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State of Farm Mechanization in Indian Agriculture

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Abstract Agricultural mechanization has been considerably progressed over the last few years. It employs about 65% of the work force and provides livelihood to about 70% of the population. About 18% of the Gross Domestic Product (GDP) comes from agriculture. It is believed that the benefits of modern technology have been restricted to farmers with large landholdings but the fact is that even small farmers are adopting and utilizing selected farm equipments for efficient farm management through custom hiring. Mechanical equipments for various farm operations are generally being used by the farming community and a decline in animate power is being observed. Use of Mechanical power is resulting in improved land usage and labour productivity owing to higher gains in farm productivity. Tractor mounted implements have become popular and being commercialized. Harvesters, elevators, threshers for cereal crops and crop specific machine are developed, been used on a large scale and commercialized. A future requirement for farm equipment and technologies include rota-tiller for seedbed preparation, till planter, strip till drill, pneumatic precision planter, sugarcane sett cutter planter, vegetable transplanter and check-row planter, for sowing and planting. Power weeders and equipment for chemico-mechanical weed management, electro-static spraying and tall tree spraying are required. Harvesting equipment for sugarcane and cotton are required to be developed. R&D institutions in the country have developed a number of useful technologies for mechanizing farm operations. A brief account of these developments has been discussed in this paper.

Keywords Triply Diffusive Convection, Rayliegh Numbers, Chandrasekhar Number, Prandtl Number, Magnetic Prandtl Number, Lewis Numbers.

Introduction

The productivity of farms depends greatly on the availability and judicious use of farm power by the farmers. Agricultural implements and machines enable the farmers to employ the power judiciously for production purposes. Agricultural machines increase productivity of land and labour by meeting timeliness of farm operations and increase the work out-put per unit time. Besides its paramount contribution to the multiple cropping and diversification of agriculture, mechanization also enables efficient utilization of inputs such as seeds, fertilizers and irrigation water. As a result of Green Revolution in the sixties, the total food grain production increased from a mere 50.8 million tonnes during 1950-51 to 235 million tones in 2010-11, and productivity increased from 522 kg/ha to more than 1,921 kg/ha (in 2010-11). The increase in production of food grains was possible as a result of adoption of quality seeds, proper doses of fertilizer and plant protection chemicals. Irrigation played a major role in increasing the productivity.

Agriculture occupies an important place in the Indian economy. It employs about 65% of the work force. About 18% of the Gross Domestic Product (GDP) comes from agriculture. The Indian agriculture has a different outlook. On one hand it includes highly mechanized farms of Punjab, Haryana and Western Uttar Pradesh and on another, it is characterized by small fragmented land holding, hill farming, shifting cultivation which in

general managed through animate source of energy. Out of total 329 million hectares geographical area of the country, 165.6 million ha is available for cultivation and during the last three decades the net sown area has remained around 142 million ha. Out of an estimated 142 m ha net cultivated area around 40% is irrigated and the rest is rain fed. The productivity of rain fed areas is very low as compared to the irrigated areas. The contribution of the rain fed areas to the overall production is about 44% of total farm output. In Indian agriculture, human, animal and mechanical power are utilized for different on-farm and off-farm activities.

Farm mechanization status is often expressed in terms of power availability per unit area of any country. The total farm power availability in 1960-61 was 0.28 kW/ha, which has increased to 1.46 kW/ha in 2005-06. The spectacular rise in agricultural production in the last four decades is largely a result application of new technology, increased use of improved seeds, chemicals and fertilizers, irrigation and mechanization, coupled with incentives for production and greater access to credit [1-2].

Mechanization Gaps in Indian agriculture

- Average size of operational holding has declined to 1.15 ha in 2010-11 from 1.23 ha in 2005-06 (Agriculture Census, 2010). About 76% farmers have less than 2 ha farm holdings with associated constraints of being resource poor, low risk abilities, thereby making the task of mechanization management further difficult.
- Average power availability on Indian farm is about 2.02 kW/ha as against the requirement of about 2.5 kW/ha by 2025.
- Indian agriculture is still a subsistence enterprise and not for commercial purposes.
- Absence of precision plant protection equipment and technologies for the field and plantation crops as well as for high density orchards.
- Absence of the woman friendly technologies. Gender issue in farm equipment has not addressed to the desired extent.
- Vast agro ecological diversity with predominance of rain fed agriculture.
- Poor realization of benefits of energy management.
- Safety, health and environmental concerns receiving inadequate attention

