COUNTRY PAPER - INDIA
AGRICULTURAL MECHANIZATION
- PRESENT SCENARIO AND PERSPECTIVE

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1. Introduction

Agriculture contributes about 25 per cent to GDP (505 billion US$ in 2003-04) and for livelihood of about 66 per cent population. India is blessed with abundant natural resources. She has traditional wisdom, knowledge, skill and crafts to practice agriculture. However, other inputs including agricultural engineering technologies are gaining importance for increasing production, productivity and cost competitiveness. Our foodgrain production has touched 213 mt in 2003-04 from a mere 51 mt in 1951-52 (Table -1).The country has attained not only self sufficiency in food grain production but also maintains buffer stock to meet eventuality. Agricultural engineering inputs have played appreciable role in increasing production and productivity through appropriate mechanization inputs for production and post production agriculture covering timely field operations, judicious application of water, appropriate post harvest technology to reduce losses and add value to the produce and by-products for enhanced economic returns and employment generation.

Table -1 Agricultural production in India during 2002-03

Crop	Area, Mha	Production, Mt	Yield, Kg/h	% Irrigation
Foodgrain	124.24	212.05	1707	44
Rice	42.41	87.00	2051	54
Wheat	26.62	72.06	2707	88
Coarse cereals	30.76	37.76	1228	12.5
Total pulses	24.45	15.24	623	13
Major oilseeds	23.44	25.14	1072	24
Cotton	7.64	13.79*	307	35
Jute & Mesta	1.05	11.20*	1923	
Sugarcane	4.00	236.18	59119	92
Potato	1.34	23.16	17321	
Onion	0.42	4.21	9912	
Tobacco	0.33	0.49	1506	52
Coconut	1.87	119.86**	6422	
Milk :873 Mt	Egg : 40.3 billion	Fish : 6.2 million tonne		Wool : 51.9 Million kg

Major research achievements in agricultural engineering have been in devising methodology for soil resource conservation, on-farm water management, land-use, increase in cropping intensity to 1.33, development of various improved agricultural equipment/ technologies for various pre and post-harvest operations by human, animal, mechanical and electrical power; modernization

of rice, wheat, oil, and sugarcane milling industry to some extent, development of technology for value addition and for health and nutritional security. However, there exists a scope for furthering the cause.

Non-availability of manpower during peak crop season is many times a problem. Water, source of assured agriculture, is becoming a scarce commodity. Thus proper harvesting and efficient utilization of water is of great significance. The overall achievement in the creation of irrigation facilities has been relatively better in India with 63% growth rate compared to world level. There is a need to increase the utilization of rainwater to enhance the gross cropped area by 30 Mha as in irrigated tracts the yield of foodgrain is almost double compared to rainfed areas. Net availability of foodgrains per head has declined from 510 g per day in 1990 to 436 g/day in 2003 and needs to be checked. The infrastructure for agricultural diversification, reducing post harvest losses of perishables, value addition to agro-produce and branding system need strengthening. To keep pace with the present population growth and consumption pattern, foodgrain requirement has been estimated to be 240 Mt by 2020 and 300 MT by 2025 (Table 2). Annual agricultural growth should be at 6.7% to meet this demand projections.

Table 2 Estimated Food requirements of India, Million Mt

Year	**2000**	**2010**	**2020**
Population, million	1000	1200	1450
Cereals @ 400/d	146	175	212
Pulses @ 45 g/d	16	20	24
Oil @ 30 g/d	11	13	16
Oilseed	Oilseed		
@ 25% oil	44		64
@ 30% oil	37		53
@ 40% oil	27		40
Milk @ 200 g/d	73	88	106
Fruits @ 200 g/d	73	88	106
Vegetables @ 300 g/d	110	131	159
Sugar @ 40 g/d	15	18	21

2. Characteristics of Indian Agriculture

Of the total geographical area of 329 million hectare, the net sown area is about 142 million hectares. The gross cropped area, however, increased to 190 million hectare in 2000-01.

With present population of 1050 million, India is required to support survival of 17% of world population on 2.3% of total land area on the planet earth. Average size of farm holdings gradually reduced from 2.58 ha to 1.57 ha. About 93 million (80%) small and marginal farmers owning 58.8 Mha (36%) land, have average land holding 0.6 ha/holder (Table-3). They have limited resources especially in rain-fed regions where productivity is low and are cultivated by animate power only. Twenty-two per cent semi-medium, medium and large farm holders, however, possess 104 M-ha (64 % of the total land), with average holding of more than 5 hectares. These farmers are better placed to utilize modern inputs for mechanization of agriculture.

