, cold, etc.) stresses account for about one-fourth of the value of agricultural produce. The storage, transportation, processing, value addition and marketing of farm produce need to be improved to enhance household food, nutrition and livelihood security.

Indian agriculture is characterized by agro-ecological diversities in soil, rainfall, temperature, and cropping system. Besides favorable solar energy, the country receives about 3 trillion m^3 of rainwater, 14 major, 44 medium and 55 minor rivers share about 83 per cent of the drainage basin. About 210 billion m^3 water is estimated to be available as ground water. Irrigation water is becoming a scarce commodity. Thus proper harvesting and efficient utilization of water is of great importance.

Intensive cultivation as a result of introduction of high yielding varieties in the mid 1960's required higher energy inputs and better management practices. Land preparation, harvesting, threshing and irrigation are the operations, which utilize most of the energy used in agriculture. The share of animate power in agriculture decreased from 92 per cent in 1950-51 to 20 per cent in 2000-01. For desired cropping intensity with timeliness in field operations, animate energy sources alone were no longer adequate. Farmers opted for mechanical power sources to supplement animate power.

Average size of farm holdings gradually reduced from 2.58 ha to 1.57 ha (Table 1). Small and marginal farmers have limited resources especially in rain-fed regions where only animate power is used resulting in low productivity. Though agricultural production is high, the per hectare productivity is much lower than world average. There is an urgent need to increase productivity.

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Smaller the farm, greater is the need for marketable surplus, so that small farmers can have a reasonable income. Achieving this goal will be possible only if we develop and disseminate eco-technologies rooted in the principles of ecology, economics, gender equity and employment generation. This is the pathway to an "ever-green revolution" in agriculture. The estimated food requirement in India and total production of major crops indicate that to keep pace with the present population growth and consumption pattern, food grain requirement has been estimated to be 240 MT by 2020 and 300 MT by 2025. Annual agricultural growth should be maintained at 6.7 per cent to meet these demand projections.

Table -1 Number and area of operational holdings by type of holding

Major size classes	Number, '000			Area, '000 ha		
	1981	1990-91	2000-01	1980-81	1990-01	2000-01
Marginal, <1 ha	50.122 (56.4)	63.389 (59.4)	76122 (63.0	19,735 (12.0)	24,894 (15.0)	30088 (18.82)
Small, 1-2 ha	16,072 (18.1)	20,092 (18.8)	22814 (18.9)	23,169 (14.2)	28.827 (17.4)	32260 (20.18)
Semi-medium, 2-4 ha	12,455 (14.0)	(13,923 (13.1)	14087 (11.7)	34,645 (21.2)	38,375 (23.2)	38305 (23.96)
Medium, 4-10 ha	8,068 (9.1)	7,580 (7.1)	6568 (5.4)	48,470 (29.6)	44,752 (27.1)	38125 (23.84
Large, >10 ha	2,166 (2.4)	1,654) (1.6)	1230 (1.02)	37,705 (23.0)	28,659 (17.3)	21124 (13.21)
All size classes	88,883 (100)	1,06,637 (100)	120822 (100)	1,63,724 (100)	1,65,507 (100)	159903 (100)

Note : Figures within parentheses indicate per cent contribution

Non-availability of manpower during peak crop season is many times a problem. The overall achievement in the creation of irrigation facilities has been relatively better in India with 63 per cent growth rate compared to the world average. There is a need to increase the utilization of rainwater to enhance the gross cropped area by 30 Mha as the yield of food grain in irrigated areas is almost twice that in rain-fed agriculture. Per capita availability of food grains has declined from 510 g per day in 1990 to 436 g in 2003 and this trend has to be arrested. The infrastructure for agricultural diversification, reducing post harvest losses of perishables, value addition to agro-produce and branding system needs to be strengthened.

Agricultural Production and Productivity

The nation is striving to find ways and means to keep its burgeoning population adequately fed. On the one hand it is facing the problem of declining productivity and on the other, challenges posed by liberalization. In such a scenario, leveraging the available natural resources and existing infrastructure is the only way to make the ends meet. Management of the already built infrastructure in harmony with natural systems is the clarion call of the day. Knowledge of the extent of existing infrastructure and natural resources is one of the most basic pre-requisites to utilize them effectively and in a sustainable manner. The discipline of agricultural engineering endeavours to develop technologies for enhancing productivity and reducing the cost of cultivation. Traditionally animate power was used for field operations and processing activities. As a result of introduction of mechanical power, agricultural engineering activities have expanded considerably. To sustain the project population of 1.363 billion by 2025 the productivity has to be increased by 100 per cent from the present level by intensification of agriculture. It is estimated that the energy input to agriculture would have to be increased form the present level of 1.3 to 2.4kW/ha.

The constraints of low productivity in agriculture were realized and thus, central and state governments emphasized the need for accelerated development of agriculture. Adoption of high yielding varieties by farmers coupled with the use of higher doses of fertilizer and assured irrigation through tube wells accelerated the pace of progress in agriculture. As a result of adoption of improved inputs and management practices, the total food grain production increased from a mere 50.8 million tonnes in 1950-51, to 212 million tonnes in 2006-07 and productivity increased from 522 kg/ha to more than 1707 kg/ha (Table 2). The productivity of wheat, rice and oilseeds increased to a greater extent than other crops. The increase in production of food grain was possible as a result of adoption of quality seeds, higher dose of fertilizer and plant protection chemicals, coupled with assured irrigation. The growth in production of fruits (46 million tonnes), vegetables (91 million tonnes), milk (81 million tonnes), fish (57 million tonnes) has also increased. As a result, not only the country has achieved self-sufficiency in foods but have adequate agro-produce for export. Our agriculture is now at the crossroads (Table 3). The use of certified/quality seeds by the farmers has increased to 700,000 tonnes. The fertilizer consumption has increased to 21.65 million tonnes (more than 112.69 kg/ha) in 2006-07 from 0.29 million tonnes in 1960-61. It increased at an annual growth of 11.7 per cent. The use of technical grade plant protection chemicals has increased to 56.11 thousand tonnes (0.4 kg/ha) from a meagre of 8.62 thousand tonnes in 1960-61.

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 agricultural productivity and profitability resulting in higher income for farmers and better quality of life.

Table 2 Production and productivity in agriculture

(Area: million ha, Production & Consumption: million tonnes, Yield: kg/ha)

Crop		**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07** (Provisional)
All food grains	Area	121.05	122.78	113.86	123.45	120.00	121.60	124.07
	Production	196.81	212.85	174.77	213.19	198.36	208.60	211.78
	Yield	1626	1734	1535	1727	1652	1715	1707
Rice	Production	84.98	93.34	71.82	88.53	83.13	91.79	91.05
	Yield	1901	2079	1744	2077	1984	2102	2084
Wheat	Production	69.68	72.77	65.76	72.16	68.64	69.35	73.70
	Yield	2708	2762	2610	2713	2602	2619	2617

Crop		2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07 (Provisional)
Oilseeds	Production	18.44	20.66	14.84	25.29	26.10	27.98	23.26
	Yield	810	913	691	1067	967	1004	895
Sugarcane	Production	295.96	297.21	287.38	237.31	232.32	281.17	322.94
	Yield	68577	67370	63576	58986	63806	66828	66833
Pulses	Production	11.08	13.37	11.13	14.91	13.13	13.39	14.11
	Yield	544	607	543	635	577	598	594
Coarse cereals	Production	31.08	33.38	26.07	37.60	33.47	34.07	32.92
	Yield	1027	1131	966	1221	1153	1172	1158
Milk MT	Production	80.60	84.40	86.20	88.1	92.6	97.1	100..9
Fish	Production	5.66	5.96	6.20	6.40	6.30	6.57	6.87
Irrigated area, Mha		75.95	78.81	75.87*	77.94*	78.00*	80.00*	82.63*
Fertiliser consumption MT		13.88	17.36	16.09	16.80	18.34	20.34	21.65
Per capita availability of food grains (gms/day)		495.50	416.20	494.10	437.6	462.7	422.4*	445..3

Table 3 Global ranking of India in farm production and productivity

Crop	Production rank	Productivity rank
Paddy	2nd	30th
Wheat	2nd	22nd
Maize	7th	35th
Total cereals	3rd	36th
Groundnut	2nd	40th
Rapeseeds	3rd	28th
Pulses	1st	44th
Potato	4th	26th
Fruits	2nd (10 per cent share)	-
Vegetables	2nd (9 per cent share)	-

Farm mechanization

Mechanization is viewed as package of technology to (i) ensure timely field operations to increase productivity, reduce crop losses and improve quality of agro-produce (ii) increase land utilization and input use efficiency (iii) increase labour productivity using labour saving and drudgery reducing devices besides, being cost effective and eco-friendly. Appropriate machinery have been adapted by farmers for ensuring timely field operations and effective application of various crop production inputs utilizing human, animal and mechanical power sources. Diverse farm mechanization scenario prevails in the country due to size of farm holdings (average farm holding size 1.6 ha) and socio-economic disparities. Indian agriculture continues to be dependent upon human (agricultural workers population 234.10million in 2000-01) and draught animal power (27 million pairs). Hand tools and animal drawn implements are extensively used which involve a great amount of drudgery. Adoption of tractors has been on the increase. Sale of tractors during 2005-06 touched 292000 nos.

Mechanization indicator is one of the measures of modernization of agriculture of a country (Table 4). The availability of farm power or energy per unit area (kW/ha) has been considered as one of the parameters for expressing level of mechanization. Ratio of machine work and sum of manual and machine work has also been considered to estimate the level of mechanization. The unit farm power available from all sources (animate and mechanical power) increased from 0.20 to 0.90 kW/ha (on the basis of net cropped area) from 1950-51 to 1996-97. The ratio of tractive power to total farm power has increased from 0.82 to 32.25 per cent.

Table 4 Level of mechanization

Sl. No.	Operation	Percentage
1	Tillage Tractor Animal	40.2 15.6 24.7
2	Sowing with drills and planters Tractors Animal	28.9 8.3 20.6

3	Irrigation	37
4	Thresher- Wheat Paddy and others	47.8 4.4
5	Harvesting Reapers Combines	 0.56 0.37
6	Plant protection	34.2

A number of machines and equipment suitable for different farm operations suited to different agro-climatic regions and categories of farm have been developed and tested (Table-5). Most of these machines are available commercially and have been well adopted.