Table 1: Status of farm power sources in India [3-4]

Year	Agril Workers	Draft Animals	Tractors	Power Tillers	Diesel Engines	Electric Motors
	Number (million)	Number (million)	Number (million)	Number (million)	Number (million)	Number (million)
1960-61	131.10	80.4	0.037	0	0.230	0.200
1970-71	125.70	82.6	0.168	0.0096	1.7	1.6
1980-81	148.0	73.4	0.531	0.0162	2.88	3.35
1990-91	185.30	70.9	1.192	0.0323	4.8	8.07
2000-01	234.10	60.3	2.531	0.1147	5.90	13.25
2010-11	263.00	53.50	4.207	0.3213	8.20	16.50
2011-12	266.08	53.0	4.553	0.3621	8.30	16.70
2012-13	269.20	52.8	4.858	0.4021	8.35	16.80
2013-14	272.00	52.0	5.237	0.4409	8.45	17.00

Table 2: Contribution of Agricultural Mechanization

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

Table 3: Level of mechanization

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

The fact that Indian agriculture was powered by about 183 million agricultural workers, 71 million draught animals, over 12 million motors and engines and 1.2 million tractors during the year in 1990-01. This figure changed to about 234 million agricultural workers, 54 million draught animals, over 23.7 million motors and engines, and 3.4 million tractors during the year 2007-08 reflects the unique Indian approach to mechanization (Table 1). With the increase in farm power availability, the necessity of farm equipment for various farm operations has also increased. During the past four decades a large number of farm tools, implements and machines have been developed for different farm operations such as land leveling, seed bed preparation, sowing and planting, weeding and hoeing, plant protection, harvesting, threshing, dehusking, decorticating, etc. (Table 2). The rate of growth, however, in animal operated machinery has remained low as compared to a tractor or power operated machinery. The level of mechanization has also increased (Table 3) in various operations of agriculture.

The R&D institutions in the country have developed a number of useful technologies for mechanizing farm operations. Quite a few of these technologies have been commercially exploited and adopted by the farmers. A brief account of these developments is as follows:

Farm Machinery Availability in India: In India most of the farmers are enlightened with the importance of the farm machineries and also most of them have adopted the technologies available for the farming. The most common types of agricultural machineries are enlisted in (Table 4).

Some Selected Improved Agricultural Machineries in India

Laser land leveler: It is trailed type equipment used for achieving precise fine leveling with desired grade. It has four basic units' viz. laser emitter/transmitting unit, laser-receiving unit with soil bucket having a double actuating hydraulic valve and level control box. The laser emitter unit sends continuous self-leveled laser beam signal with 360° laser reference up to a command radius of 300-400 m for auto-guidance of the receiving unit. This unit actuates the hydraulic control for moving up/down the leveling bucket for the desired cut/fill operation.

Riding Type Engine Operated paddy Transplanter: It helps to transplant required plant population in medium and heavy soils. The machine consists of 4.8 hp engine, transmission system, main frame, float and plating system using fixed opening type fingers. The machine uses mat type nursery. The effective field capacity of this machine is 0.15-0.20 ha/h while planting 8 rows with a spacing of 22.5 cm between the rows. It requires 5-6 persons for its operation, including the uprooting and transport of nursery. The machine saves about 60 percent labour and 40 percent cost of operation in comparison to transplanting in addition to increase in yields.

