AGRICULTURAL MECHANISATION: NECESSITY FOR SUSTAINABLE DEVELOPMENT

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ABSTRACT

India's agricultural production has stagnated at a time when the broader elements of it's economy have grown. **In order to sustain a overall growth rate it is imperative for agriculture sector to grow proportionately**. Though, India has achieved self sufficiency in food grain production, but we witnessed that the growth rate of food grain production lagged behind that of the population of thecountry.

While efforts such as introduction of high yield varieties and expansion of irrigated area have played a crucial role in achieving the goal of food self sufficiency in the past, rapidly growing demand for food brings the need for building efficiencies in the agriculture to the forefront. Towards this objective and also to meet the goal of **"No poverty and Zero Hunger**" of the Sustainable Development Goals (**SDGs**) adopted by the United Nations General Assembly on 25 September 2015,it is imperative to focus on improving the intensity of agricultural mechanisation.

Mechanisation covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorisedequipments. It eases and reduces hard labour, relieves labour shortage, improves productivity and timeliness of agricultural operation, improves the efficient use of resources, enhances market access and contribution to mitigate climate related hazards. Sustainable mechanisation considers technological, economic, social, environmental and cultural aspects when contributing to the sustainable development of food and agriculture sector. Mechanisation plays a key role in enabling the growth of commercial agriculture food systems and the efficiency of post harvest handling, processing and marketing operation, and as such can be a major determinant in the availability and accessibility of food, the food prices paid by urban and rural poor, as well as contributing to increased household foodsecurity.

This Paper is specifically about Agricultural Mechanisation and opportunities provided by mechanisation for intensifying production in a sustainable manner, in value addition and agro-food value chain development, as well as the inherent opportunities implied for improved economies and livelihoods. The establishment of viable business enterprises, agro processors, transport services, and so forth as a result of increased agricultural mechanisation in rural areas, is crucial to create employment and income opportunities and thereby, enhancing the demand for farm produce, Thus, achieving **sustainable development**in Farm Sector to achieve the goal of food security.

Keywords: Agricultural Mechanisation, Sustainable Development, Food Security.

JEL Classification: A29, Q01

AGRICULTURAL MECHANISATION: NECESSITY FOR SUSTAINABLE DEVELOPMENT

I. INTRODUCTION

Agricultural production of our country has stagnated at a time when the broader elements of it's economy have grown. In order to sustain a overall growth rate it is imperative for agriculture sector to grow proportionately. Though, India has achieved self sufficiency in food grain production, but we witnessed that the growth rate of food grain production lagged behind that of the population of thecountry.

While efforts such as introduction of high yield varieties and expansion of irrigated area have played a crucial role in achieving the goal of food self sufficiency in the past, rapidly growing demand for food brings the need for building efficiencies in the agriculture to the forefront. Towards this objective and also to meet the goal of **"No poverty and Zero Hunger**" of the Sustainable Development Goals (**SDGs**) adopted by the United Nations General Assembly on 25 September 2015,it is imperative to focus on improving the intensity of agricultural mechanisation.

Agricultural mechanization has a key role in economic development process as depicted in the Tablebelow:

Table1
The potential contribution of mechanization to green food value chaindevelopment

Production ➡	PostHarvest/Storage ➡	Processing ➡	Marketing
Crop Establishment	Drying	Chopping	Packaging
Weeding	Grading	Milling	Transport
Fertilisation	Winnowing	Grinding	
Irrigation	Cleaning	Pressing	
Crop Protection	Storage		
Harvesting			

There is no doubt that agricultural mechanization for the multitude of smallholder farmers in our country has been an issue for discussion for too long. The application of farm power to appropriate tools, implements and machines – "**farm mechanization**" – is an essential agricultural input with the potential to transform rural families' livelihoods by facilitating increased output of higher value products while eliminating the drudgery associated with human muscle-powered agricultural production. Such an improved situation for smallholder farmers can enable access to input supply chains and integration in modern food systems and thus provide for more income, renewed business opportunities and further value addition. Moreover agricultural mechanization in its broadest sense can contribute significantly to the development of food systems, as it has the potential to render post-harvest, processing and marketing activities and functions more efficient, effective and environmentally Integrated Crop Management income, renewed business opportunities and further value addition. Moreover agricultural mechanization in its broadestsense can contribute significantly

to the development of food systems, as it has the potential to render post-harvest, processing and marketing activities and functions more efficient, effective and environmentally friendly.