Table 3 All India Operational holdings, 1995-96

Category	Number (000), (%)	Area operated '000 ha, (%)	Size, ha
Marginal (< 1ha)	71179 (61.6)	28121 (17.2)	0.40
Small (1 to 2 ha)	21643 (18.7)	30722 (18.8)	1.42
Semi-medium (2 to 4 ha)	14261 (12.3)	38953 (23.8)	2.73
Medium (4 to 10 ha)	7093 (6.1)	41398 (25.4)	5.84
Large (>=10 ha)	1404 (1.2)	24163 (14.8)	17.21
All Holdings	97155	165507	1.41

The Indian agriculture is characterized by agro-ecological diversities in soil, rainfall, temperature, and cropping system. Besides favourable solar energy, the country receives about 3 trillion m^3 of rainwater. 14 major, 44 medium and 55 minor rivers share about 83% of the drainage basin. About 210 billion m^3 water is estimated to be available as ground water. Presently, the cropping intensity is 133% and more than 55 million hectare net area is under irrigation.

Intensive cultivation as a result of introduction of high yielding varieties in 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 has 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 sufficient. Farmers opted mechanical power sources to supplement animate power. Irrigation, tillage and threshing operations, which not only require more energy but also are arduous to perform, have been mechanized. But other field operations continue to be performed primarily by animate power.

3. Agricultural Productivity

The efficacy of agricultural inputs -seed, fertilizers, chemicals, and natural resources - land and water has been increased through adoption of appropriate agricultural equipment and improved farm machinery (Table - 4). The present average productivity is more than 1700 kg/ha. The productivity of wheat, rice and oilseeds increased more than other crops like coarse cereals, pulses and oil seeds due to low inputs applied by the farmers besides, cultivation of these crops in marginal lands.

Table 4 Trends in use of agricultural inputs

Inputs	1950-51	1960-61	1970-71	1980-81	1991-92	1999-2k	Growth rate, (%)
Seed, 10^3 T	-	-	200	240	570	910	5.21

Inputs	1950-51	1960-61	1970-71	1980-81	1991-92	1999-2k	Growth rate, (%)
Seed, 10^3 T	-	-	200	240	570	910	5.21
Fertilizer, kg/ha	0.55	2.17	16.14	34.27	70.3	88.62	11.67
Agro-chemicals, kg/ha	0.02	0.06	0.15	0.26	0.38	0.35	6.28
Diesel, kg/ha	-	-	0.93	6	12.45	-	12.2
Electricity, kWh/ha	-	-	27	84	276	642	11.6

Source: Agricultural Statistics at Glance, 2000, Teddy, 1999-2000

4. Agricultural Mechanization

Efficient machinery helps in timely farm operation, input use efficiency, increasing productivity by about 30% (Table 5) besides, enabling the farmers to raise a second crop or multi crop making the Indian agriculture attractive. Raising cropping intensity by limiting the turn around time through greater engineering inputs is the need. Thus, development and introduction of high capacity, precision, reliable and energy efficient equipment and their judicious use can bring in the precision and timeliness in field operations. Today, with 260000 tractors/year and 13 manufacturers, India is the largest producer of tractors in the world. During 1970-90, the compound annual growth in the sale of tractors was more than 8% and during the last 10 years (1991-92-2000-01), about 205 million tractor and 1,17,000 power tiller were sold in the country. The total power availability during the period increased from 0.295 to 1.231 kW/ha. At present in India, tractors are being used for tillage of 22.78% of total area and for sowing 21.30% of total area and only about 35-40% of the agricultural land is being tilled through mechanical power sources. Power tiller manufacture in India started in 1961 with Japanese collaboration. About 17000 units are produced every year. Few models are being imported from China.

Table 5 Advantages of mechanization

Increase in productivity up to	12-34%
Seed-cum-fertilizer drill facilitates Saving in seeds	20%
Saving in fertilizer	15-20%
Enhancement in cropping intensity	5-22%
Increase in gross income and return of the farmers	29-49%

Note: Report of the Sub-Group on Agricultural Implements and Machinery for Formulation of 9th Five Year Plan, Govt of India, 1996

With increased cropping intensity, farmers have supplemented animate power with tractors, power tillers, diesel engines and electric motors. Mostly small size general-purpose tractors are manufactured in India, ranging from 15 kW to 37.5 kW for field operations such as

ploughing, sowing and haulage. Custom hiring of tractors and agricultural equipment has become popular for tillage, transport and threshing. It was triggered by GOI scheme on promotion of Agro Service Centres. The average capacity in ploughing is 0.23 ha/h and in harrowing about 1ha/h. For crop production human, animal and mechanical energy is extensively used (Table 6). The share of tractive mechanical power is given in Table 7.

Table 6 : Share of farm power sources

Power source, million kW	1971-72	1996-97	2000-01*
Human power	6.29 (14.2)	10.12 (7.4)	11.12 (6.49)
Animal power	20.19 (45.8)	19.23 (14.1)	19.17 (9.89)
Mechanical and electrical	17.57 (40.0)	107 (78.5)	112.94 (83.62)
Total farm power	44.05	136.35	143.23

Note: The values in brackets indicate percentage of total farm power.

* Estimated

Table 7 Share of tractive mechanical farm power

Power	1951-52	1961-62	1971-72	1981-82	1991-92	1996-97	2000-01
Total farm power, MkW	23.54	28.28	44.05	69.13	113.64	136.33	167.07
Mechanical over total power, %	3.6	8	40	63.7	74.5	78.5	55.56
Tractive over total power, %	0.82	2.48	7.78	17.61	25	30.57	44.44

The agricultural workers population in India increased from 97.2 million in 1951 to 234.1million in 2001. Of the total agricultural workers, 91.2 million (39%) is comprised of women and they contribute substantially. The work out put of the workers is being improved by reducing drudgery through adoption of ergonomically designed tools and equipment. To ensure effective use of available resources improved tools have been developed and commercialized.