Table 4: Farm Machinery Availability in India at farmers site

Agricultural Operation	Power Source			
	Manual	**Animal**	**Tractor**	**Power tiller**
Tillage	-	Harrow-cum-Puddler	M.B.Plow	Power Tiller with Rotary
	-	Helical Blade Puddler	Disc harrow	Ridgers
	-	Patela Harrow	Ridgers	-
	-	Naveen Bakhar Blade	Rotavator	-
Planting	Garlic/Multicrop Planter	CIAE Animal Drawn Tool Frame	Pneumatic Planter	-
	Dibblers	Animal Drawn Vegetable Planter	Vegetable Planter (plug type)	-
	-	Jyoti Multicrop Planter	Vegetable Planter (picker wheel type)	-
	-	-	multipurpose implement for sugarcane	-
	-	-	Tractor mounted inclined plate planter	-
	-	-	Sugarcane Cutter Planter	-
			Tractor mounted raised bed planter	
Seed cum fertilizer drill	Single row oil Seed	Three Row Seed-cum-Fertilizer Drill	Seed cum fertilizer drill	Three row seed drill
	Fertilizer Broadcaster			
Rice transplanter	6-row Rice Transplanter	-	-	-
	low land rice seeder			
Intercultural operation	Sickle	-	-	Weeder
	Dry land weeder	-	-	
	Wheel Hand Hoe	-	-	
	Cono weeder	-	-	
Pesticide applicators / Sprayers	Knap sack sprayer and dusters	*	Tractor operated aero blast sprayer	Power tiller operated boom sprayer
Harvesters			Front Mounted Vertical Conveyer Reaper Windrower	
			Tractor operated fodder harvester	
Thresher	Tubular Maize Sheller		High capacity multi-crop thresher	
	Pedal Operated Thresher			
	Groundnut Stripper (Comb Type)			
	CIAE Groundnut cum Castor Decorticator			
	Portable Rice Thresher			

Self-propelled rice transplanter: It is suitable for manual transplanting paddy seedlings in puddled soils. The machine uses mat type seedlings and it can transplant 1.2-1.5 ha/day with the help of 5 persons by working at a speed of 1.1-1.5 km/h. It saves about 65% labour and 40% cost of operation as compared to manual transplanting.

Power tiller mounted air assisted seed drill: The germination percentage varies widely for small seeds such as sesame. Though there are a number of seed drills developed in the country for handling different types of seed, most of these equipment are found unsuitable for very small seeds. Air assisted drill is one machine, which is capable of drilling any size of seed to the desired seed rate. The spacing between the rows can be adjusted from 300 mm for 4 rows to 600 mm for 2 rows. The machine covers 0.25 ha/h.

Tractor operated zero-till seed-cum-fertilizer drill: The zero-till seed-fertilizer drill has been developed to sow wheat directly in rice-harvested fields without preparing the seedbed. It is a 9/11/13-row unit consisting of fluted rollers for seed metering and agitators over adjustable openings for fertilizer metering. The ground drive wheel supplies power through sprockets and chain for metering of seed and fertilizer. The furrow openers are of inverted 'T' type, spaced at 200 mm (adjustable). The field capacity of the machine is 0.3-0.4 ha/h with about 75% efficiency.

Tractor operated Strip-till Drill: The strip drill consists of a standard seed drill with a rotary attachment mounted in the front. The rotary system has C-type blades, which prepare a 75 mm wide strip in the front of every furrow opener. Thus with every row, 125 mm of the strip is left untilled and only 40 percent of the area is tilled. Tilling and sowing is done simultaneously. Strip till drills are used for sowing wheat after paddy without any prior seedbed preparation. It can save 50-60 % fuel and 65-75 % time as compared to conventional method.

Self-propelled power weeder: A light weight power tiller consists of a 4.1 kW diesel engine mounted on the power tiller chassis, power transmission system, two MS wheels, a frame and a rotary. The adjustable). The wheels with lugs are provided for the traction The speed of power weeder can be varied from 2.3-2.5 km/h with an effective working width of 550 mm giving a field capacity of 0.10 to 0.13 ha/h. The equipment saves 90% operating time and 30% in the cost of weeding as compared to hand weeding by Khurpi. Power from the engine is transmitted with the help of belt and chain to the rotary and through gear train to the ground wheels. The rotary has been provided with 16 blades fitted on high-pressure pipe of 37.5 mm diameter with the help of nuts and bolts to the flanges. The working width of the machine is about 45 cm (The use of the machine in the weeding of vegetables, fruits and other horticulture crops is very beneficial for farmers.

Tractor mounted 3-row rotary weeder: Manual weeding is laborious and time consuming and hence efficient mechanical weeders are being developed to obtain good yields from the farm. Hence a tractor mounted rotary weeder has been designed and developed. The field capacity of the machine is 0.24 ha/h with a weeding efficiency of 83-87%. The saving in cost in comparison with the manual method is 52%, whereas the saving in time is 78%.

Self-propelled Boom Sprayer: To meet the requirement of a high capacity effective sprayer, a self-propelled boom sprayer with 14 nozzles was mounted on a frame of the self-propelled vertical conveyor reaper. The spacing of nozzles can be varied from 300 to 600 mm. Height of boom can be
varied from 400 to 1200 mm. It can cover 3-5 ha/day.