Table 5 Present Status of mechanization in Farm Mechanization

Technology	Present Status
Land Development	
Land levelling and grading	Bull dozers, power rakes, land planes etc. are commercially available. Animal drawn and tractor levellers are available for wetland and laser land leveller for large scale levelling.
Summer ploughing and subsoiling	Tractor drawn mould board ploughs, disc plough and subsoilers, para plough are available commercially.
Seedbed preparation - conservation tillage seeding raised bed planting	T/M strip till drill, roto till drill and zero till seed cum fertilizer drill field, till planter tested in light soils of northern India and found useful for sowing of wheat.
Seedbed preparation - Flat bed	Tractor mounted mould board, disc ploughs, disc harrows, cultivator etc are available commercially and being used by the farmers. Adoption of T/m rotavator is increasing.
Seedbed preparation - low land	Good designs of A/d and T/d puddlers, levellers, hydro tiller and rotavator are available commercially.
Pit making	Tractor mounted augers were imported and tested. Few indigenous designs of tractor and power tiller mounted augers were developed and commercialized.
Manure application	Manual spreading and transportation through tractor is practised. Power tiller and tractor-operated designs are ready for commercialization.
Sowing and Planting	
Drilling	Animal draw, Tractor mounted and Power tiller operated seed drills, seed cum fertilizer drill are available
Planting/hill planting/ Precision drill	Dibblers, inclined plate planters and pneumatic plate planters are available
Planting of tubers and rhizomes	Potato planters of animal, tractor and power tiller mounted are available.
Weeding and Interculture	
Manual weeding and earthing	Tools are available commercially; grubber, twin wheel hoe, cono weeder are common on Indian farms.

Technology	Present Status
Power weeders	Developed and tested. Rotary power weeder has been adopted in different agro-climatic regions.
Power tiller operated cultivation and earthing	Developed and tested. Power tiller mounted cultivator, power tiller mounted earthing cum fertilizer is under promotion in sugarcane crop.
Tractor mounted cultivator and earthing	Commercially available
Plant Protection	
Manual sprayers Manual dusters	Commercially available on large scale
Animal operated sprayers	Few commercial models are available. Bullock drawn sprayer for soybean and cotton is being promoted.
Engine operated sprayers and dusters	Many models are available
Self propelled sprayers and dusters	High capacity sprayers are commercially available.
Power tiller operated sprayers and dusters	Few models developed by R&D Centres. Commercialised in Andhra Pradesh, Tamil Nadu and Maharasthra. Power tiller operated orchard sprayer with turbo nozzle has been commercialised.
Tractor mounted sprayers and dusters	Commercially available. Few imported models field-tested and adopted by farmers. Aeroblast sprayers are in use for horticultural crops.
Air assisted spraying and dusting	Manual and tractor mounted equipment have been developed/adopted
Harvesting & Threshing	
Manual sickles	Locally made available at large scale. With serrations many designs are available for commercialization
Reaper-windrowers Walking type	Walk behind type models were designed, developed, tested and commercialised
Riding type	Prototypes available
Power tiller mounted	A platform type reaper made and tested
Tractor mounted	A number of models are being manufactured on large scale. Now again its scope is increasing due to the requirement of wheat and rice straw for fodder pin poses.
Groundnut diggers	Animal drawn, power tiller mounted and tractor mounted diggers are available.
Potato diggers/sweet potato harvesters	Animal drawn, Tractor mounted semi and automatic potato diggers developed and tested. Power tiller mounted potato digger is available.
Power threshers Specialized threshers	Commercially available. Threshers for sunflower, maize, groundnut, castor etc. have been developed.
Multicrop thresher	Small and high capacity threshers developed and tested for rice, wheat, mustard, sunflower, safflower, sorghum, maize, pigeon-pea etc.
Combine harvesters - rice	Commercially available

Technology	Present Status
General purpose grain combine	Commercially available
Straw combine	Commercially available for wheat
Plot combine	Limited scope. Imported models are available
Noise and Vibration on tractors and power tillers	Studies have been carried out which indicate that operators of these power units are exposed to high level of noise and vibration, which are detrimental to health and work performance.

Modernization requires sophistication in mechanization, which is possible at relatively large scales of operations with capital and management constraints overcome. Marginal and small farmers are increasingly becoming part time, with absentee farmers, periurban farmers, wage earners on a part or full time basis. Industry and service sectors, trade and commerce unable to reduce land based livelihoods compel rural people to remain on land based livelihoods, forcing a steady increase in the number of land holdings but with average land holdings going down making mechanization more challenging and difficult. Scaling down of farm machines reduces mechanical advantages. Instead of owning farm machinery other than hand tools, such marginal farms can meet their needs through custom servicing. (if it is well developed).

Farm Power Availability

India has made remarkable progress in agricultural mechanization technology. The country evolved a selective mechanization model using a power mix based on animate and inanimate power sources. The mix of power sources includes human beings, animals, power tillers, tractors, engines and electric motors. One of the globally used Index of Agriculture Mechanization (IAM) is power availability per unit area. The power availability is computed by taking both animals and inanimate power sources. Nearly 80 per cent of the power in agriculture is contributed by inanimate power sources. Table 6 shows the farm power availability and density of different power sources in India. Table 8 shows the farm power availability versus food grain production. It is apparent from these tables that agricultural productivity is directly related to farm power availability. States with higher power per unit area also have higher food production (Table 7). It is evident that higher power availability will have to be ensured in the states with lower power availability. This is also true for rainfed areas, where the power availability is barely 0.54 kW./ha. The power availability in hilly areas is also quite low.

The increasing use of tractors and irrigation pumps operated by electric motors and diesel engines are the indictors of the fact that use of mechanical power in India has increased many fold during the last two decades. Power availability was 0.32 kW/ha in 1965-66 and increased to 1.34 kW/ha in 2005-06 and needs to be increased to 2 kW/ha. The cultivable area per tractor was 2162 ha in 1965-66 and has come down to about 50 ha per tractor in 2005-06 with the addition of a large number of tractors. However, it is seen that the most popular model of tractor has a rating of 35 hp, which has a command area of about 15-20 ha.

Table 6 Status of farm power sources in India

Sources	Unit	1960-61	1970-71	1980-81	1990-91	2000-01	2004-05
Agricultural workers	Number, million	116.0	124.2	149.3	183.5	214.9	227.7
	Power, mkW	5.8	6.2	7.5	9.2	10.7	11.4
Draft animals	Number, million	80.4	82.6	73.4	70.9	60.3	56.5
	Power, mkW	30.6	31.4	27.8	26.9	22.9	21.5
Tractors	Number, million	0.037	0.168	0.531	1.192	2.472	2.812
	Power, mkW	1.00	4.38	13.86	31.11	64.52	73.39
Power tillers	Number, million	0	0.096	0.0162	0.0312	0.0775	0.0783
	Power, mkW	0	0.054	0.0196	0.175	0.434	0.438
Diesel engines	Number, million	0.230	1.700	2.880	4.800	6.226	7.595
	Power, mkW	1.298	9.52	16.13	26.88	34.86	42.53
Electric motors	Number, million	0.200	1.600	3.350	8.070	13.250	14.467
	Power, mkW	0.74	5.92	12.39	29.86	49.03	53.53
1 Human = 0.05 kW, Draught animal pair = 0.38 kW, Power tiller = 5.6 kW; Tractor = 26.1 kW, Electric motor = 3.7 kW, Diesel engine = 5.6 kW.							

Table 7 Cultivated area, production and power availability in India.

Year	Cropping intensity (per cent)	Net sown area Mha	Gross sown area Mha	Irrigated area Mha	Productivity T/ha	Net sown area per tractor ha	Power availability, kWha
1980-81	124	140.3	173.3	38.7	1.023	264	0.55
1985-86	127	141.0	178.8	42.1	1.184	174	0.73
1990-91	130	142.2	185.5	48.0	1.468	119	0.87
1995-96	131	142.8	186.8	53.0	1.499	84	1.05
2000-01	131.6	141.2	185.7	54.83	1.630	57	1.29
2004-05	135.6	141.0	191.2	56.21	1.650	50	1.44

Table 8 Farm Power availability and average productivity of food grains in India in 2001

State	Farm Power availability, kW/ha	Food grain productivity, kg/ha
Punjab	3.50	4032
Haryana	2.25	3088
Uttar Pradesh	1.75	2105
Andhra Pradesh	1.60	1995
Uttranchal	1.60	1712
West Bengal	1.25	2217
Tamil Nadu	0.90	2262
Karnataka	0.90	1406
Kerala	0.80	2162
Assam	0.80	1443
Bihar	0.80	1622
Gujarat	0.80	1169
Madhya Pradesh	0.80	907
Himachal Pradesh	0.70	1500
Maharashtra	0.70	757
Rajasthan	0.65	884
Jharkhand	0.60	1095
Jammu & Kashmir	0.60	1050
Orissa	0.60	799
Chhattisgarh	0.60	799
All India	**1.35**	**1723**

Irrigation

Water is an essential natural resource for the survival of life, a key input for plant growth and is instrumental in the upkeep of the environment. Although water is a renewable source, it is quite dynamic and scarce. The source of all water is annual precipitation/rainfall and it is affected by a number of factors. As a result, rainfall in India is highly variable, irregular and undependable with widespread variation among various meteorological sub-divisions in terms of distribution and amount. The highest and lowest annual average rainfall in India is 10,000 mm (Khasi-Jaintia Hill, Meghalaya) and 100 mm in Rajasthan, respectively. The distribution of water is highly skewed and to make it better the technical feasibility of inter basin transfer of water by linking Himalayan and Peninsular rivers has been investigated and the proposal is under consideration of the Government of India. It is estimated that after the development of full irrigation potential of 140 million ha as against the cropped area of 200 million ha by the year 2010, about 60 million ha will be left as rainfed. It, therefore, demands that every drop of rainfall should be conserved and it can be done by in-situ and ex-situ harvesting of rainfall. Significant progress has been made in the development of water harvesting, conservation and utilization technology. For better water use efficiency, it is necessary to adapt efficient irrigation methods that are technically feasible, economically viable and socially acceptable. Drip and micro irrigation systems need to be adopted and popularized for row crops, horticulture and especially for widely spaced high value crops in undulating terrains, shallow and porous soils and in water scarce areas. However, the associated issues/problems of high initial cost, clogging of drippers, cracking of pipes, lack of adequate technical inputs and insufficient extension efforts need to be addressed on a priority basis. This may require an integrated approach involving local R&D and extension agencies, manufacturers and end users/farmers.

Optimum development and efficient utilization of water resources, assumes great significance**.** The average annual rainfall as per the estimate of the Central Water Commission (2000) is 1869 bcm, which is about 4 per cent of global supply. Out of this 1122 bcm (690 bcm from surface water and 432 bcm from ground water) can be utilized for meeting diverse demand. The spatial and temporal distribution of water resources in the country is highly uneven. The present extent of utilization has been estimated to be 605 bcm out of which about 83 per cent is for irrigation purposes. The projected demand of water for various purposes by 2025 is estimated at about 1050 bcm (MOWR 1998), comprising 700 bcm of surface water and 350 bcm. of ground water (Table 9).