Traditionally, draught animals are used in India for field operations, transport and agro-processing. Even today, it is estimated that more than 57 % area is commanded by draught animals. Field operations in hill regions are performed only by human and animal power due to difficult terrain. The country has about 34 million pair draught animals, and for their gainful utilization. engaging them to productive output is the priority.

A considerable growth has also taken place in the use of pumpsets for irrigation. Major water resources are from rivers, lakes, canal, reservoirs, tanks and ground water. In India, around 88% water is being used in agriculture sector, covering around 80 Mha area under irrigation. Water is drawn either from a dug well or a shallow tube well with centrifugal pumpset. Presently there are about 11.85 million electric motors and 5.84 million diesel engine pumpsets for lifting water from various sources (Table 8). These consume about 90 billion kWh of electricity and 3.6 billion litre of diesel annually. The operational efficiency of irrigation pumps in diesel operated pump sets is about 12.7 per cent and 31.1 per cent in electrically operated pump sets and needs emphasis to increase their efficiency by selection

of appropriate pump, prime mover, proper couplings, selection of proper size of suction and delivery pipes, proper installation of system and regular maintenance.

Table 8 Population growth trends in stationary farm power sources in India for pumpsets

(in million)

Mechanical power	**1961-62**	**1971-72**	**1981-82**	**1991-92**	**1996-97**	**1997-98**	**2003-04***
Electric pump	0.1	1.63	4.33	9.34	11.57	11.85	16
Diesel pump	0.23	1.55	3.1	4.59	5.58	5.84*	9

* Estimated

Source : Agricultural Statistics at A Glance, 2004.

Energy use scenario : The total animate energy availability is decreasing over the years from 2937 MJ/ha in 1971 to 2514 MJ/ha in 1996-97 due to decrease in availability of animals (Table 9). To meet the operational energy need, the contribution of mechanical energy has to be increased substantially which require more diesel.The average specific energy availability on all India basis with present growth rate would be of the order of 5860 MJ/ tonne of food grain as compared to present level of 5480 MJ/ tonne in 1996-97.

With the shifting trend from use of animate to electro-mechanical energy in agricultural production and increased on-farm and off-farm agro and food processing activities, the demand of energy will increase manifolds.

Table 9 Operational energy use pattern in agriculture, MJ/ha

Energy	**1970-71**	**1975-76**	**1980-81**	**1985-86**	**1990-91**	**1996-97**	**2000-01***
Diesel	23	78	148	190	288	480	550
Electrical	322	668	1002	1563	3233	5308	7720
Total mechanical	345	746	1150	1753	3521	5788	8270
Animal	1606	1485	1404	1293	1101	980	907
Human	1331	1363	1401	1348	1409	1525	1607
Total	3282	3594	3955	4394	6031	8773	10784
Share of Mechanical, %	11	21	29	40	58	71	76

*Estimated . Capacity: Diesel, 63.27 MJ/kg; electricity, 11.93 MJ/kWh Bullocks pair, 10.10 MJ;

Human , 1.84 MJ (male , 70% and female, 30%)

Note: 40% of the total diesel used in rural sector assumed for crop production and remaining for transport and other agro-industrial activities.

5. Rural Energy Needs

Energy needs in rural sector are for rural home management, production agriculture, cottage industries and agro-processing (Table -10). Cooking alone consumes 70% of the total energy which is met by wood, crop residues, and animal dung cake etc.. About 3-5 kg of fuel wood per household is required every day. One of the bottlenecks in establishing Agro-Processing enterprises in rural sector is inadequate availability of assured electricity.

Table 10 Rural energy needs

Activity	% of energy use
Home management and rural industries	: 66 - 80
Agricultural production	: 16 - 25
Post harvest activities	: 2 - 4
Animal husbandry and dairying	: 2 - 5

6. Renewable Energy

The 'renewable energy' or 'bio-energy' sources now supplement and substitute electro-mechanical power sources. Since petroleum is largely imported and electricity being costly, efforts are on to conserve commercial energies by supplementing and substituting these with renewable sources of energy. Renewable energy sources -solar, wind, and biomass have potential to be utilized as supplementary energy source. The decentralized production of electricity using agro-residues may be an opportunity. About 600 million tonnes of bio-mass is available from various crop residues and agro-wastes. Besides about 27 million tonnes municipal waste, urban wastes from house hold and industries is also available 0.4 kg/person/day with calorific value of about 850 kcal/kg, which has potential to be utilized for energy generation, through bio-degradation and gasification. It is estimated that 35-40% of bio-mass is utilized for animal feed and the remaining as energy source through direct combustion either for cooking, heating, etc.