Multi Orchard Sprayer: It consists of two elliptically shaped booms of 1350 mm length. The boom covers half of the tree canopy on either side of the sprayer. Each elliptically shaped boom consists of four hollow cone nozzles. It is suitable for spraying chemicals in orchards like grapes, citrus, pomegranate, etc. It can cover 0.40-0.70 ha/h at travel speed of 1.20-1.50 km/h.

Self-propelled walking type vertical conveyor reaper: The need of a small self-propelled vertical conveyor reaper powered by a light weight diesel engine was felt keeping in view the specific situation prevailing in paddy growing areas. Self-propelled vertical conveyor reaper includes 6 hp lightweight diesel engine, crop row

dividers, star wheels, standard cutter bar having 76.2 mm pitch knife sections, vertical conveyor belts, steel lugged wheels and power transmission system. Effective cutter bar width is 1 m. Self-propelled vertical conveyor reaper is used for harvesting cereal crops like wheat, paddy, soybean, safflower, oilseed crops, etc. It cuts the crop, conveys it vertically to one side and drops in a windrow for easy collection. The field capacity of the machine is 0.15 - 0.17 ha /h at a forward speed of 2.5-3.5 km/h. The fuel consumption is about one litre. There is a saving of 90-95% in labour and time.

Self-propelled fodder harvester (cutter bar type): Harvesting of forage crop is done manually with sickle and scythe. Sickle is the most popular hand tool for forage harvesting and requires 160 man-h/ha. Due to increase in the area under fodder crop, appropriate harvesting mechanism for fodder crop are required so that damage to the crop is minimized. The effective field capacity of the machine is 0.1 ha/h at a forward speed of 1.5-2.0 km/h.

Harambha (High Capacity) Thresher: Haramba thresher is suitable for threshing wheat crop and is highly popular. It is basically a chaff-cutter type thresher and has higher capacity. It consists of threshing cylinder, concave, two aspirator blowers, reciprocating sieves, feeding chute with feed conveyor and feed rollers. Also a safety lever in the feeding mechanism is provided. Safety lever prevents entrapping of hands by the feed rollers in case of any mis-happening. Haramba thresher is operated with a tractor of 35 HP and above. The power from the tractor PTO to the thresher is supplied through a universal shaft. Feeding of the crop is manual by standing on a platform provided with the thresher. Generally 3-4 persons are required for continuously feeding of the crop. The labour required for threshing with haramba thresher including the transportation of crop vary from 30 to 35 men-h/ha. The time required for threshing, one-hectare crop is 4 to 4.5 h.

Axial flow sunflower thresher: It consists of a feed hopper, bar type cylinder, thrower, two sieves, concave and a blower. It works on axial flow principle. The cylinder of length 1500 mm has two portions, the first one of 1300 mm for threshing and the second of 200 mm for straw throwing. The threshing portion has raised spikes. The cylinder-concave clearance is 40 mm and is uniform throughout its length. The cylinder is of hexagonal shape and is fitted with seven louvers at a spacing of 180 mm. The louvers are made of 3 mm thick MS sheet and have a depth of 70 mm. The cleaning system consists of a centrifugal blower and three sieves inclined at an angle of 7-15^{o}. The thresher eliminates human drudgery and also provides quality produce. It saves 70-80% of labour and operating time. The machine is operated by 7.5 HP motor/tractor and has a capacity of 8.0 q/h clean grains. The threshing efficiency of the thresher is more than 99 percent.

Tractor operated Straw Combine: Straw combines are used to recover wheat straw after combines operation and is operated by a tractor. This machine cuts and gathers the left over straw from the field chops into fine straw and transfers this into the trolley. It is mostly 2 m wide and is operated with the tractor of about 35 HP or above. Straw recovery is about 55-60%. The straw is used as animal feed. It consists of a cutting mechanism, conveying mechanism and a bruising unit and a blower. Traditional trolley having net or wire mesh is used for collecting the straw. The capacity of the machine varies from 0.4 -0.5 ha/h and is operates at 3.0-4.0 km/h. There is also a recovery of 75-100 kg of grain per hectare. One person operates the machine and 3-4 persons are needed to unload the trolleys of straw.

Tree climber: In order to harvest coconut and arecanut at a faster rate with proper safety, a tree climber has been developed. The developed tree climber is free from any accident risk during its operation. By standing on the lower component, the upper component can be moved up or down over the tree. The operator can safely climb a tree of 10 m height in 1.5 min without any risk.