Table 9 The break up of the future demands into various uses

Sl. No.	Purpose	Projected utilization (bcm) by the Year 2025 A.D
1.	Irrigation	770
2.	Domestic Water Supply	52
3.	Industrial Use	120
4.	Power	71
5.	Others	37
	Total	1050
	Surface Water	700
	Ground water	350

Source: MOWR (1998), Govt. of India

Although, the average water availability in the country remains more or less fixed according to the natural hydrological cycle, the per capita water availability is progressively reduced due to increasing population. The per capita water availability is reducing with time, 5300 m^3 during year 1955 to 2200 m^3 as of now. It is projected that during 2025 this availability will be 1500m^3, which is at stress level and during year 2050 it will be scarce with availability of less than 1000 m^3. The average annual precipitation including snowfall is estimated to be of the order of 4,000 billion cubic metre (bcm). Out of this 1500 bcm flows into sea due to floods (Abdul Kalam, 2005). Floods normally affect 8 major river valleys spread over 40 million hectares of area in the entire country affecting nearly 260 million people. Similarly drought affects 86 million people who are spread in 14 states covering a total of 116 districts. If we have to prevent the damage due to the flood and reduce the severity of drought, we have to harness this 1500 bcm of water and distribute it to the drought affected areas. Therefore, National Water Grid (NWG) needs to be developed by interlinking of the country's major river basins.

In India, major water resources are from rivers, lakes, canal, reservoirs, tanks and ground water. Globally, fresh water at a tune of 3,240 m km^3 is being utilized. Of this, 69 per cent is being used in agriculture sector, 8 per cent in domestic, 23 per cent in industrial and other sectors. In India, around 88 per cent water is being used in agriculture sector, covering around 80 M ha area under irrigation. Due to liberalization of industrial policies and other developmental activities, the demand for water in industrial and domestic sectors is increasing day by day, which forces the reduction of the percentage area under irrigation in the agriculture sector. Thus, pressure lies on agriculture sector to reduce the share of water and increase the production, which could be achieved by enhancing increased water use efficiency.

Water is drawn either from a dug well or a shallow tube well fitted with a pumpset. In both cases a horizontal centrifugal pumpset is commonly used. It was estimated that there are about 16.0 million electric motors and 9.0 million diesel engine pumpsets for lifting water from various sources (Table 10) as of 2003-04. These consume about 100 billion kWh of electricity and 4.0 billion litres of diesel annually. Several field studies revealed that most of the agricultural pumpsets selected and installed operated at much lower efficiency than achievable. The standing committee (Government of India) on the study of operational efficiency of irrigation pumps clearly observed that overall efficiency in diesel operated pump sets was 12.7 per cent and 31.1 per cent in electrically operated pump sets. The efficiency can be increased by selection of appropriate pump, proper installation of system, selection of prime mover, selection of proper couplings, selection of proper size of suction and delivery pipes and regular maintenance. Because of improper management of the systems, lack of clear cut guidelines and lack of emphasis on water management at farm level, the overall efficiency of these systems continued to remain low. It is reported that, a farmer can save up to Rs. 3300 per year over his present expenses for pumpset operation if his pumping system is properly selected. Such correct selection would not only salvage the farmer from his avoidable yearly financial loss but would also save the nation a few hundred crores worth of power by way of savings in diesel oil consumption and electric power.

Table 10 Population growth trends in stationary farm power sources in India (pumpsets per million)

Mechanical power	1961-62	1971-72	1981-82	1991-92	1996-97	1997-98	2003-04 (Est.)
Electric pump	0.1	1.63	4.33	9.34	11.57	11.85	16.0
Diesel pump	0.23	1.55	3.1	4.59	5.58	5.84	9.0

Principal factors influencing watershed operations are physiography (size, shape, land slope) soils and geography, vegetative cover, design peak runoff rate, precipitation, socio-economic factors, organization and analysis after treatment to land with soil conservation measures.

Agricultural Drainage

Drainage has become the part of integrated water management, removing or conserving water as required and also being much concerned about water quality and environmental values. The Food and Agriculture Organization of the United Nations (FAO) assessment (FAO 1996) puts the developed world cropland as 1500 million ha (Mha) of which about 1200-1250 Mha are used for rainfed cropping while about 270 Mha (about 18 per cent of the total cropland) have irrigation facilities. The area provided with improved drainage is estimated to be of the order of 150-200 Mha (10-14 per cent of the total crop land). Land drainage and irrigation are complementary to each other for maintaining sustainable agricultural productivity. Large areas have been degraded in the country due to the problem of water-logging and salinity, especially in the irrigated alluvial tracts in north-west India (Haryana, Punjab, Gujarat etc.). In India about 4.528 Mha and 7.006 Mha land is having water-logging and salinity problems respectively. A survey conducted for assessing drainage problems in Madhya Pradesh, revealed that at present, 14.06 per cent, 1.20 per cent and 0.90 per cent of command areas are affected due to water-logging in *Chambal*, *Tava and Barna* respectively. Farmers of temporary water-logged lands and low lying areas are not able to remove excess water from their fields due to lack of natural or manmade drainage network /grid. Farmers in adjoining areas of natural drains are often using open ditches for excess water removal from their fields. Therefore, farmers either leave the fields fallow during monsoon season or they get very low yield from their crops. In order to restore these degraded lands drainage becomes an essential measure. Drainage measures consist of mainly to evacuate salts and water from the crop root zone.

The National Water Policy (2002) emphasized adoption of drainage systems and reclamation measures for water-logged areas for sustainable development. Good drainage absorbs and stores more rainfall reducing runoff from the soil surface that causes soil erosion, reduces the chances of water-borne diseases, allows plant roots to receive enough oxygen to mature properly, improves seeds germination due to increased soil surface temperature and increases the number of days available for planting and harvesting crops. Land drainage thus increases crop yields and land value.

Indian Experiences in Drainage Technology

In India, the performance of drainage systems was evaluated in fields for sandy and sandy loam soils under Rajasthan Agriculture Development Project (RAJAD), Central Soil Salinity Research Institute (CSSRI), Karnal under Haryana Operational Pilot Project (HOPP) and AICRP on Agricultural Drainage. These studies revealed that SSD systems had resulted in control of soil salinity/alkalinity effectively and significant increase in yields (about 50 to 75 per cent) of important crops (i.e. rice, wheat, cotton). Studies on performance of drainage systems under heavy clay soils (*vertisols*) were carried out at the Water Management Research Center, Parbhani (Maharashtra) and the Central Institute of Agricultural Engineering (CIAE), Bhopal (M.P.).

Drainage field studies including mole drainage conducted at CIAE Bhopal for soybean, and water sensitive maize and pigeon pea crops. in temporary water-logged vertisols revealed the following:

- Open drainage channels at 15 to 20 m interval and 0.5 m deep with side slopes of 1: 1 and bed gradient less than 0.5 per cent were found to be effective for providing enough relief to crop root zone for soybean.
- For SSD system drainage coefficient (DC) was found to be 5.10 to 5.34 mm/day. The SSD system with 20 m drain spacing and 1.0m drainage depth using corrugated perforated PVC pipe of 72/80 mm diameter covered with geo-textile filter is required for effective drainage.
- Surface drainage system resulted in 25-40 per cent increase in yield over control and the SSD system resulted in 40-64 per cent increase over control for soybean, maize and pigeon pea. SSD also resulted in 12 - 15 per cent

increase in yield of subsequent rabi season wheat and chickpea over the control.

- The cost of making surface drains may vary between Rs 1250 – 1500 /ha depending upon the field orientation and drain layout. The total cost of SSD systems is found to be Rs 65,000/ha due to closer drain spacing in vertisols. The cost of mole drainage at 4 m mole spacing varies from Rs. 2000 - 2500/ha
- Cost economics of drainage systems resulted into benefit-cost (B/C) ratio of 1.77, 1.35 and 1.53 for cultivating soybean, maize and pigeon pea respectively. The B/C ratio for SSD system is 1.36, 1.44 and 1.55 for soybean, maize and pigeon pea respectively. The B/c ratio for soybean cultivation with mole drainage was found to be 1.91. The payback period for SSD systems for crops sensitive to water-logging is 5-7 years.

Energy in Agriculture

Fossil fuels, which also covers electricity generation are extensively used, but these resources are finite. It is estimated that 81792 million units of electricity and 40.12 million tones of high-speed diesel are available in the country to meet the energy demand in 2005-06. The studies undertaken on Energy Requirement in Agriculture has indicated that use of energy for crop production varied considerably from 9600 MJ/ha to as high as 21000 MJ/ha including seeds and fertilizer. Energy in fertilizer contributed the maximum followed by irrigation. The average operational energy use on all India basis for crop production increased from 3,374 to 8,138 MJ/ha (annual growth rate of 3.6 per cent) during 1970 to 1996 period.

More than 600 million tones of biomass are available from various crops residues and agro-wastes for fuel wood and animal feed. It is estimated that 35-40 per cent of bio-mass is utilized for animal feed and the remaining as energy source through direct combustion either for cooking food (improved *chulha* 284.89 lakhs) or for processing of agro-produce (bagasse co-generation 84 MW). This is also available for generation of bio-gas (27.13 lakhs plants) and gasification (28.53 MW). Bio-gas and producer gas can partially substitute HSD in compression ignition engines. Alcohol and plant oils are compatible with fuel injection system of compression engines and can be used after transesterification. Solar dryers and solar cookers (456674 nos) are available to supplement rural energy.

Rural Energy Needs

Energy in the rural sector is required for rural home management, production agriculture, cottage industries and agro-processing. It is estimated that about 66-80 per cent of the total energy for the rural sector is used mainly for rural home management and 16-25 per cent for agriculture production. These are met by bio-energy, natural energy, electricity, fossil fuel and coal. Cooking alone consumes 70 per cent of the total energy, which is met by wood, crop residues, and dry animal dung. About 3-5 kg of fuel wood per household is required for every day. Yearly requirement of fuel wood for rural sector alone will exceed 200 million tonnes. The rural energy needs are different from urban needs due to economic disparity (Table 11 and 12). As per NSSO Report No 404, 1997, about 78 per cent of rural households use fire wood compared to 30 per cent in urban areas for cooking and about 31 per cent rural homes use electricity for lighting compared to 85 per cent in urban areas. Only about 86 per cent villages are electrified. The remaining households use kerosene. This requires about 4 litres of kerosene per month per family. This would require more than 300 million litres of kerosene in rural homes for lighting. One of the reasons of poor industrialization of rural sector is due to inadequate or non-availability of assured electricity in the villages.

