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Role of conservation agriculture and agricultural mechanization on productivity, sustainability and income generation in north west India

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Abstract **:** Agricultural mechanization and conservation agriculture refers to interjection of improved tools, implements and machines between farm workers and materials handled by them. Independent India ushered in a process of agricultural mechanization and revival of rural agro processing which got acceleration during post-green revolution period. Irrigation pump sets, power threshers, tractors, power tillers and matching implements, including for 65 million draft animals have became popular. Seed and seed-cumfertilizer drills, planters, mechanical rice transplanters, vertical conveyor reapers,and combines soon followed. In the recent past, zero-till drill and raise bed planters, laser land leveler, turbo happy seeder have found good acceptance from the farmers. Currently mechanization is in increasing demand. Farmers and policy makers and developmental agencies now realise that for increasing productivity and sustainability at reduced unit cost of production, free of arduous labour, agricultural mechanization is essential. It is brought in centre stage with globalization of world markets.Shifts in agriculture leading to crop diversification towards horticulture,animal husbandry, fishery and forestry are going to bring in greater degree of mechanization.Western Uttar Pradesh dominated by small and marginal land holdings may not have same trend of mechanization as the developed world but it is going to grow close to it with its own variant as labour wages go up and WTO competition compels us to keep reducing unit costs of production,processing,packaging,and retail and situations demanding provision of custom servicing, custom agro-processing and acceptable standards of living. The conventional mode of agriculture through intensive agricultural practices was successful in achieving goals of production, but simultaneously led to degradation of natural resources. The growing concerns for sustainable agriculture have been seen as a positive response to limits of both low-input, traditional agriculture and intensive modern agriculture relying on high levels of inputs for crop production. Sustainable agriculture relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes such as nitrogen fixation, nutrient cycling, soil regeneration, and protection of natural enemies of pest and diseases as well as the targeted use of inputs.Agricultural systems relying on such approaches are not only able to support high productivity, but also preserve biodiversity and safeguard the environment. Conservation agriculture has come up as a new paradigm to achieve goal of sustained agricultural production. It is a major step toward transition to sustainable agriculture. Agriculture has always been taken for granted, over recent years the discussion has shifted to the 'crisis' being faced with'concerns' raised about the 'reality' of the situation and what needs to done.We all know that these developments have been influenced by human actions and have not emerged as an over night phenomenon. Thus, it is to be expected as with any deteriorating situation, the solution sought/ professed may be equally strong, and many a times bordering on the impractical. It is in such a scenario that conservation agriculture (CA) is trying to find its feet within India. The world over, CA has gained ground due to the stated balance, it has been able to achieve between needs of productivity and sustainability. With its basic approach directed at conserving resources and maintaining productivity, most would agree that it can offer a way forward to attain goals of sustainable agriculture. Several studies have indicated that there was significant increase in cropping intensity due to the use of tractors and irrigation as a consequence of mechanization.The increase in cropping intensity has been reported to be 165, 156 and 149 per cent for tractor-owning, tractor using and bullock operated farms, respectively. Furthermore, the per cent gross cropped area irrigated was positively related to cropping intensity.The facilities of tubewell irrigation and mechanical power helped the farmers in raising the cropping intensity of their farms concluded that cropping intensity was mainly dependent on annual water availability and the farm power available. It was also reported that the States like Punjab, Haryana,Western Uttar Pradesh which had higher per cent irrigated area, higher doses of fertilizer and higher power availability per hectare also had higher grain yield per hectare. The studies regarding effect of agricultural mechanization on

human labour employment have shown that agricultural mechanization helped in overall increase in the employment of human labour. The reduction in aggregate labour used on tractor operated farms was quite nominal (1.3 to 12%) as compared to bullock operated farms. The increase in employment of casual male labour was reported to be upto 38.55 per cent. There was slight decline in the employment of casual labour.To sum up, agricultural mechanization studies had shown that farm mechanization led to increase in inputs due to higher average cropping intensity, larger area and increased the productivity of farm labour. Furthermore, farm mechanization increased agricultural productivity and profitability on account of timeliness of operations, better quality of work and more efficient utilization of crop inputs.Undoubtedly, farm mechanization displaced animal power from 60 to 100 per cent but resulted in less time for farm work. Also mechanization led to increase in the human labour employment for the on-farm and off-farm activities as a result of manufacture,repair, servicing and sales of tractors and improved farm equipment.

Key words **:** Conservation agriculture, Productivity, Sustainability

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Mechanization refers to interjection of machinery between men and materials handled by them. In agriculture materials are soil, water, environment, seed,fertilizer, pesticides, growth regulators, irrigation, agricultural produce and by-products such as foodgrains, oilseeds, fruits and vegetables, cotton, sugarcane, jute and kenaf and other cash crops, milk, meat, eggs and fish etc. There is scope of mechanisation in every unit operation of production agriculture, post-harvest and agro-processing, and rural living. Mechanisation has varied connotations. While in the developed world it tends to be synonymous to automation but in developing countries, like India, mechanisation means any improved tool, implement, machinery or structure that assists in enhancement of workers' output, multiplies the human effort, supplements or substitutes human labour that is enabling and removing, avoids drudgery or stresses that adversely affect human mental faculties leading to errors,imprecision and hazards and eventually loss of efficiency. It also means automation and controls that assure quality, hygiene. Agricultural mechanisation in a limited sense relates to production agriculture.