Tractor mounted banana Stem shredder: The banana stem shredder helps in disposing of the stem immediately after harvest. Shredded material is suitable for mulching in the banana garden and also for vermin compost. A tractor operated banana stem shredder has been developed. The stem is cut into small pieces and the water and fibre are separated. It takes 1.2 minutes to shred the stem having an average height of 2400 mm. About 52 stems are required for shredding in one hour.

Tractor operated banana clump remover: Banana crop is maintained for two years to get the benefit of two harvests. The crop needs removal of clumps (plants along with root portion) after two years. During the process of removal of the clump, the entire mother plant along with the rhyzome and side suckers as a whole mass has to be removed so as to prepare the land for the next crop. Manual labourers using crowbars and spades do this operation. A tractor operated banana clump remover has been developed. The field capacity of the machine is 0.5 ha/h.

Mechanization of Hill agriculture

The hilly terrains in many areas, though having heavy rainfall face acute shortage of water both for human beings and plants. Ironically, most of the operations are done manually with age old hand tools. Scarcity of moisture due to the quick runoff necessities introduction of efficient, light and low cost powered tools and machinery to improve timeliness of field operations. Plot size (generally less than 10 x 10 m), undulating terrain, growing crops on bench terraces, coupled with economic conditions, are major bottlenecks in use of mechanical power in the hilly regions. Women folk constitute major working hands in hill agriculture. Except ploughing, all other operations are performed by women mainly. Efficient, hand tools and light power machinery, capable of doing operations from tillage to threshing, are required to keep women-machine anthropometric data in mind. The valley areas of hills are fit for introducing power tillers of 8-12 HP and even tractors of lower horsepower with matching equipment [5]**.**

Constraints in Hill Farm Mechanization

There are a few constraints in the Hill Agriculture preventing farmers from owing desired level of power source and matching equipment. These are:

a) Poor economy of the hill people
b) Low-land-to-man ratio and fragmented land holdings
c) Women based agriculture and poor contribution of men in running agricultural operations
d) Complex and multiple farming systems
e) Acute problems of run-off and soil erosion
f) Climatic diversity within or between the farming situations
g) Poor fertility management of soil
h) Non-adoption of improved cropping/farming systems
i) Inefficient agricultural tools and implements
j) Lack of technical know-how and proper extension services
k) Lack of organized system of marketing
l) Migration of hilly people towards the plains

Mechanisation in vegetable plantation

India is producing about 80 million tonnes of vegetables and 40 million tonnes of fruits every year. The hybrids of vegetable are giving the maximum yield. The seeds of these F1 hybrids cost from Rs.10,000 to Rs.50,000 per kg and a large number of private companies are producing the hybrid seeds and the germination of these seeds is very low, about 60 to 80%. Due to the high price and low germination of hybrid seeds a large number of nurseries have come up around Bangalore to raise the seedlings in portrays and sell them to farmers at Rs.0.60 to Rs1.1.00 per seedlings. Farmers are able to purchase the exact number of healthy seedlings grown under greenhouse or net house and need not take effort to raise their own nursery. The pro-trays are generally kept in the greenhouse or net house for filling with media, seeding and germination. The rooting media is sieved, sterilized, mixed and filled in the pro-trays (98 or 49 cells) manually. The depressions in the pro-trays are made and individual seeds are sown in each cavity manually. The extra rooting media fill in the depressions to cover the seed. The pro-trays are regularly watered and it takes about one month to raise the seedlings suitable for transplantation. Four labours are required to sieve, sterilize, mix and seed 400 pro-trays (40,000 seedlings) per day. This is very slow and laborious process and the production capacity of most of the vegetable nurseries is limited due to non availability of labour [6]**.**

Some of the selected machineries for nursery mechanisation

Media siever: A motorized rotary screen type media siever has been developed by IIHR, Bangalore. It is useful to sieve Farm Yard Manure, Vermicompost, Cocopeat, Sand and Soil and remove all the particles larger than 1.5mm in the form of stones, clods, straw, etc. The capacity of the machine is 1 tonne/ha and it is operated by 0.5 HP motor.