Biogas plants (3million installed) are estimated to save 3 million tonnes of fuel wood per year and generate organic manure containing nitrogen equivalent to about 0.9 million tonnes of urea per annum. A total of 32 million improved *chulhas* (cookstoves) have been installed and are expected to save over 10 million tonnes of fuel wood per annum. Fuel wood is estimated to meet between 70-80 percent of the rural energy budget and 40% of India's overall total energy consumption. Ninety percent of all bio-mass removal from India's forests is for fuel-wood and energy consumption.

India receives 5000 trillion kWh of solar radiation per year with parts of the country having 300 clear sunny days. It is possible to generate 20 MW solar power per square kilometre land area. Presently, solar energy is being utilized through two routes, namely, thermal and photovoltaic. Solar thermal technologies are now finding ready acceptance for a variety of applications. Over 500000 sq.m of collector area has so far been installed covering 50000 units of domestic water heaters. Around half a million box type solar cookers are also in use. Over 700000 solar PV system of 32 different types have been deployed for rural, remote area and commercial applications, including home and street lighting/water pumping and rural telecommunication systems.

The gross wind power potential of India is estimated to be about 20000 MW. A capacity of 1,167 MW has been added so far, which places India in the fifth position in the world, after Germany, USA, Denmark and Spain.

7. Adoption of Farm Machinery

Commercialization of equipment is rather slow as these are generally manufactured by small-scale manufacturers. Potential manufacturers are associated at feasibility testing stage. Organized farm equipment manufacturers like tractor manufacturer, power tiller, and other self propelled farm machinery manufacturers rely on their own R&D or their principals.

Large capacity implements and machines suitable to Indian conditions can be adopted on reverse engineering basis.

Land development and tillage equipment : Animal drawn buck scraper, floats, V-ditchers, bund formers developed are used for levelling**,** smoothing and land shaping. The tractor drawn equipment have come in use and are available in the market. Heavy earthmoving machinery are costly but finding use in farm pond construction, drainage system etc. The use of animal drawn equipment is on the rise (Table - 11.)

Table 11 Trends in growth of population of bullock drawn implements

(in million)

Implements	**1966-67**	**1971-72**	**1981-82**	**1991-92**	**2000-01**
Steel plough	3.52	5.36	6.69	9.60	11.70
Cultivator	-	-	4.26	5.79	6.54
Puddler	2.72	1.69	2.32	2.37	2.81
Sowing devices	1.14	4.09	5.62	6.74	8.26
Cane Crusher	0.65	0.68	0.69	0.75	0.73
Sprayer & Duster	0.21	0.44	1.55	1.79	1.86

Singh G. (2000). Agricultural Situation in India, January, 2000

Sowing and planting equipment : The animal drawn local sowing devices are preferred due to less cost. For precise application of seed and fertilizer, mechanically metered seed drill and seed-cum- fertilizer drill operated by animal and tractor are commercially available. For sowing in small areas dibbling i.e., making holes or slits by a tool and dropping seeds is practised. Multi-row traditional seeding devices with manual metering of seeds are quite popular with experienced farmers. Different designs of improved seed drills/planters have been developed for are getting acceptance. Zero till drill is a highly accepted equipment.

Interculture and plant protection equipment : Weed control is a serious problem and the yield is affected to the extent of 20-60%, if not controlled. Hand hoe takes 300-700 man-h/ha to remove weeds whereas wheel hoe/ peg type weeders, reduce weeding time to 100-125 hours. Bullock operated weeder and cultivator are also used for control of weeds. Different designs of low cost hand operated sprayers and dusters are available for plant protection. For animal drawn weeding tools (blade hoe and blade harrow) labour requirement varies from 6-20 man-h/ha. Locally made hand hoe is a low cost equipment (US $ 0.6) as compared to wheel hoe (US $ 2-5). Power weeders are popular in crops like cotton, tobacco and plantation crops.

Different designs of spraying equipment have been developed for different types of applications and field crop conditions. Manually operated (Knapsack sprayers), motorized knapsack mist blower cum duster, centrifugal rotary disc type and boom sprayers are available for spray applications in crops. To apply concentrated pesticides of low and ultra low volume sprayers are available.

Harvesting and threshing: The sickle is the low cost (0.6 US$), easily available and most widely used tool for manual crop harvesting. Self-sharpening serrated sickle has been developed. Reapers operated by engine, power tiller and tractor have been developed and introduced for harvesting wheat, paddy, soybean, ragi and mustard. Harvesting of crops with sickles and reaper harvesters may continue due to socio-economic and agro-ecological

considerations. Tractor operated and self propelled combine harvester are commercially manufactured in India (about 700-800 combines are sold annually). The combine harvesting of wheat, paddy, gram and soybean has been accepted by the farmers on custom hire basis to save time.

The mechanical threshers of varying power range (5-15 hp) are commercially manufactured which not only thresh the grain but also provide good quality *trash* for the cattle feed. The farmers use thresher on individual ownership basis or on custom hire. More than 70-80% cereal crops are threshed by power threshers. Raspbar type paddy thresher causes less damage to straw can be put to better use.