Table 11: Rural energy needs	Table 12: Mechanical Power in Agriculture
• Home management and rural industries : 66 - 80 per cent • Agricultural production :16 - 25 per cent • Post harvest activities :2 - 4 per cent • Animal husbandry and dairying: 2 - 5 per cent	• Tractor :3.42 million • Power Tiller :0.11 million • Diesel engine :5.94 million • Electric Motors :14.80 million

Status of PHT and Agro-processing Industry

The size of India's food industry is estimated at Rs. 2,50,000 crore. Of this, value added processed food are forecast to rise three times from the present Rs. 80,000 crore to 2,25,000 crore. The Indian food agro-products industry is predominantly related to conservation and simple processed food. However, there is a trend towards value added, easy to use convenient products. Some of the major post-harvest technology and equipment developed in India are:

Optimum stage of harvesting, Status of traditional post harvest activities, Effect of chemicals on yield, Groundnut stripper, Maize dehusker sheller, Crop covering structures, Storage Structures, Crop driers, Cleaners and graders, Decorticators and threshers, Storage structures for onion, Solar drier and seed treater, Milling equipment for small scale operations, Leaf grinder and pyrolyser, Decorticators, Grain infestation detector, Straw baler and feed treatment structure, Pedal-cum-power operated cleaner, seed treater, Use of biogas in grain storage, Bottling of sugarcane juice, Rice puffing machine, Pantnagar dal mill, Pearler for coarse grains, Sago roaster, Ginger and turmeric polisher, PKV dal mill, Pea peeling and punching, Extraction of chillies seed, Agro Processing Centre, Garlic bulb breaker, use of waste Kagzi lime for citric acid, Enhancement of shelf life of fruits and vegetables, Cashewnut sheller, Water chestnut decorticator, Mango grader, Bengal gram stripping-shelling machine, magnetic treater for seeder, Microwave for disinfestation, Honey bee smoker, Radial honey extractor, Effluent treatment system, Blended leather boards etc.

Post harvest characteristics of agricultural produce is affected by pre-harvest treatments-seed rates, level of fertilizer use, nutritional balance, irrigation and drainage, attack f diseases and pests, growth hormones and pesticides used an d their residual toxicity, mechanical and environmental injuries during harvesting, handling, transport and storage. A strong awareness drive is needed to provide pre-harvest inputs for scientific post-harvest management of agricultural produce and by-products.

For scientific storage of agricultural produce cleaning, grading, shelling, decortication, drying to safe moisture levels -10-12 per cent in case of cereals, 8-10 per cent in case of pulses and 6-8 per cent in case of oilseeds, are important. A number of useful equipments- for such unit operations are available that need to be commercialized and extended to targeted beneficiaries. Scientific storage-room, warehouses storage bins, or even CAP storage capacity for growers to negotiate with the forces of market enabling them to earn 25-50 per cent more net returns.

The utilization pattern of produce and their by-products governs the use of process and machinery. By improved harvesting, parboiling, drying and milling technologies the total out-turn of rice can be increased by 10 per cent. There is an increasing trend towards the use of roller mills for milling wheat that give quality products. Maize is a very versatile grain having food, feed, and industrial raw material value. It yields numerous products employing dry milling, wet milling, fermentation and other processes. Sorghum and minor millets have excessive fibre causing anti-nutritional effects, to overcome this defect pearlers are used.

India is the second largest producer of fruits and vegetables (F&V) next only to China. It is growing at a rate of 6-8 per cent annually. In the absence of awareness, skills and proper PH-infrastructure post-harvest losses in F&V are excessive 20-40 per cent. Bumper harvests can face a slump in the market price creating disincentives to the growers. The major reasons for these losses are:

- Untimely harvest and mechanical injuries during the process.
- Growth of micro-organisms (yeasts, molds and bacteria).
- Life processes of these biologically active materials/post-harvest physiological factors
- Enzymatic activities, browning, discolouration
- Physical changes like desiccation, shriveling, loss of turgidity
- Chemical changes such as oxidation
- Spoilage and mechanical damage during harvest handling, packaging transport and storage

Priority in Post Harvest Technology Research and Development
Post harvest technology is commodity and location specific. However, the present requirement is to develop need-based and market driven PHT and equipment for loss prevention and value addition to raw food materials of plant, animal and aquatic origin for internal and international markets. Diversification in the present uses of rainfed and other crops may be considered (Table 13). The technology so developed must lead to rural industrialization, thereby creating employment and income generation opportunities. Appropriate PHT would help in enhancing per capita food and fibre availability from the limited and dwindling land and water resources.

Table 13 Present use and suggested diversification of field crops for better domestic utilization and export promotion.

Field Crop	Present Value-added Products	Suggested Product Diversification
Rice	Milled raw and parboiled rice, flour and flakes and puffed rice.	Quick cooking rice, Basmati rice and rice based extruded snack/breakfast cereals.
Wheat	Noodles	Puffed & flaked breakfast foods.

Field Crop	Present Value-added Products	Suggested Product Diversification
Maize	Flour and flakes, starch and dextrins and puffed corn.	Degermed maize flour and corn oil.
Sorghum	Flour, flakes and puffed sorghum.	Food and feed uses.
Millets	Flour and pearled millets.	Food and feed uses.
Oilseeds	Oil and cake.	Protein rich soybean flour, protein isolates and concentrates, dal anologs, soy-lecithin, fatty acids and derivatives, direct food uses of oilseeds.
Pulses	Dal, Besan, feed (husk and brokens) and roasted snack foods.	Quick cooking dal, mixed and speciality dal.
Cotton	Cotton and cotton yarn, cottonseed oil and cake.	Colour cotton, byproduct utilization and refinement of cotton seed oil and cake for food and feed.
Jute and Mesta	Gunny bags, carpets, ropes and bags.	For interior decortication, blended yarn, soft luggage, shoe uppers and disposable sleeper, non-woven fabric and geotextile.

Source: Ali, 1999.

Food Processing Industry

Presently only up to 6 per cent of the total produce is converted to processed and packed foods. It is targeted to reach 20 per cent in about 10 years. The industry is labour intensive and contributes around 50 per cent to industrial production. Multi-National Food Companies have played a role of creating market pull and competition. Adoption of innovative and scientific packaging methods by food industry has enabled the manufacture of safe and quality food. More than 73 per cent of rice, 55 per cent maize, 24 per cent pulses, 45 per cent oil seeds, 45 per cent sugarcane are processed by modern machinery besides other commercial crops. The Indian food industry is one of the largest in terms of production, consumption and growth prospects. However, inefficiencies in the food sector are due to 6-7 intermediaries as compared to 2-3 in other countries and results in affecting the product quality. In spite of this, the large food industry has come up in a big way with meeting international quality standards, and exporting processed foods even to the developed world.

The future of the Indian food industry can be considered to be bright only if safe and quality food products are made available covering the complete chain starting from raw material production to delivery of safe food to the end user. Indian groundnut processors are able to meet the restriction of 5 ppb afflatoxin level in peanut butter. Now, our processors have adopted a vacuum packaging approach for roasted / fried groundnut kernel based snack products to check off-flavour development. It should not be a matter of surprise if Indian, paddy processing facilities of International Standard are widely found. High value *Basmati* paddy is milled and exported with the quality standards prescribed by different International Markets like USA, Middle East, etc.

The demand for processed and convenience foods will be increasing in future and it is expected to rise from the present level of 3 per cent to 25 per cent by 2020 AD. This will call for development of appropriate technologies not only for value addition but also for handling, packaging, storage, transportation and marketing of products in domestic and international market to deliver safe food.

The food processing industry in India is labour intensive and offers a major employment opportunity. The industry employs 18 to 20 per cent of country's labour force. It is estimated that per Rs. 1000 Crore investment in the large-scale food industry provides direct employment to 54000 persons whereas in cottage scale the employment potential is 354000 (7 times) for same investment. To provide food security through financial empowerment the Govt. is keen to provide employment many through this sector. Also, normally, producers do not get enough income /returns due to low price or glut. Under such circumstances, it is a must to initiate processing activities in the production catchments to improve the raw material quality and enhance shelf life. Also, these units can take-up the activities of supplying primarily processed good quality raw material to large-scale industries. Thereby reducing the industrial load of cities and ease out pollution related problems. With the above analysis in view, it appears necessary to develop a network- of cottage to small-scale enterprises in rural areas for processing of agricultural produce to provide:

- Opportunities of employment and income generation
- Good quality food raw material to local /rural population at relatively lower rates.
- Primarily processed good quality raw material to large industry in cities

Employment Potential: The agriculture processing sector has immense employment potential for rural people, provided the primary processing activities are undertaken, as in the past, in rural areas. Cottage and industrial level primary/ secondary processing include, rice mills, grain mills, fruit and vegetable processing, etc. The case of employment generation by food grain processing in production catchments was worked out, showing huge potential even for processing 20-50 per cent of total food grain production in rural area. However, a systematic approach needs to be considered.

Realising the low price pattern in the production season, grape growers in Maharashtra State have taken-up on-farm primary processing activities for producing raisins. Quality aspects are kept in mind all throughout and the end product processed in rural areas can be exported. There is a need to understand that 'growing' is futile without 'processing'. It is important to appreciate that 'growing' and 'processing' are complementary and need to be promoted together for more income to the poor. Primary processing of cereals, pulses, oil seeds, fruits and vegetables can be conveniently taken up for value addition and income generation.