FAO (2014b) summarizes the main reasons for changing the power source for crop production from muscles (human or animal) totractors:

i. Potential to expand the area undercultivation.

ii. Ability to perform operations at the right time to maximize production potential.

iii. Multi functionality – tractors can be used, not only for crop production, but also for transportation, stationary power applications and infrastructure improvement (drainage and irrigation canals and roadworks).

iv. Compensation for seasonal labour shortages (or, indeed, release of labourfor more productivework.

v. Reduction of the drudgery associated with the use of human muscle power fortasks, such as hand hoeing for primary tillage – especially important in tropical areas where high temperatures and humidity (sometimes associated with inadequate nutrition) make manual work extremelyarduous.

In spite of these perceived benefits and the fact that animals had been largely replaced by tractors in our country, arguments were still put forward urging caution. The main preoccupation is the effect of mechanization on rural employment opportunities. But, it is not understood that mechanization affects mainly on-farm family employment, not hired labour. Mechanization, in fact, enables farm family members not only to increase farm productivity via production intensification and/or expansion, but also to seek off-farm employment opportunities as a result of the increased time made available to look for and be engaged in such employment. Moreover, it is not appreciated that mechanization applied only to specific farm production tasks (in particular land preparation), and consequently has little effect on hired labour unemployment as presumed. However, mechanization is more likely to increase labour demand when it enables more land to be cultivated and when it is profitably applied along the value chain. Mechanization is just one component in the agricultural intensification process. Moreover, mechanization increases value addition (post-harvest operations and primary and secondary processing), as well as services to support agricultural mechanization development. Given the widening array of mechanization options available, employment in **primary agricultural production** is expected to decline, and this is a credit to the increasing productivity of farming. However, jobs are not actually "lost", because increasing agricultural productivity means that more jobs are created in **secondary employment** related to agriculture, for example, in the agro food value chain and machinery-relatedservices.

Other concerns those are expressed with regard to agricultural mechanization are Fuel costs which is high and continually rising, and fields are small and fragmented and therefore, perceived as an obstacle to tractorization – without land consolidation mechanization would not be viable. All these considerations leadsto a reduced focus on mechanization as an essential input throughout the country. But, we can develop and use mechanized technologies like, 2-wheel tractors, fostering and development of the private sector (an enabling business environment with public support, research systems connected to stakeholders, and good equipment distribution networks especially in rural areas), infrastructure development (development of feeder roads into main road networks), elaboration ofthefinancialsystem(appropriatefinancialproductsdevelopedtoenableinvestmentinagricultural

equipment), organization of the fiscal system (reduction of import tariffs on machinery), enhancement of extension service networks (mainly rural and connected to research and development centres) and, importantly, policy implementation.