8. Dryland Farming Mechanization

Dryland agriculture constitutes about 67% of total cultivated area (118 Mha) in India and contributes 42% to food production with average productivity of 0.7 to 0.8 t/ha. Timeliness is more important in rainfed farming to utilize the available moisture for crop establishment. Decreasing availability of draught animal power is affecting dryland agriculture. In drylands, most of the land holdings are small and scattered. Poor investment capacity of dryland farmers demands quality implements at low cost and therefore custom hire is preferred by them. The mechanization is predominately taking place for operations where traditional practices have limitations to achieve timeliness of operation.

9. Post Production Agriculture

India=s food processing mainly involves primary processing which accounts for 80% of the value. As much as 42% of the food industry is in the organized sector and 33% in the small scale, tiny and cottage sectors. The value addition to agricultural commodities is upto 10%. Food habits in India vary across the country. Busier schedules and growing number of working women has collectively led to an increase in the demand for ready-to-eat traditional and/ or newer foods. As a segment of the food industry, traditional foods is the largest, both in terms of quantity and value. The challenges in processing lie in presenting them in near natural form with added convenience, in hygienic and attractive packaging, and at low incremental costs. The challenges for the food preservation, distribution and processing sectors are diverse, demanding, and need to be addressed on several fronts. The poor segment of population needs to be provided with good quality food at a price affordable by them.

10. Agro-Processing and Agro Industries Scenario

Traditionally, agro-processing has been the source of income generation in rural areas. It is gradually shifting due to introduction of high capacity processing food industry. Now the employment generation potential is being realised and again processing of agro-produce in production catchments is emphasised to check migration to cities. It is estimated that six times employment is generated if the capital investment is done in cottage scale food sector over large scale food industry. Post harvest losses of 15,000 million US $ is an important issue in India and shift from the conventional to improved post harvest and agro-processing operations (Table 12) is emphasized.

All major grains --paddy, wheat, maize, barley, millets like: jowar (great millet), bajra (pearl millet) & ragi (finger millet) are produced in the country. Primary milling of these is most important activity in food grains.

Paddy/ rice processing : Paddy is milled into raw or parboiled rice and flaked rice. Puffed rice is also produced as snack food. Milling is mostly (65% production) done in modern rice

mills. However, combination of sheller cum huller mill is also in practice in some parts and gives low recovery (Table-13). Moreover, the by-products cannot be used economically. Modern set-ups with water-jet polish and colour sorters are used for quality and precision.

Table 12 Some of the conventional and improved post-harvest and agro-processing operations.

Operation/activity	Conventional Technology	Improved Technology
! Threshing	Manual beating and animal/tractor treading	Mechanical threshing with improved design of threshers.
! Winnowing	Manually with ordinary baskets	Mechanical winnowing with manual mechanical power.
! Cleaning	Manually operated SUPA, a simple device but of low capacity.	Manual/power operated cleaner-cum-graders.
! Drying	Open yard sun drying	Solar dryers or heated air dryers using mechanical power.
! Storage	Earthen pitchers, mud bins or bag storage	Metal bins, brick structures and concrete silos of improved designs.
! Milling	Hand and foot pounding, rice hullers, stone grinders, **oil ghanis,** etc.	Modern rice, dal and flour mills of different capacities, oil expellers, solvent extraction plants.
! Byproduct utilization	Direct feed and fuel uses	Solvent extraction of rice bran and oil cakes, pelleted animal feed, etc.
! Marketing	Selling raw materials to middlemen of trade at low prices	Selling of cleaned and graded produces, value added products directly to super/cooperative markets for better profitability
! Preparation & Utilization	Open vessel cooking and traditional food preparations	pressure and microwave cooking. Nutritionally balanced diet/recipes. Use of refrigerators, grinders/mixures.
! Social responses	Rigidity in food habits and preparations	Flexible & fast changing food habits and varieties, out of home eating, packed foods, etc.

Source : Ali, 1999.

Table 13 Average out-turn of raw and parboiled rice in various milling units/system.

Milling Unit	Out-turn of rice, %					
	Raw			Parboiled		
	Total	Head	Broken	Total	Head	Broken
Huller	65	50	23	68	61	10
Sheller	68	60	12	70	65	7
Modern	71	65	8	72	68	5

The recent investigations have shown that it is possible to increase the total out turn of better quality rice by 10 per cent with improved harvesting, parboiling, drying and milling technologies. The increase in rice out turn will be about 8 million tonnes assuming 125 million tonnes of annual paddy production. Its economic value would be approximately 1600 million US $ at the rate of 200 US $/t.

Wheat processing : Wheat is processed for flour, refined wheat flour, semolina and grits. Over 3,00,000 burr mills are used in cereal milling consisting of hand grinders and flour mills (one and 10 hp units). Roller flour mills are 800 with a milling capacity of 8-10 million tonnes.

Pulse processing : Dal milling is the 3rd largest processing industry in India after rice and wheat milling. Pulses are the major protein source in Indian diets. At the house-hold level, hand stone grinder *(Chakkis)* are used to dehusk and split pulses. Whereas, the mechanized rollers and shellers are used by the organized industry (over 11000 mills) to prepare splits *(dal)* from pulses. Some pulses are processed for roasted produces and flour.