The introduction of agricultural technology, including mechanization, is a complex process. The formulation of an AMS (agricultural mechanization system) requires comprehensive knowledge of many aspects of agriculture in its broadest sense. An AMS will very much depend on country specific characteristics of the economy, its level of development, and the agriculture sector. This means that the formulation process for an AMS cannot be prescribed in a simple set of guidelines. Therefore, the purpose of this section is to aim at a better understanding of the process of mechanization, to provide broad guidelines for strategy formulation, and to address the major issues involved. For those who will be involved in the formulation of an AMS, it is recommended that they also read FAO's guide for AMS preparation (FAO, 1997).The requirements for an AMS must be kept in the proper context. AMS formulation should not become overbearing time consuming exercise, absorbing excess manpower and other resources, as compared to the actual constraints which need to be resolved by agricultural engineering. Preferably mechanization technology should be considered in the context of an overall (agriculture) technology strategy.

Indian agriculture is characterised by overwhelmingly small holdings due to higher population density and nearly two-third of its population residing in the rural areas coupled with unabated land fragmentation due to the inheritance laws of the country.Nearly 62 per cent of the estimated 142 m ha area is rainfed. Major sources of farm power include both animate (humans and draught animals) as well as inanimate sources such as diesel engines, tractors and electric motors. India's well-orchestrated 'green revolution' began in the mid 60's. It was ushered in through the adoption of higher and balanced doses of the biological, chemical and mechanical inputs together with the timely intervention of the Government. The later ensured the availability of the required inputs of high yielding seed varieties, fertilizers, pesticides, water and improved power sources and equipment. The Government provided the minimum support price, easy access to procurement markets, rural roads and other infrastructures which helped to trigger the green revolution in selected areas of the country. Resultantly gross food production increased from 50.8 M tons in 1950-51 to 199.3 M tons in 1996-97 and land productivity rose from 0.58 tons/ha/year to more than 2.14 tons/ha/year. Whereas the quantum jump in production and productivity was brought about by a combination of factors, farm mechanization was often at the centre of controversy due to its impact on employment of human labour in a labour abundant economy. This paper reviews the findings of various researchers on the impact of farm mechanization

on agricultural production and productivity, cropping intensity, human labour employment on the farm,subsidiary and non-farm employment as well as gross farm income and net return.

Growth in agricultural mechanization:

These amendments in agriculture were accompanied with due inputs of mechanisation in natural resource development, agricultural field operations and on-farm primary processing. After intensive testing and evaluation in late 1950s, manufacturing of irrigation pumping sets commenced. Initially two-thirds were engine operated and one-third electric operated. As rural electrification advanced, proportions have changed infavour of electrical power. Animal drawn improved equipment such as seed drills, seed-cum-fertilizer drills,5hp power threshers primovers like diesel engines,electric motors got into manufacture and use. Central tractor organisation (CTO) established soon after independence to reclaim marshy lands in Tarai of UP and scrub forests elsewhere to settle displaced people who came from across the border set the pace of tractorisation in India. CTO used crawler tractors, their operation, upkeep and later on indigenous fabrication of certain fast wearing components, after OE stocks exhausted, were locally developed. For tractorisation of agricultural field operations around mid-1960s small 4-wheel general purpose tractors were brought in CKD (completely knocked down) condition and assembled,marketed, operated, and serviced by training Indian technicians. Confidence thus gained resulted in progressive indigenous manufacture. Swaraj 35 hp from M/s Punjab Tractor was the first totally indigenous tractor. A little later two-wheeled tractors popularly known as power tillers were introduced and at one stage more than a dozen firms had manufacturing licenses. However, farming system in vogue, wet cultivation during *Kharif* and upland farming during *Rabi*, and lack of proper after-sales-services support adversely affected their growth. All but two Mitsubishi and Kubota by M/s VST Tillers, Bangalore and M/s Kerala Agro-Industries Corporation survived. Today India is the largest producer of tractors in world with about 2,75,000 tractors per year and about 15,000 power tillers. China is able to market its power tillers in India at cheaper prices, nevertheless there are after sales service problems in many cases with the introduction and growth of tractors in India in production of matching equipment for scraping and land levelling, seedbed preparation, seeding and planting, seed-cum-fertilizer drilling, spraying and dusting, harvesting and power threshing, 2-wheel and 4-wheel tractor trolleys got in to indigenous manufacture and these got reserved for small scale industries (SSI) sector. It became a very competitive farm equipment industrial activity in Punjab and in pockets all over the country. However, to enhance quality of farm equipment many items have been dereserved, now.