Further, small-scale engine technologies (single cylinder diesel engines) are used for multipurpose functions: 2-wheel tractors, shallow tube well pumps, river boats, road and track transport vehicles, harvesters, threshers, grain mills, timber mills and processing equipment It is envisaged that less area of farm is to foster the need of most of the food production in the near future and it is primarily the farm holders who will have to respond to the need to increase food production At present, many smallholder farms have limited access to production inputs, especially mechanization; they therefore reach low levels of productivity, and often contribute to the increase in negative environmental impacts on already dwindling natural resources. They also have fewer opportunities to access markets and take advantage of the numerous value-adding activities that more developed food systems can provide. At the same time, the rural population is expected to decline as people, especially the young and fit, migrate to urban centres in search of a life characterized by less drudgery than that offered by agriculture. There is also a growing feminization of smallholder agriculture, as women are increasingly left in charge of the family farm while the men migrate in search of higher incomes. Agricultural mechanization can offer women in rural areas opportunities appropriately adapted to cultural, social and traditional work norms, and to the overall development of local economies; however, these opportunities are often underestimated. However, there is rapid urbanisation, rural population will continue to grow at higher rate. This population growth, though, will still see the migration of youth and others to urban centres in search of higher paying jobs that are less labour intensive than farming. Given the current important role of human muscles in smallholder agriculture, there are serious power limitation implications (Sims and Kienzle, 2015). The power sources for developing country agriculture are human muscles, draught animals and tractor engines. The use of the different sources varies across regions.

The green revolution is credited, with having kick-started the shift to profitable commercial farming, alleviating rural poverty, saving large areas of fragile land from conversion to extensive farming, and helping to avoid potential hunger threats in the face of a growing population. Overall, the proportion of undernourished in the world population declined over the period of time. However, there have been serious negative consequences. The enormous gains in agricultural production and productivity have been often accompanied by deleterious impacts on the rural natural resource base and ecosystem functions, jeopardizing the productive potential of agriculture and impacting agro food value chains. At production level, many of the effects are easily observable: land degradation (through erosion and compaction), salinization of irrigated areas, over-extraction of groundwater, build-up of pest resistance and decline of biodiversity. The uncertainty and variability of yields and reduction in product quality, combined with degraded lands and depleted water resources, have made smallholder-level processing and value addition a far more riskybusiness.

Mechanization and intensification, fertilizer use and adoption of other modern technologies have all remained at low levels across the country. Nevertheless, degraded lands are widespread throughout the India for a wide range of reasons, including the continuous use of the plough (or hand hoe) resulting in soil degradation, plough- or hoe-pans in the soil profile and loss of fertile top soil (Kienzle and Sims, 2015). Soil erosion is extensive in many regions of India, especially considering the current low level of mechanization. In the long term, if India intensifies and mechanizes its agriculture on a large scale, it must do so with care and in line with the principles of sustainable production intensification summarized by FAO in its **“Save and Grow”** guidelines. Save and Grow is based on environmentally friendly **Conservation Agriculture Mechanization (CAM)** with the aim

of achieving resilience in the face of a changing climate (FAO, 2011a, 2016a). Farming systems for sustainable production intensification offer a range of productivity, socio-economic and environmental benefits to producers, to other food value chain actors and to society in general. Implementation of Save and Growenables:

- Improved and stable environmentally friendly production, food distribution and profitability;
- Efficient use and conservation of naturalresources;
- Adaptation and reduced vulnerability to climate change; • enhanced ecosystem functioning and services; and
- Reductions in agricultural greenhouse gas (GHG) emissions and agriculture's "carbon footprint".

In summary, agricultural mechanization in the twenty-first century should be simultaneously: environmentally compatible, economically viable, affordable, adapted to local conditions and, in view of current developments in weather patterns, climate-smart. These proposed farming and food systems are based on four technical principles:

- Achievement of increased agricultural productivity while enhancing natural capital and ecosystemservices.
- Higher rates of efficiency in the use of key inputs, including water, nutrients, pesticides, energy (including farm power), land andlabour.
- Use of managed and natural biodiversity to build system resilience to abiotic, biotic and economicstresses.
- A more effective, efficient and environmentally friendly food system resulting from increased agriculturalmechanization.

The farming practices required to implement the first three principles differ according to local conditions and needs, but in all cases are based on the following concepts:

- Limited soil disturbance by minimizing mechanical tillage to maintain soil organic matter, soil structure and overall soilhealth.
- Enhancement and maintenance of a protective organic cover on the soil surface, using crops, cover crops or crop residues, to protect the soil surface, conserve water and nutrients, promote soil biological activity and contribute to integrated weed and pestmanagement.
- Cultivation of a wider range of species – annuals and perennials – in associations, sequences and rotations including trees, shrubs, pastures and crops, to enhance crop nutrition and improve systemresilience.