Oilseed processing : Oilseed production in India is used for 8% direct food uses and 85% for oil extraction. Meal/cake is generally used as cattle feed or exported. It is emphasized to use de-oiled meal as protein source for humans. Technology has been developed for adoption. Oil extraction used to be a cottage level activity in the country through *Kolhus* and *Oil Ghanis (anmal operated oil expellers).* The country has about 2.5 lakhs *ghanis and kolus*, 50000 mechanical oil expellers, 15500 oil mills, 725 solvent extraction plants, 300 oil refineries and over 175 hydrogenated vegetable oil plants. Small capacity oil expellers which could be installed in rural areas for promoting agri business. However, the cake thus obtained need to be solvent extracted for enhancing availability of edible oil for food uses. Soybean is rich source of good quality protein and oil. India produces about 7 million tonnes of soybean annually and is being put to food uses for nutritional and health benefits. Oilseed based snacks are popular and source of income for entrepreneurs.

Fruits and vegetable processing : India first in world production of fruits with first in mango and banana with more than 40% and 20% world production respectively. After China, India is second largest producer of vegetables. The losses are estimated to the extent of 20-37% and are being minimized. It is estimated that only 2% of the total produce is processed. The country's installed capacity of fruits and vegetables processing is about 2.3 Mt (2003). Simple approach of proper cleaning, grading, sorting and packaging of produce at farm level

is being considered to reduce the losses considerably and provide employment opportunities in production catchment..

Fish and fish products : India produces about 6 million tonnes of fish through 7500 km long coastline and an exclusive economic zone of 2.02 million square km; 28,000 km of rivers and 3 million hectares of reservoirs and fresh water lakes has an enormous potential for fisheries. Fish processing is done almost entirely, for export purposes through 223 freezing units with a capacity of 2,170 tonnes; 25 canning units with a capacity of 84.5 tonnes. Refrigerated handling, transport, storage and retail counter, related systems are being developed.

Animal products : India is world=s largest producer of milk with 87 million tonnes of production. The dairy cooperative sector is doing a very good job in improving the productivity and quality. The success in milk production is attributed to >Operation Flood Programme=. The domestic ice-cream market in India is valued at around 200 million US $.

Meat and poultry processing : Meat and poultry production is at 5 Mt with goats and sheeps contributing 54%, buffalow and cattle 26%, poultry 13% and pig 7%. It is used mostly fresh. But infrastructure is developing to export meat and poultry.. Poultry has done well remaining rural and developing network of marketing in remunerative distant markets. India produces about 40 billion eggs annually and its market has increased a great deal.

Processing of commercial crops : Sugarcanes, jute, cotton, tea, coffee and tobacco are major commercial crops grown in India. More than 50 per cent sugarcane is estimated to be processed by sugar mills and the balance by jaggery *(Gur) & Khandsari* industries. Although, the efficiency of jaggery *(Gur)* & *Khandsari* sector is low compared to sugar mills, but these units provide more employment opportunities to rural work force hence requires further attention.

11. Technology Transfer Related to Agricultural Mechanization

The ICAR has 492 KVK (Farm Science Centres) located in different states. The work taken-up by different agencies and organizations help the manufactures and farmers know of new developments in agricultural engineering technologies. Additionally, front line demonstrations are conducted in farmers field and manufacturers are invited for interaction meet. These organizations alone provide training to about 0.25 million persons annually in the areas including agricultural engineering. The Central government also sponsors special programmes for implements for technological innovations and extension.

12. Focus of Agricultural Engineering in Future

The Central Institute of Agricultural Engineering, Bhopal has identified the issues and the strategies to be adopted in short term, medium and long term in different areas to meet the challenges of precision agriculture, make the country eligible to meet the future foodgrain requirement, provide nutritional and health security, create of new employment opportunities at rural sector. It is felt that these may be of significance to developing world. The issues being dealt are :

Improved tools, implements and machinery for enhancing agricultural productivity and cost competitiveness , mechanization of horticulture and hill agriculture, machines for commercial agriculture with precision farming, safety in agriculture and gender friendly equipment, irrigation system for enhancing water use efficiency, technology for drainage, integrated watershed management, inputs for aquaculture, energy from biomass for domestic/ agro-industrial application, use of bio-diesel in agriculture, exploitation of solar energy, fuel cell,

energy and power machinery management for operational use, decentralized power/energy supply systems, processing of fruits/vegetable, herbal and medicinal plants, modernization of pulse processing systems, agro-processing model for income and employment generation in rural areas, ready to eat products, neturaceutical products, health applications of soybean and promotion and commercialization of equipment and technology.

More emphasis is also required to develop indigenous technology for agro- food processing. Sustaining agriculture through modernization to meet the growing domestic demand and earn Forex through export will be the guiding factors for any future developmental strategy. Growing requirement of food, feed and fibre and increasing export opportunities in agriculture and allied industries sector has put additional demands on agricultural engineers for efficient management of the costly inputs. This aspect is being attempted at CIAE through concerted inputs.