By early 1980s vertical conveyor reapers (VCR) were introduced to mechanise sickle harvesting, initially walking type, then a larger tractor version and subsequently riding type self propelled units. During 1982-84 production of tractor mounted VCRs increased ten fold each subsequent year reaching to 3000 in third year but got reduced to 2000 annual production in the fourth year, the year insurgency in Punjab touched its peak. At this point of time Punjab farmers found combining of rice and wheat cheaper and less risky. Several manufacturers (29) in small scale sector took to general purpose standard grain harvesting combines by manufacturing tractor mounted, self propelled and tractor driven versions. Combining, however, created problem of rice and wheat straw gathering, transforming and handling as bhusa. Straw disposal through incineration was found creating serious environment pollution whereas straw incorporation in to the soil was leading to nitrogen stealing. Invention and introduction of straw combines did provide a solution to reclaiming wheat bhusa but still about 50-60 per cent of the rice and wheat straw is being disposed by burning. It may not be entirely due to combines, demand for wheat bhusa has also declined. Its transport to feed deficit areas in loose farm is expensive and uneconomical. Complete feedblock bufferstocking to fight feed famines is a possibility.

Progress of conservation agriculture in India:

Over the past 2-3 decades the concept of conservation agriculture (CA) has emerged as a way for transition to sustainability of intensive agricultural production systems. CA permits efficient use of scarce resources and management for agricultural production while protecting the resources from processes that contribute to degradation. CA that refers to the system of raising crops without tiling the soil while maintaining crop residues on the soil surface with appropriate crop combinations has emerged as a way for transition to the sustainability of conventionally managed intensive production systems. In India, and other countries of the region efforts to develop and spread CA practices have been made through combined efforts of several State, National level institutions and CGIAR institutions. Efforts to adapt and promote elements of CA have been underway for over a decade but it is only in the past few years that new technologies have started finding acceptance by the farmers. It is estimated that these technologies are being adopted in over one million hectares chiefly in the Indo-Gangetic plains and it is important to draw lessons to thus benefit other regions of the country.

Due to wide variations in biophysical and socio-economic situations across the Indo-Gangetic Plains (IGP), the problems facing farmers varies a great deal across the plains.While in north-west plains (Punjab, Haryana, Western UP) farmers obtain high yields of both rice and wheat crop and farms are mechanized; in the eastern plains, yields are low as is the level of mechanization. While enhancing cropping

system productivity constitutes a major challenge in the eastern plains, the north-west region is facing increasing environmental problems arising from excessive use of chemicals, declining water tables, declining soil fertility etc. The practice of zero-tillage has been developed and been adopted by farmers for seeding wheat in the rice-wheat cropping system. The main driving force for the evolution of zero-till seeding of wheat in the system is the long turn around period (3 to 5 weeks) required for tillage operations following the harvest of rice crop that results in delayed planting of wheat, when timely planting of wheat is critical to enhancing wheat/cropping system productivity. The technology that was in the testing phase in late nineties started picking up from year 2000 onwards and in the recent context (2006-07) an estimated 1.5 million ha was planted adopting the technology. The major driving force for adoption by farmers was reduction in cultivation cost on account of fuel and machinery costs, saved on account of tilling not being carried out.

Not withstanding the initial success in the adoption of zero tillage for wheat and the associated benefits, there are a number of questions which call for serious deliberations with regard to future strategies to promote conservation agriculture that is being accepted as a way forward to achieve sustainability goals. As such, although zero tillage has been adopted over a significant area for growing wheat there are serious questions on how these initial successes will be sustained and future strategies built upon. Several constraints are already showing up. While the practice has picked up rapidly in the high productivity north-west region where this was initially tested, the spread has been slow in the eastern region due to a variety of reasons, most importantly, strong variations in respect of socio-economic and edaphic situations and the need for adaptive research backing to be able to find answers to questions which are raised by the farmers. In reality CA's ability to address problems makes it more needed to address needs of rainfed areas,thus bringing into productive use lands that have given up/are giving up on agriculture.

Current imperatives:

Mechanisation is now demand driven. With increasing labour wages and agricultural produce market prices as they are, engineered to be low for food and nutritional security and food accessibility to the masses,the farmers, specially medium and large ones, are looking for labour saving devices to remain competitive more so with the globalization of the world markets.And the farm working groups, policy makers and social scientists are looking for mechanisation to remove drudgery from farm operations so that rural educated youth do not run to urban areas in pursuit of jobs which are already in short supply. With prepondence of marginal and small farms, below 2 ha above 76 per cent of the total land holdings,custom servicing in farm operations is in vogue and rightly so because individual ownership is not affordable.