In practice, this involves the wide-scale application of conservation agriculture practices (FAO, 2015a). This paper is specifically about agricultural mechanization and the opportunities it provides for sustainable intensified production, value addition and agro food value chain development, in addition to the inherent opportunities Integrated Crop Management for improved local economies and livelihoods. The establishment of viable business enterprises, such as agro processors and transport services, as a result of increased agricultural mechanization in rural areas,is

crucial for creating employment and income opportunities and enhancing the demand for farm produce. Mechanization plays a key role in enabling the growth of commercial agro food systems and increasing the efficiency of post-harvest handling, processing and marketing operations. Consequently, it determines food availability and accessibility, as well as food prices paid by urban and rural poor, thus contributing to increased household food security with increased accessibility of agricultural mechanization contributing to India's agricultural and economictransformation.

II. CHALLENGES FACED BY AGRICULTURAL MECHANISATION ININDIA

Agricultural mechanization – in fact mechanization throughout the food system – is affected by a series of constraints in our country. These constraints needs be identified and strategies conceived to alleviate them and allow for the development of mechanization services to benefit all farmers, especially smallholder producers and other actors in agro food value chains. The World Bank's project on "**Enabling the Business of Agriculture**" focuses on identifying and monitoring regulations that negatively affect agriculture and agribusiness markets. Machinery is identified as a key input and market enabler (World Bank, 2016). Some of the potential challenges are discussed below.

1. AFFORDABILITY: Smallholder farmers are, almost by definition, resource poor and often have difficulty investing in physical assets in general and in agricultural machinery in particular. In our country, agricultural machinery suppliers are largely found in the larger towns and cities, as the perceived low demand in rural areas for equipment does not always justify the establishment of distribution networks. Smallholders are often isolated by distance and poor infrastructure (especially feeder roads). There is limited access to sources of financial credit due tothe:

- Lack of availability of financial products specifically focused on farm equipment investment;
- Misconception of many financial institutions regarding the need for targeted financial products for investment inequipment;
- Basic nature of agricultural production – i.e. a high-riskbusiness;
- Reluctance of commercial financial institutions (mainly banks) to extend credit to poor farmers with little collateral;and
- The lack of financial products to serve the purposes of small-scale farm mechanization.

Experience shows that extending credit products to farmers to invest in agricultural machinery not only allows them Integrated Crop Management to raise their productivity and participate more fully in the market economy, but can also incentivize the local machinery manufacturing industry to supply their needs (Casão-Junior et al., 2012). The restricted purchasing power of smallholder farmers depends on a series of factors impinging on the farm family'seconomy:

- Low yields (basic grain crops of < 1 tonne/ha) – caused by many factors, including lack of adequate inputs (especially seed and fertilizer) at the right price and the right time, climate change (with longer drought periods and more frequent storms) and thedegraded

condition of many agricultural soils. • Poor marketing facilities and inadequate rural, farm-to-market, infrastructure – resulting in poor returns to smallholder crop production.

- Low marketprices.
- High transportcosts.