13. Future Priorities

- Encouragement for setting up of on-farm primary processing, agro processing centres and in production catchment for preventing migration of rural youths to cities by engaging them in gainful employment.
- Standardization of agricultural implements and machines for better servicing, availability of spare parts and for easy repair and maintenance.
- Agri-Clinic Centres in each block/district for service providing (technical know how, servicing facility, custom hiring of agricultural implements)
- Develop facilities and test prototypes, set up pilot plants for intensive evaluation and extensive demonstration, training of upcoming entrepreneurs and market search.
- Development of machinery for hill agriculture, horticulture, floriculture, commercial crops, agro-forestry, etc.
- Efficient fuel utilization of mechanical power sources through better design and matching machinery.
- Enhanced utilization of natural resources like solar, wind and natural precipitation.
- Development of technology packages for production and post production agriculture.
- Technology for minimizing drudgery involved in farming
- Develop women friendly agricultural equipment/technologies.
- Refinement of available technologies for loss prevention and value addition to agricultural produces.
- Ensure hygiene and quality standard specified for domestic and export markets for fresh and processed products.
- Make better use of crop residues, processing by-products and wastes in eco-friendly and economically rewarding mode.
- Creation of atleast one Soybean Processing Unit in each block of district to provide nutritional food security at affordable cost.
- Application of bio-gas plants using agro-waste and animal dung for commercial application
- Use of direct heat energy from bio-gas and producer gas for agro-processing and in compression ignition engines as an alternative to diesel.
- R&D efforts on bio-diesel and fuel cell technology.
- Popularization of Water conservation technology
- Training and entrepreneurship development using IT
- R&D in partnership mode
- Industrial liaisoning and commercialization of technology.

- Consultancy and contract research in the areas of expertise and priority areas.
- Strengthening of R&D, testing and manufacturing promotion using computer aided design (CAD) and micro processor based facilities.
- HRD - upgradation in skill and training to meet the future challenges.
- Linkages with different organizations and countries for effective exchange of technologies.

14. Central Institute of Agricultural Engineering (CIAE), Bhopal, India in Agricultural Development

The Institute has five divisions, prototype workshop, soybean processing centre and research laboratories to conduct research on aspects related to production and post production agriculture. It is undertaking research and development in the area of agricultural mechanization, irrigation and drainage, integrated energy management, equipment for reducing drudgery in agriculture, post harvest and agro-processing. The CIAE coordinates its research & development activities through Agricultural Universities, ICAR Institutes, All India Coordinated Research Projects. During the last 28 years of its existence the Institute developed 130 machines of which 78 have been made available to end users and 23 machines released by Government of India. Technology diffusion is done through farmers, artisans, extension workers, subject matter specialists and manufacturers. Entrepreneurship development and manufacturing promotional activities have helped in commercialization and up gradation of technologies.

The CIAE has strengthened its cooperative R&D and technology transfer activities with Asian, African, European and American countries. Agricultural Engineers from Asian and African countries avail training at the Institute. Some of the prominent linkages are with APCAEM, SAREC Sweden, CIRAD France and JAICA Japan.

A Directory of Agricultural Machinery and Manufacturers, containing information on machinery for various production and post-production operations in agriculture was published, sometime back. Keeping in view the emerging trends in information technology, this directory has now been converted into a format, which can be used in interactive mode on a computer.

Recent Technological Development

Areas	**Technology developed**
Farm Machinery & Power	Light weight power tiller, Plastic mulch laying machine, Tractor operated inclined plate planter, tractor operated pneumatic planter, Self propelled 8-row rice ridge seeder, Technology for rice-wheat mechanization, Tractor operated aeroblast sprayer, High capacity pigeon pea thresher, Self propelled sugarcane cutter-chopper-harvester
Irrigation and Drainage equipment	Irrigation equipment system and testing facilities, Tractor operated mould plough, technology for surface and sub-surface drainage system, Water harvesting, recycling and recharge system, remote controlled pump switch-off device, water level indicator.
Agro-processing	Fruit grader, Low cost technology for pulse storage, Pilot plant for production of fruit bar candies, Bamboo stick making machine, Improved dal mill
Soybean Processing and Utilization	22 Soy-products and technologies were developed for dairy analogues, bakery products and soy snacks such as, soy paneer, soy sattu, ice-cream, soy nuts, okara based burfi and gulab jamun, Soy shrikhand, yogurt etc.

Agricultural Energy and Power	Solar tunnel dryer, Solar stifler, Biogas plant for vertisols, Technology for handling of biogas spent slurry, Producer gas technology using agro-residues, Automatic sun tracker for 900 Wp solar panel, Use of agro-residues for rural kitchen.

During the last two years the Prototype Production Centre at the Institute supplied 6433 prototypes of 71 designs of various agricultural machinery worth 0.24 million US $.