Status of the various technologies/ equipments available for various operations in post harvest technology, agro-processing and food industry are given in Table 14:

Table 14 Status of various process operations and equipment

Cleaning and Grading	
Scalpers and precleaners	Used by processing industry. Yet to become common in farmers' site
Seed cleaners & graders	Used by processing industry. Yet to become common in farmers' site. Some grain mandies use these.
Gravity separator/ destoners	Used by foodgrain, oilseed and seed processing industry
Disc separators	Used by foodgrain and seed processing industry
Spiral separators	Used by foodgrain and seed processing industry
Vegetable cleaner	Rarely used by processing industry. Mostly manual labour is used.
Fruit and vegetable graders	Rarely used by processing industry. Mostly manual labour is used. However, commercially available having different output capacities.
Fruit and vegetable packaging lines	Rarely used by processing industry. Mostly manual labour is used. Only large scale fruit and vegetable processing/trading units (like Mother Dairy, New Delhi), etc. have these. Also export oriented units (EOUs) do use these but not very common
Drying	
Sun and solar drying	Most commonly followed by farmers
Batch dryers	Processing industry uses these.
Re-circulation dryers	Rice mills use for drying parboiled paddy
Continuous grain dryers	Rice mills use for drying of parboiled paddy
Dryers for spices and condiments	Randomly adopted
Storage of foodgrain	
On-farm	Rarely done except farm houses
Rural godown	Operational. Mostly the problem is of management and not of the technology
Silostorages	Commonly used by Oilseed Processing Solvent Extraction Plants, Wheat mills (Roller flour mills), Grain Storage agencies like FCI etc.
Milling of Cereals	
Rice	65 per cent produce milled in modern rice mills, 35 per cent milled in hullers and URD shellers.
Wheat	10-13 per cent produce milled in 820 roller flour mills, Rest milled in over 320, 000 chakkies
Maize	Only 30-34 per cent milled in modern processing units. Rest used as feed and human food.
Minor Millets	Mostly milled in Chakkies for flour0
Pasta and macroni	Mostly imported units in operation for preparation of quality product
Puffed and flaked rice	About 10 per cent of production is processed for puffed and flakes products. Basically, it is cottage to small scale industry

Milling of Pulses	
Dal milling	Mostly conventional mills (ca. 11000) covert the pulses into dal, besan, etc. Recovery is low (73-75 per cent).
Snack foods	Mostly puffed/roasted products are prepared (10 per cent of production).
Milling of Oilseeds	
Traditional	Kolhus and Ghanis are used in rural areas and towns for oil expelling. Up to 15 per cent oil is left in cake.
Expellers	Around 55,000 expellers are used in rural areas and towns for oil expelling. Up to 8 per cent oil is left in cake.
Solvent extraction	over 700 units process the oil seeds, including soybean
Filtration and refining	It is commonly done. Filtration is done for groundnut and mustard oil. Other oils are refined through over 150 refineries. Also, 300 units are in operation for hydrogenation of oils
Processing of Commercial crops	
Sugarcane	About 50 per cent of 300mt production processed for Jaggery/ khandsari and rest for sugar through 430 sugar mills.
Processing of fruits & vegetable	
Dried dehydrated products	Not very common. Some firms make very good quality dehydrated leafy and other vegetables and fruits - up to export quality
Osmosis dehydrated products	Not much in use. Very few products are seen
Fruit juice concentrate	Industry is well equipped to produce and market very good quality product which serves as raw material for fruit based juice / drink plants
Paddy	Technology for optimum stage of harvesting, threshing, drying, cleaning, grading, storage, parboiling, milling, rice bran stabilization, husk utilization are available in the country yielding 68-70 per cent rice recovery. Poor recovery with long grain rice.
Wheat	Wheat is milled in burr/attrition and roller-flour mills for whole meal flour, refined flour, suji, dalia, etc. Wheat milling is fairly well established.
Maize	Presently used for feed starches, edible flour, snack foods (popped/ puffed), dextrins
Sorghum and millets	Used as coarse cereals for food and feed
Pulses	Milled for split pulses (dal) in traditional and modern dal mills. Recovery is poor, and broken pulses are more readily found. Noise and dust pollution is severe. Legumes like chickpea, peas, lentil, greengram are roasted/ fried for snack foods. No standardized manufacturing of dal mills.

Oilseeds	Used for oil, protein and lecithin. Utilization pattern of oilseeds in India is 5 per cent for direct food, 8 per cent for seed and 87 per cent for oil extraction. Cake is used as livestock feed but the bulk of it (80-85 per cent) is exported.
Soybean	Present utilization pattern is that 5 per cent for direct food and feed uses, 10 per cent for seed and 85 per cent for oil extraction. Oil is used within the country but 85 per cent of total soymeal is exported for livestock feed. Only 15 per cent of soymeal is used domestically for food (TSP, defatted soyflour) and feed.
Fruits and vegetables	Production of fruit and vegetables is increasing. Prices are low in season. Mostly consumed fresh. Post-production losses are very high. Production of processed products is negligible, hardly 1-2 per cent. Handling, storage, transport and marketing infrastructures are insufficient.
Sugarcane	About 80 per cent of total sugarcane production is crushed. Out of this half goes for refined sugar in organized sector and half for jaggery and khandsari. The remaining 20 per cent is for seed and chewing. Average recovery of sugar is 8 per cent.
Spices	Major spices are pepper, cardamom, ginger, turmeric, chilli, coriander, etc. Pepper is the major export earner. Quality is governed by cultivar, post-production care, packaging and storage. Post-harvest losses are more. Quality of the product in the indigenous market is poor.
Animal products	Milk and milk products are being handled with reasonably good success. Meat and egg handling and hygienic conditions are poor. Slaughter houses are of very old design. Goat and sheep contribute 55 per cent of total meat production. Poultry 13 per cent.
Fish and fish products	Fishes are mostly sold live/fresh in local markets and consumed domestically except prawn and other sea catches. Transport system is not very well developed. Handling and storage is poor. Processing is mainly done for export.
Cotton	Cotton is the natural textile fibre and is used but other parts of the cotton plant are not well utilized except cotton seed. Stalk is used as fuel. There is a need to strengthen post-harvest activities for by-products utilization.
Jute and Mesta	Mini jute carding and spinning mills have been developed. Jute sticks are poorly utilized as a fuel source through it can yield a hardwood like structure, paper and pulps, particle board etc. Jute fibre is used for gunny bags, carpets, ropes and bags.
Cold chain for the Perishables	Adopted for export of fresh fruits (grapes in Maharashtra) and vegetables.

Controlled Atmosphere and Modified atmospheric packaging.	Minimally adopted by few selected processing units.
Product Development Technology	
Paddy (Rice)	Milled raw and parboiled rice, flour and flakes and puffed rice
Wheat	Flour, maida, suji, dalia and noodles
Maize	Flour and flakes, starch and dextrins and puffed corns
Sorghum	Flour, flakes and puffed sorghum
Oilseeds	Oil and cake
Pulses	Dal, besan, feed (husk and broken pieces) and roasted snack foods
Cotton	Cotton and cotton yarn, cotton seed oil and cake
Jute and Mesta	Gunny bags, carpets, ropes and bags
Popularization of soy products	Limited products available
Handling And Transport	
Power tiller trailers Tractor trolleys, -2 wheel - wheel Tipping trolley	Commercially available

Women Friendly Improved Tools and Equipment for Agriculture

Women play a major role in rural India through their active participation in agriculture. At present, the women found in the work force in agriculture and allied sectors is estimated at about 61 million which amounts to about 30 per cent of the total rural workers in the country. They participate in different crop production and food processing operations as well as in animal husbandry and dairy and fishery activities. In addition they also carry the burden of household work and management. Studies have shown that the Indian women work for about 14-16 hours a day to carry out various activities on farm and at home.

Rural women are usually employed in arduous field operations like sowing behind the plough, transplanting, weeding, interculture, harvesting and threshing. The activities in agro processing involve cleaning/ grading, drying, parboiling, milling, grinding, decortication and storage. Women workers are also preferred in commercial agriculture like tea, coffee, tobacco and plantation crops. Bidi making, jute retting, lac cultivation, processing and lac products preparation, cotton picking, sugarcane cleaning/ detopping and spice picking, with cleaning and processing also largely performed by women.

There are more than 50 improved hand tools and equipment developed by various research organizations in the country. Out of these, 30 hand tools/ equipment have been identified which can be made suitable for women workers. These are listed below:

- Seed treatment drum
- Naveen dibbler
- Rotary dibbler
- Seed drill
- Paddy drum seeder
- Rice transplanter
- Cono weeder
- Long handled weeder (Grubber)
- Weeder (Wheel hoe)
- Fertilizer broadcaster
- Spraying safety kit
- Improved sickle
- Sugarcane stripper
- Tubular maize sheller
- Rotary maize sheller
- Groundnut stripper
- Groundnut decorticator (sitting type)
- Groundnut decorticator (Standing type)
- Pedal operated paddy thresher
- Hanging type double screen grain cleaner with sac holder
- Pedal operated cleaner grader
- Potato peeler
- Potato slicer
- Mini dal mill
- Hand operated chaff cutter
- Wheel barrow
- Cotton stalk puller
- Hand ridger
- Bhindi plucker
- Fruit harvester

Entrepreneurship development through farm machinery manufacturing

The demand for agricultural machinery is increasing over the years. To meet the demand from all corners of the country, it is not possible to supply the desired machinery through centralized manufacturing. This is due to the fact that transportation cost and repair and maintenance adds to increase in cost of equipment. Therefore, efforts are to be made to develop decentralized manufacturing of agricultural machinery. It will not be economical to marginal, small and medium farmers to possess all the equipment and machineries they need in different operations. Therefore the best option will be to hire equipment and machineries from custom hire centers. This also will ease the burden of safe storage of these machines and equipment when not in use and also from the point of periodical and preventive maintenance.

Therefore, opening up of service centers for repair and maintenance and custom hire centers through entrepreneurship in rural areas will augment the pace of farm mechanization.

Impact of Climate and Weather on Agriculture

Anthropogenic interventions are interacting with structure and function of the agro-eco system more intensively and producing increasingly higher amount of green house gases. There are documented evidences of increased production of carbon dioxide, methane, nitrous oxide and other industrial gases in the past. As a result of these global emissions mean temperature has increased by almost 0.4 to 0.7°C during last 100 years. This increase in temperature and other inter-related dynamics of climate is going to happen at a much faster rate due to industrialization, deforestation, encroachment of wetlands, grasslands and higher inputs of agro-chemicals for realizing higher productivity. As a result of that annual rainfall, availability of water and land use system is bound to be altered. Increasing temperatures will melt glaciers and transfer water form the hills and mountains to the plains or even some of it may escape to sea. Consequent rise in sea level will flood many coastal areas and shall call upon relocation and rehabilitation of the communities. Redistribution of rainfall and surface water will also impact biodiversity, productivity, both of the terrestrial and aquatic eco-systems. In order to minimize impact or manage climate changes large investments into proactive or anticipatory research is necessary to meet emerging challenges of livelihood gathering by the agrarian economies like of India.

Globally about 65 per cent of the green house gases are produced by the industry and 35 per cent is contributed by agriculture and related activities. Agriculture, however, acts both as a source and sink for the green house gases. Indian agriculture is contributing 2.4 per cent of the methane and 1.5 per cent of the nitrous oxide of the total world production. Impact on productivity is a net result of contrasting effects of higher concentration of carbon dioxide and other gases as well as temperature. Overall productivity of rice and wheat in northern India is growing to be reduced by 2070. Similarly it will be true for wheat yields in central India. Recent cold wave in the month of January, 2003 produced very adverse effects on mango, papaya, mustard, other sensitive crops and livestock in the northern India. There was only 20-30 per cent seed setting in 80.000 hectares of winter maize in Bihar during the 2002-03 season. In addition to breeding of varieties and crops which can tolerate extreme temperatures, rainfall and greenhouse gases, there are many agronomic mitigation options.

In situ management of residues instead of burning, fuel saving zero tillage, water and fertilizer management in rice, drainage of waterlogged soils, preservation of wetlands will certainly cut down production of greenhouse gases. Now a days, there is a greater concern on nitrous oxide emissions because of its very long atmospheric half-life requiring special infrastructure and human resources. Sequestration of green house gases through forestry, agro-forestry, horticultural and other plantations will become a reality especially when the Kyoto Protocol becomes binding mechanism. India is progressing rapidly noting its position in World Agriculture (Table 15) ranking 1-3 in most of crop/horticultural items.