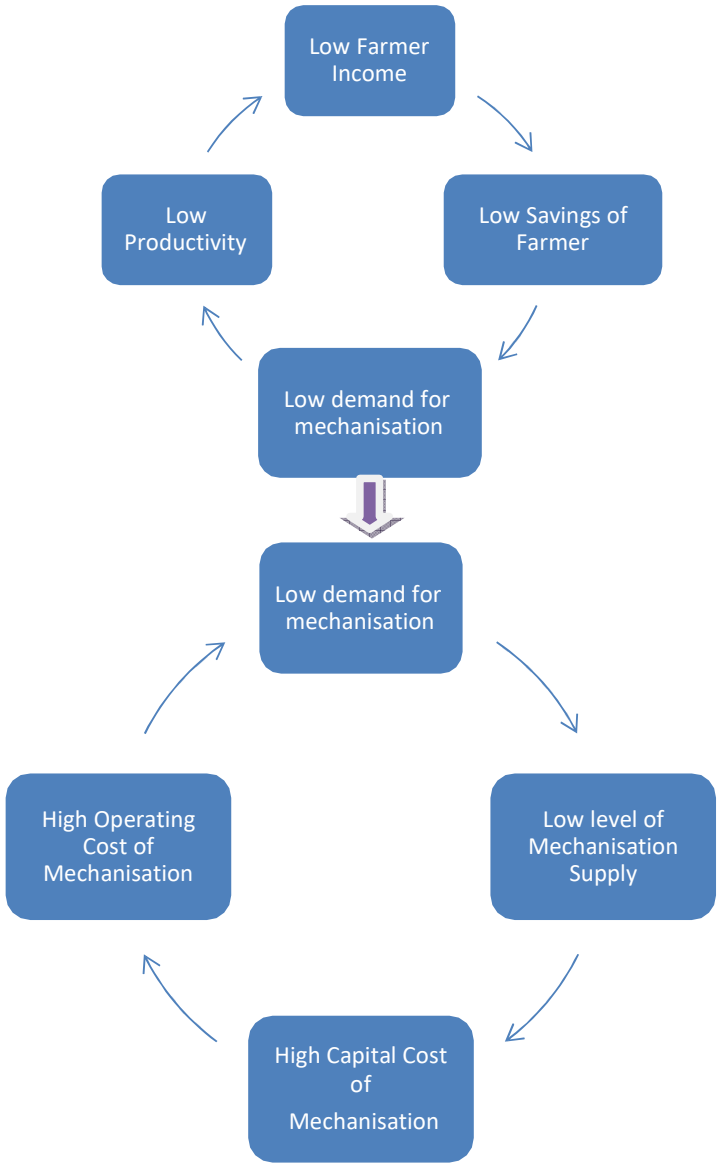
Price issues are a potentially major disincentive for smallholder farmers. Private sector-led input and output markets have not developed as quickly as expected and farmers are constrained by a lack of free competition in these markets, resulting in high prices for agricultural inputs as well as lower prices for produce. The consequent reduction in farm incomes and the lack of incentives to market produce have led to an overall decline in the level of investment in agriculture. This is reflected in low investments in fixed assets, such as agricultural machinery, that commonly have high start-up investment costs and returns spanning a long period, and which may be economically unsustainable for smallholders (even if profitable). At the same time, farmer organizations have had limited success in improving smallholders' access to markets and public services with mixed results in terms of providing machinery services to members. Although farmer organizations do recognize the economic and social benefits to farmers of mechanized services, they are not always able to coordinate such services at managerial level. However, some grassroots farmer organizations (e.g. cooperatives) successfully deliver mechanization services to their members. The cooperatives also have useful contacts with banks and other key stakeholders at local level. In India cooperatives providing mechanization services can deliver both economic and social benefits to their members with a system organized at local level, based on the active participation of small-scale farmers and the concept of self-help. For a successful transition from semi-subsistence farming to profitable, productive agriculture, land tenure must be secure and guaranteed by the state as well as by local laws and traditions. This gives farmers the security and confidence to invest in mechanization and other production enhancing inputs. In our country, there are laws to regulate land tenure but they are not always effective. Smallholders operating just above subsistence level tend to be extremely risk-averse. For the rural family, a reliable source of food throughout the year – even if well below the level of potential yields for the region – is preferable to a situation where yields may be very high in favourable seasons, but very bad in adverse years. A steady yield (albeit low), resistant to the vagaries of the weather is preferable, but does not necessarily result in a marketable surplus. For these reasons, without financial assistance, it is unlikely that smallholders can invest in the kind of mechanization technologies that could lift them out of their precariouscondition.