For the reasons explained, agricultural mechanisation in India has come a long way in the last 50 years. India produces wide range of agricultural equipment needed to practice modern intensive farming. However, there are unit operations in certain commercial crops and commodities where mechanisation is needed,and for which presently there is no viable solution. With quantitative restrictions removed from 1st April, 2001 it is faced with new challenges, some have reservations whether it will be able withstand pressures of multinational companies and countries that are aggressively marketing their goods in export markets.Indian farm equipment industry has demonstrated its resilience and responsiveness to changing market situations in the past and should come out victorious at the end adopting modernization measures. Nevertheless,the challenge is formidable.

To meet food, feed, fibre, fuel, and industrial raw material needs Indian agriculture is required to double food production in a decade *i.e.* by 2010. With the available land mass remaining at about 142 million hectares (Mha) it has to come through essentially a vertical expansion, gains through productivity in commodities and the regions there is scope like India and returns on investment favourable. Globalization and its basic demand of competitiveness asks for greater timeliness, precision in metering and placement of inputs that are going to be increasingly costlier, minimisation of pre and post harvest losses, on-farm value addition for additional income and employment that provide greater sustainability to farm families and make farming and associated post-harvest activities less arduous and economically rewarding and satisfying. Environment control in plant and animal production will have to be employed to realise the productivity levels targeted and prevent morbidity and mortality in livestock husbandry.As we can see, increasingly, there is going to be demand for precision farming, farming equipment that are ergonomically sound, economically affordable, system that reduce unit cost of production through economy in inputs use and quantum jumps in productivity.This paper aims to bring out the impact of agricultural mechanization and conservation agriculture on productivity,sustainability current efforts, and ventures in postulating likely future requirements and trends in agricultural mechanisation and income generation in North Western India.

Agricultural mechanization is a multi-sector activity.The demand for farm machinary and equipment is driven by agricultural development and labour scarcity. Use of machinery is dependent on infrastructure and services available in the rural areas.Improved agricultural tools and equipments are estimated to contribute to food and agricultural production in India by saving in seeds (15-20%),fertilizers (15-20%) time (20-30%) and labour (20-30%);and also by increased cropping intensity (5-20%) and productivity (10-15%) (IASRI, 2006). Although,India started to produce tractors in 1961 (880 units),

Table 1 : Status of farm equipment manufacturing industries

Equipment	Manufactures (Number)	Equipment	Manufactures (Number)
Agricultural tractors	20	Seed drills	2500
Power tillers	9	Ploughs, cultivators and harrows	5000
Earth movers	3	Tractors parts and accessories	546
Pumps	600	Earth moving machinery and parts	188
Sprinkler sets	35	Diesel oil engine	200
Drip irrigation system	35	Rice processing machinery	300
Plant protection equipment	300	Sugarcane crusher	50
Combines	48	Chaff cutter	50
Reapers	60	Dairy and food industries	500
Threshers	6000	Small tools (village craftmen)	1 million

Sources : Tractor Manufactures Association Reports (2003-08): Agricultural Engineering Data Book, January (2008), CIAE, Bhopal

it continued to import tractors up to 1976 (Singh,2001).The annual production of tractors increased to 33,000 in 1975; 71,000 in 1980;and 140,000 in 1990.In 1992 the industrial license to manufacture tractors was abolish.From 1997 to 2000, annual production of tractors was over 250,000 units,which increased to 352,368 units in 2006-07 and 345,172 in 2007-08.India also has a big network of agricultural machinery manufacturers.

Presently, India is the largest manufacturer of tractors in the world,according for about one-third of the global production,and more than 50 per cent of tractors are in <60 hp category. From 2004-05 to 2007-08,nearly 1.24 million tractors were sold by 11 tractor manufacturers of the country.The total number of tractors,based on sales data,was around 3.5 million in March 2008.Power tillers are becoming popular in lowland flooded rice fields and hilly terrains.Their annual sale has been around 16,000-20,000 during the last five years,including those imported from China (CIAE,2008). Steady growth was observed of manually operated tools (seed-cum-fertilizer drills, seeddrill,chaffcutters,wheel-hand hoes,sprayers, threshers, animal operated implements (wooden ploughs,steel ploughs, disc harrows,cultivators, seed-cum-fertilizerdrills, seeddrills, levelers, wet-landpuddlers, animalcarts), and equipment operated by mechanical and electrical power sources (Power operated sprayer/dusters, diesel engine pump sets, electric pump sets, cultivators,disc harrows,seed-cum-fertilizer drills, planters, levelers,potato doggers, trailers, paddy threshers, wheat threashers, maize shellers, chaft cutters, combine (both tractor-drawn and self-propelled). In manually-operated equipment, the number of sprayers almost doubled from 1992 to 2003.