Batch type media mixer: An electric motor operated batch type media mixer has been developed by IIHR, Bangalore. Peddle type agitators cum conveyors have been provided with a shaft rotating at 9 RPM for thorough mixing. The mixer has a capacity varying from 0.2 to 0.5 tonnes per batch and takes 5 minutes for thorough mixing of sand, FYM, Vermicompost, Coco peat etc. It has been observed that the rooting media with Vermicompost + Sand in equal proportion produced healthy seedlings in lesser number of days in comparison with other media.

Pro-tray filling machine: This machine is suitable for big nurseries and has a capacity of filling 400 pro-trays or 39,200 seedlings per hour. The machine mixes the media, conveys it to the bucket conveyor. The bucket conveyor takes the media to the filling hopper. The empty trays are placed on a continuous belt by the operator. Media is filled into the protrays continuously by filling hopper. The media are leveled in the pro-trays by the rotary leveler and the excess media falls back into the mixing and conveying hopper. The machine is fitted with individual motors and gear boxes (3 nos – 2 HP each) for media mixing, conveying, bucket conveyor and tray transport/endless belt units.

Pro-tray seeding machine: The protrays filled by tray filling machine are conveyed to pro-tray seeding machine by an endless conveyor belt. Depression in each cell of the pro-tray is made by rotary dibbler. The seeds are singulated by the rotary vacuum seeder with 0.3mm holes operating at 0.5kg per sq.cm. pressure with one HP vacuum pump. The seeds are individually dropped in the depressions in cells. The Media is topped in seeded trays by the media topping hopper to fill the seeded depressions. The watering is done by the watering pipe fitted with seven nozzles. The machine is suitable for 98 cells, pro-tray of 53 x 25cm size, however the modifications in the dibbler and vacuum seeder can be done for making it suitable for other pro-trays. suitable for 98 cells pro-tray of 53 x 25cm size, however the modifications in the dibbler and vacuum seeder can be done for making it suitable for other pro-trays.

Plate type vacuum seeder: The tray type vacuum seeder to pick up 98 seeds at one time using the suction of 0.5 kg/cm^2 is created by 1 HP vacuum pump has been developed. The seeds are sown into the cavities by cutting off the vacuum. The seeding capacity is up to 50 pro-trays per person per hour.

Pro-tray transport system: The trolley for transport of media filled pro-trays and pro-trays with grown up seedlings has been developed. The capacity of the trolley is 80 pro-trays for media filled pro-trays and 16 for grown up seedling pro-trays.

Tray type depopper: A tray type depopper for standard 98 cell pro-tray is developed. The rods of 4mm diameter are pushed through the drainage holes in seedling pro-trays. The seedlings are then tied in bundles for sale to farmers. Up to 50 pro-trays can be depopped per hour [7]**.**

The Adoption Process for Mechanization/Labor Productivity Enhancing Technology

The mechanization is generally identifiable at an individual farm, although when considering the agriculture sector as a whole in a particular country, the stages are usually less pronounced because of the diversity of an agriculture sector, and several stages may occur simultaneously. However, when formulating an agricultural mechanization strategy, the different options for enhancing land and labor productivity, as well as their economic and financial implications must be well understood; Sometimes, rather than advocating mechanization of certain operations, alternative options may be more attractive. Rural development programs must take into account (the future) needs of agricultural mechanization. Thus, the design of irrigation and drainage systems and the field size and layout must take into account the access of machines to fields, the width and strength of

bridges. Commercial tree crop plantations must take into account the possibility of future labor scarcity, and thus the tree variety and planting pattern be able to accommodate future mechanized operations.

Role of the Private Sector: The fundamental requirement for a sustainable sub-sector is a strong linkage between the different parties and that all of them must be able to make a livelihood from their businesses. As is mentioned previously, there are generally four main groups or levels of interested parties in the private sector: Farmers, Retailers and Wholesalers, Manufacturers, and Importers. In most free market economies, each of these groups is comprised of small to medium businesses.
Emphasis should be given to creating conditions whereby it is possible for any person, company or group of individuals to create a farm business. It is vitally important that farmers have title to their land so that they feel secure, but also so that they have collateral available for borrowing.