2. AVAILABILITY Tractors and agricultural machinery can be either imported or locally made, with potential associated problems in both cases. Locally produced machinery is usually low in quality and high in price. This is due to the underdeveloped nature of the machinery manufacturing industry, which in turn is largely the result of poor demand. Moreover, supply chains providing support to owners of tractors and agricultural machinery with spare parts, advice and other services (especially clean fuel) are often underdeveloped and do not easily reach remote rural areas (FAO, 2009d).

Analysis of the limited adoption of mechanization and of the relationships between the different determinants clearly indicates that certain conditions have led to the creation of a restrictive environment, which has held back the development of rapid mechanisation.

Figure 1

Factors weakening the demand and supply of agricultural mechanization



These interrelated factors illustrate the structural constraints faced by our country with regard to the increased adoption of mechanized farming methods. They highlight how demand and supply of agricultural mechanization inputs are interdependent. On the other hand, they also indicate how debilitating factors can be converted to enabling ones.

3. LACK OF FARMERS SKILL: Although, Indian farmers have a great deal of traditional knowledge and experience accumulated over generations, they have relatively limited access to new knowledge. The level of farmer training is relatively low and opportunities for further training are limited. Public and private extension and training services do not easily reach rural and remote areas, as distances are great and transport can be scarce. If demand for extension and training is low, it may be difficult to justify such activities in economic terms. There is a high rate of illiteracy among rural farming populations; this hinders the improvement of agricultural production and productivity and of the general level of farm management. For example, in many parts of our country, only land preparation and transportation are done using tractors, while other operations, such as seeding and harvesting, are mostly carried out manually. Farmers lack the knowledge and skills to operate mechanized equipment (FAO, 2011c), and when machines are used, this lack of proficiency leads to misuse and mismanagement of machinery – especially of more sophisticatedmachines.

4. GENDER ISSUES: In our country, women usually contribute large percent of the labourfor food production and have extensive traditional knowledge of dealing with natural resources and the natural environment. In a study it has been found that the labour burden for women is mainly concentrated in weeding, tillage and land preparation; postharvest management and transport of agricultural produce; and chopping and collecting fodder, fetching water and child care. We find few signs of mechanization to lessen the burden, because the assumption is that women are expected to work hard. Advocating for a reduced work burden for women does not fall within social norms, and women themselves do not have time available to access resources and information that might lead to the reduction of the work burden via investment in mechanization. In fact, it is often men who conduct commercial transactions at farm level and consequently men who make decisions and control the resources required to invest in mechanization (especially capital). Moreover, with the ongoing trend of male migration to urban areas, coupled with the advancement of climate change, women have an increasingly central role in agricultural production and commercialization; nevertheless, they still have little access tomechanisation.