Table 15 Position of India in World Agriculture

Agricultural commodity	Position of India		
	per cent Share	India Rank	Next to
Tea	26.10	1	-
Sugarcane	22.10	2	Brazil
Groundnut	21.20	2	China
Cotton	11.30	3	China, USA
Cereals	11.10	3	China, USA
Vegetables	9.40	2	China
Fruits	8.80	2	China
Potatoes	7.80	3	China, Russia
Tractors	5.90	3	USA, Japan
Soybean	3.25	5	USA, BRazil, Argentina, China
Coffee	4.20	7	Brazil, Columbia, Viet Nam, Indonesia, Cote Divoire, Mexico

Energy and Cost Effective Technology and Equipment for Sustainable Agriculture

As of now, scientific management of natural resources for sustainable agricultural production is very crucial. With the advent of high yielding crop varieties, augmentation of irrigation facility; increased use of fertilizers, adoption of improved agronomic practices, tools and implements; concerted efforts of scientists, planners, governments and above all, that of farming community have lead to green, yellow, blue, white and horticultural revolutions resulting in a quantum jump in agricultural production. This high achievement in agricultural production has lead to food self-sufficiency. However, this has put natural resources under intense strain resulting in fast degradation and lowering of their production efficiency.

Agriculture now should shift to knowledge-based from resource-based technology, in the quest to wipe-off food and nutritional insecurity on a sustainable basis in India. The demographic pressure is rapidly mounting on natural resources and it is estimated to be 1.4 billion by 2025 and 1.7 billion by 2050. This scenario along with increasing industrialization and urbanization are putting tremendous strain on the limited and dwindling land and water resources. Unless corrective measures are taken, there may be irreversible damage to the environment and the resource base. The challenge is to produce enough food on sustainable basis to meet the basic requirements of the ever-increasing population while maintaining the natural resources and preserving bio-diversity. It, therefore, calls for knowledge and resource conservation based technology and machines for sustainable agricultural production and productivity.

Tillage and Sowing Technology

Tillage is a physical manipulation of soil to get an appropriate soil-tilth, which can provide favourable conditions for plant growth. Tillage is hard work and energy-intensive. As crop cultivation became more sophisticated, tillage operations and equipments are altered and specialized. Powered machinery and cheap fossil fuel brought in the age of maximum tillage, resulting in loose and fine seedbed, weed and trashes free fields and extensive mixing of soil, lime, crop residues, manures and fertilizers, at a higher energy expenditure and overall cost of operation. It is now being realized that extensive tillage is neither ideal nor required as it causes formation of hard-pan, soil erosion and more energy and labour needs. All these lead us to have a new appraisal of tillage concept. The conventional tillage operations such as ploughing and harrowing, involve repeated soil disturbances making it vulnerable to soil erosion, loss of soil structure, etc. While shallow tillage helps in breaking dormancy of weed seeds by exposing seeds to light, deep tillage protects the weed seeds by burying them deep in the soil horizon. The primary objective of tillage is to control weeds and around 50 per cent of the energy required for tillage is spent for weed control. Until herbicides became available in 1940s and beyond, tillage for weed control was an integral part of crop production. With the dramatic improvements being made in the field of herbicide technology, the necessity of soil manipulation for weed control has decreased. Herbicides to kill weeds are more effective and eliminate extra trips over the field, which results in both fuel (energy) and labour (time) saving.

Tillage includes all the operations and practices that are carried out for the purpose of modifying the physical character of soil so as to provide favourable conditions for plant growth. Different forms of tillage, and seeding and planting system and equipment now being advocated are conventional, minimum, reduced, conservation, ridge and zero tillage and surface seeding and furrow irrigated raised bed planting system (FIRBPS).

Conventional tillage is being followed by most of the farmers in the form of primary and secondary tillage operations using ploughs, harrows, cultivators, etc. It varies depending upon crop, soil and agro-climatic condition. It uses more energy and the cost of operation is high. Now the trend is toward reduced tillage in India as well as in developed countries.

Minimum tillage is the level of tillage required for crop production or for meeting the tillage requirements under specific soil and climatic conditions. This system eliminates excess tillage operations. Reduced tillage is defined as any combination of tillage operations, which do less tillage than all the operations used in conventional tillage. The main advantages of reduced tillage are less soil erosion and saving in time and cost of operation.

Conservation tillage is a tillage system that leaves at least 30 per cent of crop residue/stubbles on surface to control soil erosion and moisture loss. It is conducive to sustainable agriculture. In India, residue management is very important in rice-wheat cropping system because a large amount of crop residues are left on soil surface, especially where combines are used for crop harvest.

In Zero tillage technology, crop seeds are sown in a single operation using specially designed tractor operated seed-cum-fertilizer drill without any field preparation in the presence of rice crop residues./stubbles at optimum to slightly wetter soil moisture regime. Zero-till drilling of wheat has become very popular in Indo-Gangetic plains of India under rice-wheat cropping system. The incentive for a change from conventional tillage to zero-tillage has come from improved productivity, profitability and sustainability of rice-wheat cropping system. With better herbicides and its application technology, the necessity of soil manipulation for weed control has decreased. Zero-tillage technology has reduced the cost of wheat sowing from Rs. 2000-2500/ha to Rs. 400-500/ha. Also, there is saving of labour and time.

Almost all the results of the experiments conducted at different places in India revealed higher wheat yield in zero-tillage than conventional practices (Table 16). It was observed that zero tillage system was more energy (fuel) efficient (Table 17) and saved tractor time as shown in Table 18.

Table 16 Production, economics and energy use in zero-till drilled and conventionally sown wheat after harvest of rice in vertisols

Parameter of comparison	Previous field soil conditions					
	Puddled transplanted rice/wet plastic soil			Direct-dry seeded rice/friable soil		
	ZT	CT	per cent benefit	ZT	CT	per cent benefit
Grain yield, t/ha	5.24	5.14	1.90	5.40	5.25	2.80

Cost of production, Rs/ha	9097	11689	22.20	9548	11682	18.30
Benefit : cost ratio	3.34	2.55	23.65	3.28	2.61	20.43
Specific energy use, MJ/kg	1.24	1.79	30.73	1.35	1.74	22.41
Specific cost of production, Rs/kg	1.73	2.27	23.79	1.77	2.23	20.63

Table 17 Fuel used for wheat sowing under different tillage systems

Tillage system	Fuel used, l/ha					
	Pantnagar	Ludhiana	Jabalpur	Bhopal	Karnal	Average
Zero-tillage (ZT)	7.1	12.5	9.0	14.0	6.0	9.72
Conventional tillage (CT)	67.8	33.0	84.0	38.0	65.0	57.56
Saving in ZT over CT, per cent	**89.5**	**62.2**	**89.3**	**63.5**	**90.8**	**79.06**

Table 18Tractor time required for wheat sowing under different tillage systems

Tillage system	Tractor time required, h/ha					
	Pantnagar	Ludhiana	Jabalpur	Bhopal	Karnal	Average
Zero-tillage (ZT)	1.6	2.3	3.0	3.5	1.6	2.40
Conventional tillage (CT)	13.7	11.2	24.0	11.5	9.4	13.96
Saving in ZT over CT, per cent	**88.3**	**79.9**	**37.5**	**70.0**	**83.3**	**81.80**

In FIRB Planting System crops are sown on raised beds. Generally 2-3 rows of wheat are sown on the top of the bed, 70 cm wide, and irrigation is done through the furrows. The inter-row bed space is used to control weeds by mechanical weeding during the early growth of weeds. In the crop sequences, where wheat follows soybean, maize or cotton this system of reduced tillage can be followed by reshaping the same beds without opening up the soil for field preparation. FIRB system of cultivation also helps in better input use efficiency. The technology is suitable for almost all types of soil except black cotton soils.

In Rotary tillage technology (RTT), soil is pulverized, seeds and fertilizers are placed and then soil surface is planked; all these three activities are done in a single operation. Soil is pulverized to a depth of 10 cm and thus the existing weeds and germinating weed seedlings are killed and incorporated into the soil along with crop residues resulting into increased organic matter content of the soil and at the same time it also reduces air pollution as straw burning is avoided. Tractor based RTT consists of a rotavator and a seed-cum-fertilizer drill. It reduces the number of operations from 6-8 to only one and thereby the total saving of energy and time is 70-80 per cent. Tractor rear-mounted rotavator-cum-drill is priced at about Rs. 45,000 and can be driven by a 35-45 hp/tractor. Experiments conducted at DSWR, Karnal have shown that 7-10 per cent higher grain yield of wheat can be obtained as compared to ZT and FIRB planting system of wheat.

Ridge tillage system is a form of conservation tillage that appears to overcome many of the soil micro-environmental, soil compaction and weed control problems associated with other conventional and un-tilled systems. In ridge tillage system, crop is planted on ridges formed during the previous growing season. During planting the surface (5 cm) of the ridge is scraped into the inter-row valleys. Seeds that were shed on the ridge in the previous season are thus moved to the valleys where seedlings can be destroyed by inter-row cultivation. At layby, when crop plants are at least 40 cm tall, the truncated/scraped soil is excavated from the furrows and moved back to the ridge crests. Such soil management may affect weeds, weed control and crop-weed interactions.

Surface seeding is the simplest no-tillage system being followed/promoted in areas like Eastern India, Nepal and Bangladesh; where wheat sowing in lowland rice fields gets delayed considerably due to excess soil moisture. In this system, seeds of wheat, legumes and/or other crops are broadcasted on wet soil in standing rice crop, about a week before harvesting or on wet/muddy soil after rice harvest. This system is also called Utera or paira cropping.

Resource Conservation Measures

Resource conservation agriculture generally implies to the systems of cultivation with minimum tillage, in-situ management of crop residues, savings in water use and that of inputs. Minimum tillage is aimed at reducing tillage to the minimum necessary that would facilitate favorable seedbed condition for satisfactory germination, stand establishment and growth of crop. Excessive tillage may be minimized either by eliminating the operations which are not cost-effective or combining the tillage, seeding and fertilizer application in one pass operation. Zero tillage is however an extreme form of minimum tillage. Experiments have shown that minimum tillage has improved soil conditions due to decomposition of plant residues in-situ, facilitated higher infiltration due to vegetative matter present on the top soil and passage formed by the decomposition of old roots, less compaction to soil by the reduced movement of tractor and heavy tillage equipment and less erosion compared to conventional tillage. These advantages are more visible in coarse and medium textured soils. Use of appropriate equipment and power sources save considerable amount of energy and time and thereby lead to reduction in cost of cultivation.