Table 2 : Growth in availability of farm machines in India

Farm machines	1992	2003
Manual operated	18,634	40,138
Animal operated	89,281	105,811
Tractor/power operated	16,910	25,914
Total	124,825	171,863

Source : Livestock Census (2003)

Mechanization and productivity:

Agricultural mechanization in India may be characterized with large variations in power availability,varying from 0.60 kW/ha in Orissa to 3.5 kW/ha in Punjab.The average farm power available was about 1.46kW/ha,comprising about 84 per cent from mechanical and electrical sources and 16 per cent from animal power and human labour (IASRI,2006).There is a strong linear relationship between power availability and agricultural productivity.Estimated mechanization level of various farm operations are: 40 per cent for tillage, 30 per cent for seeding/ planting, 37 per cent for irrigation, and 48 per cent for threashing of wheat, 5 per cent for threashing of rest of crops, and 35 per cent for plant protection (CIAE, 2008). There seems to be a relationship between irrigation and power availability in Punjab, Haryana and western Uttar Pradesh.But, there has been enhancement in farm power despite limited irrigation facilities in Andhra Pradesh,Assam and Uttarakhand.

Singh and Chancellor (1974) found that though,tractor and tubewell farms had significantly higher yields than bullock farms in case of wheat, much of the difference was accounted for by difference in other factors such as level of irrigation. The use of tubewell was found to be associated with significantly higher yields compared to the persian wheel irrigation. ITES, Madras (1975) found that tractor - owned farms obtained increased productivity of paddy, sugarcane and groundnut by 4.1 to 28.3 per cent, 13.1 to 34.2 per cent and 9.8 to 54.8 per cent with an average value of 15.8 per cent, 23.2 per cent and 31.8 per cent, respectively.Likewise, the average increase of productivity on farms hiring tractors was reported to be 11.8 per cent, 13.0 per cent and 16.0 per cent for paddy, sugarcane and groundnut, respectively.

Constraints in mechanization:

It is true that farm mechanization has shown good results as of raising the agricultural production and improving the

standard of living of cultivators within very short period. But a number of arguments have been advanced against farm mechanization such as:

- Small size and scattered holdings of the farmers stand in the way of mechanization. As a result of this, farm machinery generally remains underutilized.
- Majority of small cultivators are poor who are not in a position to purchase the costly machinery like tractors, combine harvesters etc.
- The use of tractor operated machinery may render some of the draft cattle population surplus. Studies under UPCAR Project on 'Resource conservation technologies for sustainable development of agriculture' indicate that tractor owning farms do use draft animals for certain jobs. Like-wise farms using animatesources of farm power, use tractor on custom service for certain jobs.
- The farm machinery have large turning radius and thus require comparatively larger farm for economical use. Mechanization may lead to structural change in agriculture in respect of the occupational distribution in the rural economy. No doubt, the increasing farm mechanization is going to increase employment in secondary and tertiary sectors but it does displace labour in farm operations.
- Lack of proper knowledge of farmer to purchase farm machinery, operate and maintain it properly leads to wrong choice, makes it uneconomical and risky too.
- There is great shortage of diesel in the country as a whole. Thus, to use so extensive oil based farm machinery is not desirable.
- The lack of repair and replacement facilities especially in the remote rural areas is another hindrance in efficient small farm mechanization.
- Due to the seasonal nature of the agriculture, the farm machinery remains idle for much of the time. Thus, idle machinery means unnecessary high costs unless proper alternate use of such machinery in the off-season is made.

According to Singh and Mittal (1994), the chief bottlenecks of farm mechanization can be cited under following three heads:

- Research development and testing of farm machinery and equipment, particularly suitable to small farms, dry farming, for operations such as paddy transplanting,residue management,sugarcane and fodder harvesting, spraying tall plants such as fruit and forest trees, cotton, sugarcane etc., sugarcane planter, cotton picking and so on.
- *Manufacture, standardization and quality control:* Poor quality and lack of matching and standard designs of equipment and acute shortage of testing facilities.
- *Education, training and popularization of farm equipment*: Inadequate training facilities for farmer-users and artisans, inadequate service centers and lack of regulations on custom hiring services.

The need for mechanization / productivity enhancing technology:

Farm Power -consisting of manual labour, agricultural tools, draught animals, tractors, implements, equipment, and machinery – is an essential farm input. In almost any agricultural production system the annual expenditure on farm power, whether on labour, draft animals, or fuel and depreciation of machines, largely exceeds the costs of other inputs such as agro-chemicals and seeds. In many developing countries, agricultural production and food security are adversely affected because of insufficient use of farm power, low labour productivity and/or labour scarcity. The need to improve agricultural labour productivity is increasingly recognized. In the case such as pump sets for irrigation, the need for machinery is undisputed. Rather than agricultural mechanization, it would be preferable to use the term farm power or labour productivity enhancing technology, to recognize not only the importance of manual labour and handtools, draft animals, and mechanical power, but also other issues related to labour scarcity, such as cropping- and farming systems.

Finding solutions to environmental problems in agriculture requires (improved) agricultural tools and machinery, for example for soil tillage and pesticide application, the latter also addressing health concerns. Similarly, machines are required to assist with post-harvest loss reduction and on-farm processing. Thus it is now (again) recognized that agricultural mechanization is crucial in the fight against hunger and poverty, and at the same time to address environmental and health concerns. In order to avoid recurrence of the past mistakes such as described in the introduction, formulation of efficient mechanization strategies are required.