Important Publications During 2003-05

Power availability in Indian Agriculture
Assessment of Agricultural Pumping System
Production and Economic Factors Growth in Indian Agriculture.
Harnessing Animal Power
Materials and Manufacturing Process for Agricultural Machines
Horticultural tools and equipment
Directory of Agricultural Machinery and Manufacturers
Data Book for Agricultural Machinery Design
Material for Fabrication of Agricultural Machines
Product Catalogue -2004.
Analytical methods for quality evaluation of foods
Soybased food entrepreneurship development
Renewable energy technologies for rural sector
Farm Mechanization Package for Dryland Agriculture
Energy use in crop production system in India

15. Enterprise Development Through CIAE Technologies

Identified approach for employment/entrepreneurship development cover :

- Setting up of Agro-processing enterprises/agro service centres in the rural areas and motivate the farmers to adopt modern techniques.
- Service, repair and maintenance facilities for agricultural machinery.
- Establishing agri-implement bank by entrepreneurs to provide the machinery on custom hire basis to farmers when needed.

CIAE technologies have very good potential for entrepreneurship development in different parts of the country and also in developing countries. Training programmes are organized regularly to empower unemployed youth, farmers, farm women, agriculture graduates and upcoming entrepreneurs. Nominal fee is charged for some of these. Some of the technologies identified are production agriculture, agribusiness in improved farm implements, setting up of household/cottage and small scale food processing industry, soy processing unit, safe packaging and transport for loss minimization, primary processing of food raw material and on renewable energy gadgets, irrigation and drainage, etc. Adoption of these technologies help reduce population migration to some extent, provide direct employment to 4-8 persons per unit, higher income to farmers, better rural health, higher value for the products and minimizes loss to a considerable extent. The initial investment to set these enterprises vary in between 4000 US$ to 20000 US$ depending up on the type of enterprise selected.

Scope of entrepreneurship development for employment and income generation on agricultural mechanization and renewable energy through Agri-business is of high order. This

include: Repair and maintenance support for farmers, custom hiring services, input supply and management; link between end users, R&D institution, Government Agencies, NGOs and financial institutions, setting up of agro-waste/biomass based enterprises for supplementing rural energy needs, charring, briquetting, improved sigri, solar café, input supply and management.

Soy based technologies includes full fat soy flour, soy fortified biscuits and soy paneer (TOFU) and many other. Full fat soy flour is one of the simplest soy product to be used in combination with cereals and pulses. 10% addition of soy flour is recommended in food products. Some of the soy products, processing equipment and technology developed for food uses of soybean have been commercialized. Over 160 cottage scale soy food enterprises have been established by the trainees of CIAE.

16. CIAE - APCAEM Project on Enhancement of Employment Opportunities of Rural Women

This project was started in July 1994 with a view to educate and train rural women on primary processing of agri-commodity for income and employment generation. Based on the survey conducted in two districts, women groups were identified and 292 women were trained in agro-processing activities covering primary processing of cereals, pulses, oilseeds and spices. The rural women group trained at CIAE earlier in Agro processing activities was provided with processing equipment (700 US $) (Table 14) and the Centre was established in 1999 at Pachama Village. The women group was involved in processing cereals, pulses, spices etc. and generating income from the agro-processing centre through the sale of primarily processed products. The Centre could generated upto 2560 US $ upto 2002-03 (Table 15). Another domestic scale unit was established at Gunga village and spice and cereal milling activity was undertaken. Now activity is being established for women group. Continuance and strengthening of such activity under APCAEM programme is considered essential.

Table 14 Details of processing equipment given for establishment of agro-processing activity at village Pachama, MP, India.

Sl. No.	Name of the Item	Quantity
1	Pedal cum power operated cleaner (without motor)	1
2	CIAE dal mill (without motor)	1
3	Multi-purpose grain mill (without motor)	1
4	Motor- 1 hp for grain mill	1
5	Motor - 2 ho for dal mill	1
6	Motor - 0.5 hp for cleaner	1
7	Accessories V belt Pullies	42
	Total 700 US $	

Table 15Profit earned by Agro-Processing Centre, Pachama, Dt. Sehore, MP, India

Financial year	Net profit, US $
1999-2000	400
2000-2001	700
2001-2002	760
2002-2003	700
Total	2560

17. Inputs for APCAEM Supported Programme

- Creation of database regarding agriculture related activities, especially on machinery, food processing, horticulture and aromatic plants and made available them on Web by all APCAEM participating countries.
- Mechanism for free flow of information, technologies and machines among APCAEM countries for mutual benefit and minimization of duplication of research..
- Formation of Core Group, one member from each APCAEM country, to visit each APCAEM countries, at least once in two years, to acquaint with the technological innovations/gaps.
- Organization of joint exhibition of agricultural products/technology/machineries at least once in every four year in member countries.
- Publication of APCAEM Newsletter regularly.
- Publication of updated technology catalogues/compendium at specific intervals.
- Program Development for setting up of
    - Agro-service centres in rural areas for higher productivity, to facilitate extensive and intensive cultivation, for higher returns to the farmers,
    - Agro-processing centres in rural areas to minimize post harvest losses, supplement rural income, enhance employment opportunities for rural women and youth in production catchment areas,
    - Soybean processing unit at each block of district to enhance availability of nutritional food products at affordable cost and for employment generation.

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