Energy and Cost Effective Equipment

Direct drilling equipment

No-till drilling, strip till drilling and roto till drilling of wheat after harvest of rice were compared with the conventional tillage sowing as practiced by farmers. Brief specifications of the direct drilling machines are given in Table 19.

Table 19 Specifications of direct drilling machines

Particulars	No till drill	Strip till drill	Roto till drill
Source of power	45 hp tractor	45 hp tractor	45 hp tractor
Type/number of furrow openers	Inverted 'T' type/09	Shoe type/09	Shoe type/11
Row spacings, mm	180 (Adjustable)	200 (Fixed)	160 (Adjustable)

Working width, mm	1600	1800	1750
Drive wheel	Angle lug – front mounted	Angle lug – side mounted	Star lug – rear hinged
Weight, kg	250	280	300
Unit price, Rs	15000	35000	45000

Table 20 No-tillage and minimum tillage seeding compared to conventional tillage- sowing of wheat

Particulars	No tillage seeding	Strip tillage seeding	Roto tillage seeding	Conv. tillage (3 passes) and sowing
Time, h/ha	3.23 (70.15)	4.17 (61.46)	3.45 (68.11)	10.82
Fuel used, l/ha	11.30 (67.36)	17.50 (49.45)	13.80 (60.14)	34.62
Operational energy, MJ/ha	648.96 (67.16)	1001.76 (49.31)	783.60 (60.35)	1976.11
Cost of operation, Rs/ha	639.54 (66.39)	979.95 (48.51)	807.30 (57.58)	1903.04

() Values show percent savings over conventional practice

The results showed that no tillage drilling was the most time, energy and cost-effective for 70.15, 67.16 and 66.39 per cent respectively over the conventional practice. The roto tillage seeding combined with full width shallow tillage in single pass operation was 60.35 per cent energy efficient and 57.58 per cent cost-effective compared to the conventional practice. The strip tillage seeding although of single pass operation and found advantageous over conventional tillage-seeding but for the intermittent strip tillage the operational energy and cost requirements were higher compared to the roto tillage and no tillage seeding (Table 20).

Cultural practices specific to direct drilling systems were developed in terms of frequency of irrigation and fertilizer applications. First irrigation of 40-50 mm was critical for all the direct seeding systems for initial establishment especially in no tillage seeding. Performance of direct drilled wheat are given in Table 21.

Table 21 Production economics and operational energy of direct drilled wheat (HI-8498) after harvest of rice (IR-36)

Particulars	Zero till drilled	Strip till drilled	Roto till drilled	Conven-tionally sown
Grain yield, t/ha	4.84	4.62	4.78	4.60
Cost of production, Rs/ha	8635	9114	9315	10710
Benefit-cost ratio	3.64	3.29	3.34	2.79
Operational energy, MJ/ha	8114	8712	8444	9516

* Sale price of wheat (HI-8498), was taken as Rs 6.50/kg.

The results show that in direct drilling systems although the grain yields were found at par, the benefit-cost ratio were higher at 15.2-23.4 per cent with savings in operational energy at 8.4-14.7 per cent as compared to the conventional practice.

Raised bed planter

Raised bed planter is used for planting of crops on raised beds. Making of beds on tilled soil, planting of seeds, basal application of fertilizer and covering and dressing of planted beds are done in a single operation. For planting of seeds on permanent beds the same machine is used for single operation adding to the advantage of conservation tillage to the raised bed planting thus reducing the cost of planting compared to those on fresh beds or flat sowings.

The production economics have shown that on permanent beds the benefit cost ratio was higher at 15.8 per cent over the fresh beds (Benefit-cost ratio=3.26) mainly because of the reduced cost of cultivation. In permanent beds the water retention was higher in furrows due to compaction effect by tractor wheels helping to provide catchment effect for longer periods by slow infiltration of water to the root zone of crops on beds.

In general performance of wheat on fresh and permanent beds were found higher in terms of grain yield (8.5-9.4 per cent) and benefit cost ratio (14.4-27.9 per cent) compared to the conventional flat sown yield of grain was 4.6 t/ha while the benefit cost ratio was 2.79.

Network for Agricultural Machinery Design and Development

The early farm machinery development in India was greatly influenced by technological development in England. Horse drawn and steam tractor operated equipment were imported during the latter part of the 19^{th} century. In 1888-89, Watts and Kaisar ploughs, corn grinders and chaff cutters were introduced at Cawnpore (now Kanpur) Experimental Farm in Uttar Pradesh. Sardar Joginder Singh (1897-1946) introduced steam tractors in India in 1914. He was Agriculture Minister in the Punjab Government during 1926-37. The horse drawn equipment imported from England were not suitable for bullocks and buffaloes being used in India. These were suitably modified to suit Indian draught animals and as a result mould, board plough, disc-harrow, and cultivator were introduced in India. With the establishment of Allahabad Agricultural Institute, Allahabad, the development activities in agricultural machinery accelerated. Meston, Shabash and Wah-Wah ploughs were introduced in Uttar Pradesh, manufactured by the Agricultural Development Society, in the early forties. The development of spike tooth thresher at this Institute in 1960s revolutionized wheat threshing technology in India.

Agricultural machines are by and large fabricated by village craftsmen and small scale industries. Tractors, engines, milling, dairying equipment and oil mills are manufactured by organized sectors. Small-scale industries seldom have R&D facilities and they depend upon public institutions for technological support. They require not only drawings but also prototypes and technical guidance in manufacture of the equipment. These industries however, upgrade the technology with experience. The Indian Council of Agricultural Research (ICAR) with the cooperation of Agricultural Universities and industries developed simple low cost hand tools and animal drawn region specific improved machinery to suit local cultural practices. The ICAR also established the Central Institute of Agricultural Engineering at Bhopal to address issues related to agricultural engineering. The CIAE provides leadership and coordinates research through a network of research centres established all over the country for developing commodity and location specific technologies. The CIAE also created facilities for manufacture of commercial grade prototypes.

The ICAR for the first time sponsored a scheme to conduct a state-wide survey of existing tools and implements used by the farmers in 1954. The results were published in the form of a book entitled "Indigenous Agricultural Implements of India" in 1960. During the sixties, ICAR made serious efforts to promote research and development on improved farm implements by establishing 17 Research Training and Testing Centres (RTTCs), one in each of the major states, which were operated by the State Department of Agriculture. The major mandate of these RTTCs was to test and modify existing implements and develop new improved implements suitable for different agro-climatic conditions of the country. During the latter part of the sixties (IV Five Year Plan Period) two Zonal Research and Testing Centres, one at IARI, New Delhi and the other at TNAU, Coimbatore and four research centres at Ludhiana, Pune, Hyderabad and Mandi were established.

In 1971-72, ICAR sponsored the All India Coordinated Research Projects (AICRP) on Research & Development of Farm Implements & Machinery, Production of Prototype and their evaluation under different agro-climatic conditions. With the establishment of CIAE, the scheme was shifted to Bhopal in 1977. The research in the area of farm machinery further strengthened with the creation of other AICRPs on Power Tiller (1980), Utilization of Animal Energy (199)Human Engineering and Safety in Agriculture (1994) and a NRC on Reducing Drudgery of Women in Agriculture (1994). The AICRPs undertake research and development keeping regional needs of the farmers and conduct front line demonstration for pilot introduction.

Training and Testing activities for tractors and farm machinery

The Ministry of Agriculture, Government of India has four Farm Machinery Training and Testing Institutes one each in North, South, North-East and Central India. The Central Farm Machinery Training and Testing Institute, Budni is a premier Institute functioning since 1955. The other sister institutes are located in Hisar (Haryana), Anantpur (Andhra Pradesh) and Biswanath Charially (Assam). The main objectives of the institutes are training in agricultural machinery and promotion of farm mechanization and testing of tractors and agricultural machinery.

Institutes conduct training on working principle, operation, adjustment, service, maintenance, repair, selection and management of tractors and farm machinery for progressive farmers, technicians, engineers, in-service personnel, defense personnel, foreign nationals and women in farming.

Testing Activity at Budni

Test as per Central Moor Vehicle Rules 1989:

The Institute has been designated as one of the agencies for testing of tractors and allied agricultural machines as to their conformity to the Central Motor Vehicle Rules, 1989, as amended from time to time and issuance of the certificates to that effect.

Commercial and confidential tests are carried out at the Institute for establishing performance characteristics of machines that are in or ready for commercial production and confidential tests are carried out for providing information to the manufacturers on the performance of their machines and any other data that may be required by them.

The objective of Batch Testing of agricultural tractors is to ensure continuous up gradation in the quality of the tractors that are being manufactured in the country. These tests are conducted at a regular interval of three years. The test reports under batch testing programme are released in two parts. The first part contains results of laboratory and field tests conducted at the Institute and the same is released as the Commercial Test Report. The second part, which contains information based on the user's survey, is released as the Confidential Report so as to provide feedback to the manufacturers for their further improvements. The batch test programme has proved very useful.

The institute has trained more than 40,000 trainees under various courses and tested more than 1000 tractors and other farm machinery.

Testing activities in Farm Machinery Training and Testing Institutes

Testing Activity at Hisar

The testing wing of this Institute is equipped with specialized and modern scientific equipment/ instruments for conducting various tests on a wide range of agricultural machines. The Bureau of Indian Standards also accredits the laboratories of the Institute for testing of the samples under BIS central certification marks scheme. BIS accredit the following laboratories.

i. Engine tests laboratory for testing of stationary diesel engines as per IS:10001 and petrol/ kerosene engines as per IS:7347.
ii. Centrifugal pump test laboratory for testing of centrifugal pumps as per IS:6595.

Apart from the accredited laboratories, the testing wings have following operational laboratories for testing of other Agricultural machines.

a. Plant protection equipment test laboratory.
b. Implement test laboratory.
c. Fuel filter test laboratory.
d. Design and drawing section.
e. Instrumentation cell.
f. Computer cell & Reprographic section.

This Institute is also authorized by the Ministry to test self-propelled combine harvesters. The testing wing is fully commissioned to take up the tests on self-propelled combines having output capacity and engines having output capacity from fractional horsepower to 700 kW.

Testing Activity at Anantapur

This institute has been testing various agricultural machinery/ implements operated by animals, power tillers and tractors including engines for stationary applications such as threshers and pump sets.

Testing Activity at Sonitpur

This institute has been testing various agricultural machinery/ implements including components, hand tools, power operated threshers, decorticators, sheller, winnowers, animal drawn, power tiller operated, tractor drawn and manually operated seed cum fertilizer drill/ planters, straw reaper, mini rice mill power seed cleaners/ graders. Samples received from BSI such as centrifugal pump, diesel engine, spark ignition engine, sprayers, dusters, etc. are also tested.