The term mechanization is unfortunately often very narrowly perceived while its real purpose, namely, enhancing productivity of land and labour is often not well understood. In fact an agricultural mechanization strategy ought to be part of an 'agricultural technology strategy', which is to be part of an overall agricultural development strategy. In this context, three principal purposes of mechanization may be summarized as follows:

- Increase in labour productivity. The introduction of machinery to substitute for labour ("laboursaving") is a common phenomenon associated with the release of labour for employment in other sectors of the economy or to facilitate cultivation of a larger area with the same labour force.
- Increase in land productivity. The purpose of mechanization is here to produce more from the existing

land. Machinery is a complementary input, required to achieve higher land productivity, for example, through the introduction of pump sets, or faster turn-around-times to achieve higher cropping intensity. In labour surplus economies, net labour displacement or replacement should be avoided.

– Decrease in cost of production. Introduction of a machine may lower production costs or offset increased costs of draft animals or labour.Usually, in various degrees, a combination of the three objectives will be achieved. Additional benefits to the user may be associated with a reduction in the drudgery of farm work, greater leisure, or reduction of risk. These are subjective benefits and difficult to translate into cash. Frequently mechanization increases an individual's workload, can be hazardous to health and may reduce the social interactions associated with farm work.

Labour productivity enhancing technology:

When reviewing the process of applying labour-saving (or labour productivity enhancing) innovations in agriculture, it is a serious but frequently made mistake to assume that this can be achieved only through applying mechanical engineering technology. In this context, nine different stages in the process of enhancing labour productivity may be distinguished (Rijk, 1989):

Stage I: Application of improved hand tool technology. This process started in prehistoric times when early civilizations developed stick and stone tools which were the only means to enhance labour productivity. In many parts of the world, handtools are the only technology used in agriculture, and even in highly mechanized agricultural systems, improved handtools are still important.

Stage II: Draft animal power application. At this stage animal muscle power is substituted for human power, a process which already started in ancient civilizations. A large variety of implements and machines have been developed which use animals as the principle power source.

Stage III: Stationary power substitution. Mechanical power is substituted for human and animal power, used in stationary operations. Stationary operations are mechanized first because motive power sources required to move across the field are technically more complex and, therefore, require higher investment. Typically, operations mechanized at this stage are paddy dehusking, grain milling, pumping water, and threshing.

Stage IV: Motive power substitution. At this stage, substitution of mechanical power for muscle power takes place for field operations. It focuses on power-intensive field operations (for example,plowing), and machinery is of relatively simple design, and easy to operate. Mechanization is still straightforward, and crop production practices are usually unchanged. At Stage III and IV,mechanization takes advantage of lower costs of new power sources as compared with traditional ones.

Stage V: Human control substitution. At this stage the emphasis is on substitution of the human control functions. Depending on the complexity of the control function and the degree of its mechanization, machinery becomes increasingly complicated and costly. A potato lifter is simple in design, but fruit and cotton harvesting machinery are complex and expensive .

Stage VI: Adaptation of cropping practices. This stage features the adaptation of the cropping system to the machine. For example, removing weeds in broadcast crops cannot be done with machines but row seeding and seed drills may be introduced to facilitate mechanization of weeding. Other examples include the increase in row distance to accommodate heavier and larger machinery to speed up field operations.

Stage VII: Farming system adaptation. The farming system and production environment is changed to facilitate further increase in labour productivity and to benefit from economies of scale, necessary to make the investment in expensive machinery financially feasible. An example of this is the rapid decline of mixed farming systems in Europe since the late 1960s when farmers specialized in either dairy, poultry, hog, or crop production. Some crops which are difficult to mechanize may disappear if acceptable substitutes become available, or if these can be produced in countries with low labour costs.At this stage, investments in land development, land consolidation, and rural infrastructure are often needed to facilitate advanced degrees of mechanization.

Stage VIII: Plant adaptation. This stage features the adaptation of the plant and animal to the mechanization system. Mechanization has advanced to a stage were engineering alone can no longer provide further gains in labour productivity. Breeders increasingly take into account the suitability of new varieties for mechanized production.

Stage IX: Automation of agricultural production. This stage is progressing in countries with high labour costs and sophisticated demands on production and quality. Examples are automated rationing of concentrate feeding for individual dairy cows based on their milk production, and sprinkler irrigation systems activated by soil moisture.

The above sequence of 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 labour 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. For example, a frequently made mistake is to propose the introduction of mechanical rice transplanters to offset labour cost increase, while changing to broadcast rice is in most cases technically and financially a better solution. 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 labour scarcity, and thus the tree variety and planting pattern be able to accommodate future mechanized operations. These examples explain why a holistic approach and a multidisciplinary input in strategy formulation is very important.