Credit and Finance
Credit and Finance should be available for all sizes and types of farm operation. Collateral requirements should be realistic and physical access to sources of credit should be facilitated, but with the condition that the business plan and cash flow projections appear realistic and attainable. This may mean the development of rural agricultural banks within easy reach of farming communities and/or the promotion of other community savings and credit schemes. The providers of credit should, ideally and if necessary, be in a position to assist farmers in the formulation of investment and business plans. If a high-risk element exists (small farms, low collateral, the marginal profitability etc) development agencies might be called upon which might be prepared to take on higher risk. However, in general, credit should not be made available exclusively for farm machinery nor should special conditions be made available for the purchase of farm machinery only. A bias towards particular investments will result in distortions in the agricultural economy and particularly in the rural labor situation. Credit for Contractors and Group Users of Farm Machinery Credit should be made available on the same conditions as for farmers. Contractors and other arrangements for the multi farm use of farm machinery, particularly in certain situations, can make an important contribution to agricultural production. These arrangements facilitate an efficient use of machinery and make available to farmers machines, which they might not be able to afford individually.

Choice of machinery
This is essential in a free agricultural economy. Notable in centrally planned economies was the restricted type and sizes of farm machinery available and the low level of technology available. Different farms require different types and sizes of machines. Also, what is generally forgotten or overlooked is that individuals wish to be able to be individual in their choice of what they invest in.

Farm gate Prices
Prices will influence farmers purchasing decisions. Governments should be continually aware of the profitability of farming and how this affects investment in inputs. Market information systems for farmers are essential for this. Subsidies and Price Support Subsidies. Price Support are common in many countries in the world. If countries do decide to use subsidies for farm machinery, then the purpose and time limitations of the subsidies should be clearly stated and understood. Capital subsidies for specific technologies (e.g. providing subsidies or preferential interest rates for tractors) should be avoided. Choice of machine then rests under the farmer's control and he is not influenced to purchase a particular type of machine or technology through financial incentives rather than for pure business reasons.

Technical Assistance
Technical assistance is required at both farmer level and government level. Farmers require assistance in all aspects of their activities: agricultural advice, financial advice, planning advice. Governments require assistance to develop the above services. This may be through individual ministries or through agricultural banks or other appropriate institutions. Farm Machinery Importers, Manufacturers, Distributors and Dealers The existence of sales outlets, which are within easy reach of farmers, is essential to the development of a successful and

sustainable private farming system. Special attention is needed to create conditions so that importers, distributors and small retail outlets can develop. These commercial units, may range from a small, one family shop in a village to a large national distributor for domestically produced and imported machinery.

The Role of Government : The Role of the Government must be clearly defined. In general the traditionally accepted role of government has been in some or all of the following areas. These areas and whether Governments should be involved in them in a free market situation is discussed **[8-9].**

Policy

Policy instruments that most frequently need to be considered are:

- Exchange rate policy.
- Policies influencing relative agricultural input prices - direct market intervention to manipulate input prices, tariffs and import restrictions, and input subsidies.
- Policies influencing agricultural product prices.
- Policies influencing farm and non-farm employment - employment and wages policy, migration.
- Land ownership and tenure policies.
- Farm power research, policy - agricultural machinery research and agricultural sustainability, transfer of farm power technology.
- Agricultural extension policy.
- Infrastructure policy - rural transport and marketing infrastructure, irrigation infrastructure.
- Agricultural financial markets.
- Industrial development policy.
- Transport policy and motive power.

Conclusions

Agricultural mechanization and engineering technology are slated to play a pivotal role in the success of the Indian agriculture to bring about a turnaround in agriculture in this region. There is a growing trend to introduce higher machineries. This trend is influenced by the emerging trend for custom hiring, contract farming and to reduce the cost of cultivation. Contract farming is essential to produce raw materials for agro-processing units proposed to be set-up in rural areas. This trend is to be encouraged, as it would save the farmers from graving indebtedners by spending heavily in acquiring expensive machinery like tractors, sprayers, combine-harvesters, etc. This would also call for revising the agricultural credit policy, which requires mortgaging of land to get the loans. This policy deprives the small farmers, landless laborers and unemployed youths from getting loans for buying the tractors and other machines for custom-hiring jobs. Indian farmers have adopted mechanization inputs especially, irrigation, tractor, and threshing. Custom Hiring of mechanization inputs is getting popular for which high capacity machines need to be developed. Agriculture Service Centers need to be developed in rural areas for marketing and service supports of inputs including engineering inputs. Quality of Machines needs to be improved through material selection and manufacturing. The R&D Institutions need to develop crop and location specific agricultural machinery to promote rapid mechanization. Governments should develop an integrated and inter-linked education, training and extension programme. The type and level of education and training will need to be geared towards the requirements of the agricultural manufacturing and production sectors.

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