Concerns and Strategies for Agricultural Mechanization in India

Agriculture continues to be the major occupation of the people of India and it is endowed with varied agro-climatic conditions, which offers immense scope for the cultivation of various kinds of agriculture and horticulture crops. India needs basic reforms for achieving success in agriculture and horticulture. India has unparalleled intellectual potential but timely efforts are needed to evolve a strategy, which supports the dissemination of the technology to needy farmers. Further research, development and policies should take into account all these issues. The onus is on the researchers and policy makers to maintain a holistic approach to farm mechanization and agriculture rather than looking at them in isolation.

Diverse farm mechanization scenario prevails in the country due to size of farm holdings and socio-economic population. Hand tools and animal-drawn implements are extensively used which involve drudgery. Presently, the contribution ff animate power to total farm power has come down to only about 19 per cent and from rest of the sources such as tractors, power tillers, electric motors and diesel engines; it has increased to 81 per cent.

Concerns

No doubt there have been spectacular advancements in various sectors of agriculture, which have propelled the country from a food deficit to self-sufficient and in some commodities a surplus nation. India is a large country with diverse agro-ecological differences having predominance of rain fed agriculture, as irrigated agriculture is limited to 40 per cent of the country. Farm holdings are small due to higher population density and land fragmentation will continue in part due to 'Laws of Inheritance' and the 'Hindu Succession Act'. The majority of the farmers have limited surplus money to modernize farms or invest in improved inputs. Draught animals and increased agricultural workers may remain the chief source of farm power for soil tillage and for handling crops. Mechanical power for tillage, irrigation, harvesting and threshing will be preferred including custom hiring by those farmers who can not afford to own machines.

Major constraints in modernizing Indian agriculture are low productivity, high cost of production, slow diversification in agricultural exports, export of raw materials and low value added products, difficulties of meeting quality standards; lack of appropriate infrastructural facilities in the production catchments, supply routes and ports, inadequate transport and marketing facilities, inadequacies of market intelligence and trained manpower, technological deficiencies - failure to harness latest technologies at scales compatible to small scale decentralized resource and management constraint situation, poor quality and costly packing materials, weak networking and reluctance of the processors to share profits of value addition with the producers, global trade blocks and their compulsions to meet shortfalls from member states, emergence of strong competitors and global politics etc. Other constraints are as follows:

- Plateau in agricultural productivity and production in main grain bowl aes.
- Low annual growth rate of agricultural sector (<2 per cent).
- Declining average farm size due to rising demographic pressure
- Environmental degradation due to excessive use of agro-chemicals.
- Damage to natural resources like soil, water and biodiversity.
- Decline in total factor productivity.
- High cost of production, higher risk and low returns to farmers and poor utilisation efficiency of inputs like water, seeds, fertilizers and chemicals
- Indebtedness of farmers due to high cost of production and low profitability.
- Excessive post harvest losses and low value addition.
- Poor quality of produces and processed products.
- Lack of modernization of agricultural markets for both durables and perishables.
- Insufficient support prices for different commodities.
- Interest rates on loan are non-conducive
- Only 29 per cent of precipitation is conservedOnly 5per cent of produce is processed in the country as against 40-60 per cent in other Asian countries with negligible value addition in production catchments leading to distress sale and low returns to farmers.Huge post harvest losses in grains and perishables, amounting to Rs 60 billion per annum;
- Increased requirements of conventional energy sources in Agriculture compounding the energy crisis in the countryNutritional
- insecurity of rural population;
- Benefits of R&D in Agricultural Engineering not reaching the farmers effectively

Challenges

- Improving input use efficiency of seeds, chemicals and fertilizers and water through engineering interventions
- Reducing cost of cultivation
- Improvement in production and productivityDiversification necessary to substitute crops requiring high inputs (need for multi faceted ventures)
- Reducing post harvest losses and facilitating non-land primary and secondary processing for value addition and by product utilization
- Providing nutritional security for rural populationChecking and reducing environmental degradation (soil and water)Checking over exploitation of natural resources (Ground water and soil nutrients)Improving power availability and

energy use efficiencyEasing the pressure on conventional energy sources by substitution with renewable energy options in crop production and processing

- Bringing more area under efficient water application methods and harnessing available resources through watershed management, rainwater harvest and ground water recharge
- Making the fruits of R&D in engineering, available to farmers through effective transfer of technology and commercialization
- Making agriculture information-driven and the farmers information-guided
- Empowerment of women by forming cooperatives and evolving woman friendly technologies;
- The Indian farmers have limited access to the latest equipment and technology. This results in high production cost and difficulty in competing in international market for sale of surplus produce. Further, there is little feed back from the farmers for product improvement and assessment of product acceptance. There is a need top generate more interaction among the farmers, R&D workers, departments of agriculture and industry.
- There are wide technological gaps in meeting the needs of various cropping systems and regions. Urgent steps need to be taken to make farm machinery R&D Base stronger.Reduction of drudgery and improvement of safety and comfort in agricultural sector;
- Empowerment of farmers for equitable distribution and efficient utilization of water, energy, agro processing and marketing of farm produce. The widely fragmented and scattered land holdings in many parts of the country need to be consolidated to give access to the benefits of agricultural mechanization.Appropriate equipment is required to improve moisture conservation and timeliness of operations in rainfed agriculture.

Strategies

- Agricultural mechanization should contribute to sustainable increase in yields and cropping intensity so that the planned growth rates in agricultural production are achieved.
- The income of agricultural workers (cultivators and labourers) should increase at a satisfactory rate so that the disparity between urban and rural income is eliminated so that agricultural workers are able to lead a dignified life and prevent them migrate to urban areas.
- The benefits of agricultural mechanization should be extended to all categories of farmers with due consideration to small and marginal framers and to all regions of the country especially the rainfed areas.
- 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.
- Agricultural mechanization should contribute to conservation of land and water resources and more efficient use of inputs such as seeds, chemicals, fertilizer and energy.
- Loss of agricultural production, both in quality and quantity should be reduced through timely operations and improvement in equipment and techniques. Equipment, technologies and approaches need to be developed for loss reduction and value addition of agriculture produce in production catchments.
- Development of appropriate technologies for value addition, handling, packaging, storage, transportation and marketing of agricultural products for safe and quality

food.

- 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. Regular training to scientists and farmers are to be extended to acquaint them with modern technologies such as precision farming for higher input use efficiency.
- Conservation agriculture technologies such as zero-till drill, till pant machine, roto-till drill, strip till drill, raised bed and furrow planting systems with straw management will have to be adopted on large area.
- Scientific water resource management through in-situ and ex-situ harvesting and conservation of rainwater and its recycling, consumptive use of rain and ground water, increasing ground water efficient through efficient irrigation, ground water recharge as well as ensuring management of watersheds and command areas.

- 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 adopted. Improving efficiency of irrigation systems and pumping systems is essential to save energy and water.
- Sustainable management of soil resources by devising efficient agricultural production strategies and developing crop models/farming system
- Integrated nutrient and pest management
- Farm mechanization through custom hiring of package of farm equipment with high capacity and high labour productivity.
- Adopting farmer-friendly farming systems approach instead of the cropping system approach. This approach would call for diversification of agriculture to include livestock fisheries, horticulture, agro-forestry etc.
- Partnership and participatory research by involving private sectors and NGOs
- Promoting agri-business such as processing, marketing, infrastructure and environments.
- Promoting post-harvest technologies and value addition.
- Ensuring environmental sustainability.
- Reorienting agricultural research priorities. It should be programme based, demand driven, problem solving and participatory mode.
- Agricultural production and productivity has to be increased almost to double in 2025 to meet the demand of the then population. With weather conditions becoming more erratic, to perform the farm operations timely, the energy input to agriculture will increase from present level of 1.35 kW/ha to 2.5 kW/ha by 2025. About 65 per cent of this power will have to come through tractors and sel-propelled machines.
- More than 60 per cent of cultivated land is under rain-fed and dry-land areas. Development and popularization of agricultural machinery under varied conditions are required.
- High labour intensive farm operations for horticultural crops and hill agriculture needs to be appropriately mechanized for drudgery reduction and productivity enhancement.

- Development of gender specific tools and equipment and imparting training to female farmer workers on operation and maintenance of farm tools and equipment.
- Farm mechanization data need to be collected and updated regularly and made available on-line to formulate viable Farm Mechanization Policy.
- The designs of agricultural machineries and equipments need to be ergonomically evaluated to avoid accidents and other causalities.
- Bio-fuels for tractors, IC engines and automobile will have to be developed and used on mass scale.
- Decentralized power supply system based on locally available biomass and renewable sources of energy may be west up to meet the energy requirement of rural areas.
- Over 600 million tonnes of available biomass be converted to briquettes or other forms for minimizing the dependence on conventional energy sources.
- Establishment of agro-processing units in production catchments for creation of employment and income generation to check migration to urban areas, to minimize post-harvest losses and increase returns to the framers.
- Manufacturers of agricultural machinery need training and orientation on quality product manufacturing through modern manufacturing technology. They may be encouraged to use standard parts.
- Creation of Farm Implement Bank/Custom-hire Centres/Agro-Service Centres involving entrepreneurs, Farmers' Cooperatives/Agri-business centers to supply machines on custom hire basis to small and marginal farmers.
- Identification of agricultural equipment and machinery for promotion.

Conclusions

The country has made significant progress in the adoption of modern methods of cultivation and creating infrastructure for effectively and sustainably utilizing the national resources available at its command. It has transformed its image from that of a ***'begging bowl' to bread basket*** due to the efforts of various agencies combined with scientific and engineering inputs in agriculture. Indian agriculture has evolved into a mature and modern enterprise over the last five decades. Farm mechanization has reached a level of maturity pushing the net sales of machinery to over Rs 50,000 crore, almost entirely through indigenous efforts. Farm mechanization programmes pursued in the country after attaining independence were directed towards optimal utilization of available farm power sources. The impact of tractorization as against oxenisation is evident from the fact that India is the largest producer of tractors in the world. Increase in cropping intensity, timeliness of operations and reduction in drudgery have been shown to be the needed incentives for farmers and farm workers to adopt modern methods of cultivation. An increase of 15 per cent in productivity and a reduction of 20 per cent in the cost of cultivation can be achieved by engineering interventions. These interventions have been limited to a few field crops, farm operations and post harvest activities. There is an urgent need to extend it to the entire gamut of production agriculture in the country.

The Country has an extensive research and development system for farm machinery design and development for production agriculture, post harvest, and utilization of renewable sources of energy covering various zones and agro-climatic regions.

Extensive facilities for the testing of farm equipment and machinery including different kinds of prime movers is also a part of the agricultural equipment development network in the country which meets not only the national requirements but is also available for neighbouring countries.

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