Energy:

Agriculture in a way is an energy- conversion industry.Excessive use of commercial energies in Indian scenario, where 70 per cent petroleum products are imported and electrical power is costly and in short supply,means increased unit cost of production of agricultural products and reduced profitability and global competitiveness.Rural electrification and socio-economic development have enabled use of electricity,kerosene and biogas in the resourceful rural homes.However,supply of electricity to the rural areas is not adequate;it is not there,when required.A number of renewable energy applications such as biogas plants,solar cookers,solar water heaters,solar dryers,photovoltaic irrigation pumps and illumination systems are under massive popularization to make up for the energy deficient in the rural areas.

Energy and agricultural production:

Total energy input in Indian agriculture increased by 5.4 times during 1951 to 1995 while the production during the same time increased by 3.6 times (Singh,1997).Thus a close relationship exists between energy (farm power availability) and agricultural productivity.

The total energy use in production of principal crops has increased 4.5 times between 1970 and 2005 with productivity increase from 837 to 1,583 kg/ha.The contribution of animal energy has decreased significantly from 44 per cent to 6 per cent and human energy from 37 per cent to 8 per cent.Commercial energy has increased significantly-electricity from 0.20 per cent to 38 per cent,diesel from 2 per cent to 18 per cent and fertilizer from 16 per cent to 30 per cent.This exhibits the increasing dependence of Indian agriculture on commercial energy. Agricultural mechanization,energy use and agricultural production and productivity are closely linked.

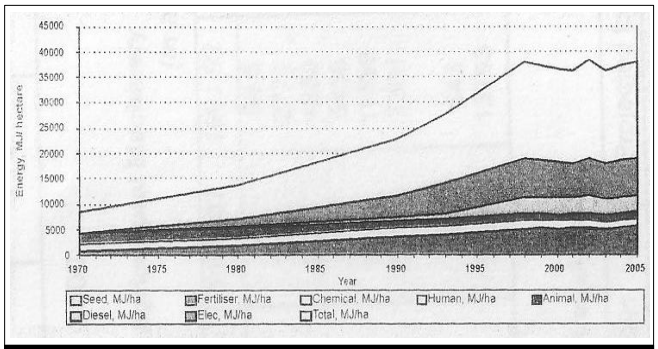

Fig. 1 : Source-wise energy consumption in Indian agriculture

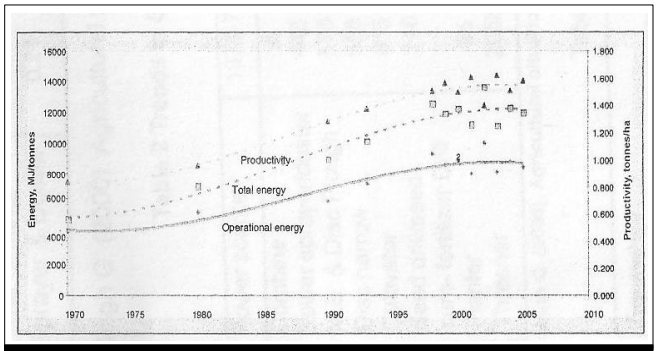

Fig. 2 : Operational energy consumption trend

Emerging trends:

Agricultural mechanization trends are linked with the trends in agriculture and rural living, globalization of world markets and market trends, WTO obligations, and State and Central Government policies and demands of political constituents. Agriculture is a state subject. Decisions at state or regional level self sufficiency or policy to concentrate on exploiting agroecological advantages and meeting short falls through imports from other states of the Union or a foreign source are likely to affect the mechanization trends. As of now things are in the state of flux. Country is faced with contradictory situations each having its own requirements including mechanization. Modernization requires sophistication in mechanization which is possible at relatively large scales of operations entailing capital and management constraints. Globalization puts heavy demand on competitiveness, reduced unit cost of production, indirectly demanding mechanization and to a certain extent automation. These will lead to tractorisation. Marginal and small farmers are increasingly becoming part time, absentee farmers, peri urban farmers, wage earners on part or full time basis. Industry and service sectors, trade and commerce unable to reduce land based livelihood compel the rural people to remain on land based livelihood, forcing steady increase in number of land holdings but 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.

- Country is faced with the basic livelihood issue of the rural masses. With per capita arable land availability dwindling and average land holding coming down to levels that it is too difficult for the farm families to have minimum acceptable standards of food, shelter, clothing, health care,and education, the Central and State Governments are seized with the issue of ways to widen livelihood base of these people. Increasing productivity; crop diversification towards horticulture, livestock husbandry and forestry; post-harvest management for minimization of post harvest losses, value addition and agro-processing for additional income and employment are some of the developmental measures enunciated and related schemes and programmes launched.
- Governments are also encouraging contract farming *i.e.* farmers producing specified agricultural produce needed as raw material for industries. Governments are also reducing intermediaries between growers and consumers. Growing middle classes where both husband and wife are working need processed and semi processed,ready to cook, ready to eat items.
- Under such complex scenario the emerging trends in mechanization of agriculture and rural living are as follows:

Farm implements and machines:

- Improved energy efficient matching implements and machines for different unit operation of agriculture are expected to be available soon.
- High ground speed machinery for tillage, sowing,and planting using rolling, rotary and vibratory actions.
- Custom hiring in field leveling,seedbed preparation, sowing,planting, transplanting, harvesting and threshing and other specialized unit operations where ownership of a costly equipment is not justified.
- Trade in used farm machinery, repair,reconditioning is likely to come up in order to reduce capital requirements of farming.
- Conventional tillage and sowing are going to be supplemented and substituted by rotary tillage,conservation tillage, raised-bed systems for economy, efficacy, and enhanced productivity.
- Conventional manually transplanted rice are going to be supplemented and substituted by mechanical transplanted rice using manually operated and self propelled transplanters and mat type nursery. Dry drilling and paddy sown with pregerminated paddy seeder in levelled puddled field (Lehi substitute) have already made in-roads. Check-row transplanted and bidirectional mechanically weeded paddy crop has yield advantages and thus likely to gain ground provided affordable check-row planters and efficient weeders are developed and made available.
- Zero-till drill,turbo happy seeder and inclined plate raised bed planters in rice-wheat ecology are going to become still more popular for the economy in use of irrigation water (35-50 saving), reduction in unit cost of production (3500-4000 Rs/ha), better control on phalaris minor and yield advantages (about 5%).
- Mechanical weeders-manual, animal drawn,power tiller and tractor mounted and selfpropelled power weeders for wide row such as well as rice-wheat are going to be in greater use and would be available in wide range.
- Sugarcane planters; cutter-planters which makes sets, plants, applies fertilizer, weedicide and pesticide in one go are going to gain popularity.
- Drills and planters for direct seeded vegetables, vegetable transplanters for potted and soil block mature seedlings of brinjal, chillies, cole crops, onion, garlic etc. are expected to be in use as vegetable cultivation gets commercialized.
- Power threshing is already in vogue for most of the crops through owned or custom hired power threshers. Trend is emerging in favour of large capacity, bulk fed, multicrop threshers. There are going to be power threshers difficult to thresh for crops like pigeonpea.

Conclusion:

A common finding that emerged from various studies was that tractorisation displaced mainly bullock labour up to about 60 per cent in some situations, but its impact on man-power was much less, the displacement being less than 15 per cent. Various studies concluded that owing to this relatively low displacement of man power that was unavoidable, mechanization should not be viewed in isolation. Indeed, mechanization opened up new avenues for human employment such as managerial and supervisory jobs on the one hand and driving, servicing,maintenance and repair of the machines on the other.Therefore, recommended selective mechanization in an increasing manner for farms between 5-20 ha groups,which constituted 40 per cent of the area under cultivation,and near total mechanization in operational holdings greater than 20 ha., which accounted for 13 per cent of the cultivated area. NCA supported the view that animal, mechanical and electric power work complemented each other. NCA advocated tractorization for time bound operations like sowing, planting especially in rainfed areas where the operations were required to be completed in a short span of time while the rain occurred and for harvesting and threshing,

as well as for non repetitive works such as land reclamation, levelling,terracing, eradication of wild-shrubs and perennial weeds like kans, (*Saccharum spontaneum*), as well as for command area development works.

Studies were also conducted by several other organisations and individuals on the impact of conservation agriculture and farm mechanization on agricultural inputs and outputs. Almost all such studies led to the following broad conclusions:

- Developing and spreading awareness of virtues of CA to society, highlighting benefits of resource conservation, environment, climate change mitigations,economics. Exchange and sharing of information nationally and internationally would also be important.
- Promoting integrated crop-livestock CA systems and other means of minimizing conflict of demands on crop residues through better understanding of farming systems.
- CA has to be linked with appropriate agribusiness strategies to increase employment in areas where it is adopted. At the same time looking to needs of mechanisation, a system of affordable custom hire must be encouraged for improved availability on an affordable basis. Adaptation of such mechanisation to needs of women, small farmers, and those in hill regions would also have to be understood.
- Supporting policy development for bringing about a paradigm shift necessary to improve adoption of CA practices by farmers, technicians, educationists and policy makers. This will require a correction of policy imbalance promoting non eco-friendly technologies.
- Need for new funding arrangements and public-private partnership mechanisms encouraging scientists, farmers and the business community to work for mutual gain, within a more responsible framework of agriculture pursuit.
- That farm mechanization led to increase in inputs on account of higher average cropping intensity and larger area and increased productivity of farm labour.
- That farm mechanization increased agricultural production and profitability on account of timeliness of operation, better quality of work done and more efficient utilization of inputs.

That farm mechanization increases on- farm human labour marginally, whereas the increase in off- farm labour such as industrial production of tractors and ancillaries was much more. That farm mechanization displaced animal power to the extent of 50 to 100 per cent but resulted in lesser time for farm work.

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