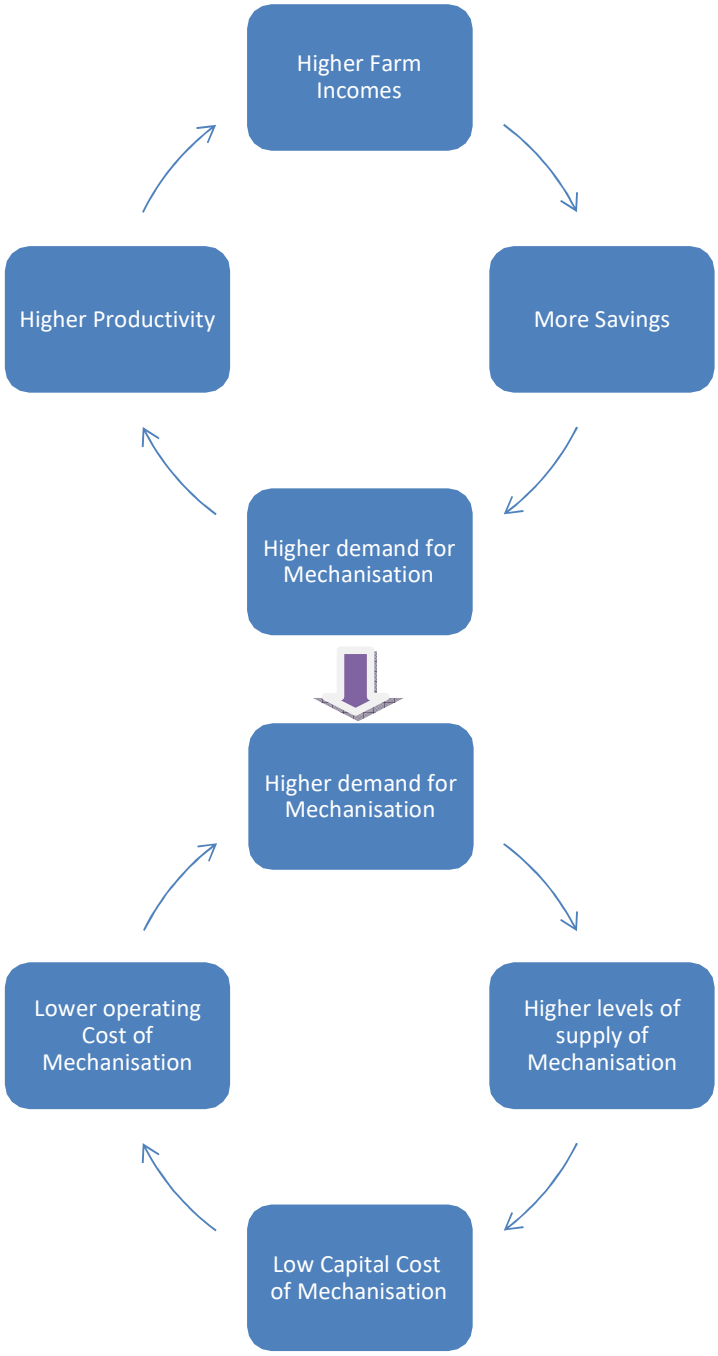
III. OPPORTUNITIES PROVIDED BY AGRICULTURALMECHANISATION

Raising farmer's incomes through sustainable crop production, intensification and sustainable commercialization.

Given the current state of agricultural mechanization in India, the most promising prospect is to convert the **vicious cycles** (Figure 1) into **virtuous cycles** (Figure 2). Figure 2 show that a sustainable increase in farm family income can have a positive knock-on effect on the supply of essential farm power and mechanization. First, raised incomes allow greater savings and the demand for agricultural mechanization services or the acquisitions of farm machinery (and other inputs) become feasible prospects for the farmer. This in turn raises productivity, leading to further improvements in farm incomes. At the same time, in the lower circle, it can be seen how increased demand for agricultural mechanization leads to a concomitant improvement in supply as a market response. An expanding market means that operating costs per unit are reduced and prices can fall without jeopardizing profitability. Lower costs are a catalyst for increased demand and, hence, the virtuous cycle is complete.

Figure 2

Virtuous cycles resulting from sustainable crop production intensification



Ending poverty is the primary goal of our government also it a global priority. It is evident that large percent of the India's extreme poor live in rural areas and are mostly dependent on agriculture. In addition, agricultural growth in low-income and agrarian economies is at least twiceas

effective as growth in other sectors in terms of reducing hunger and poverty. Farm family incomes can be improved through investment in rural development, establishing social protection systems, building on **rural–urban linkages** and focusing on boosting the incomes of the critical agents of change, including smallholder farmers. Raising the productivity of smallholder farmers must be a sustainable process, taking into account the lessons learned from the green revolution(GR).

Beginning in the Green revolution and continuing till date, the GR produced changes in crop varieties and agricultural practices across the country. The production model, which focused initially on the introduction of genetically improved, higher-yielding varieties of wheat, rice and maize in high potential areas (Hazell, 2008; Gollinet al., 2005), was based on homogeneity, promoting genetically uniform varieties grown with high levels of complementary inputs (e.g. irrigation, fertilizers and pesticides), often replacing more environmentally friendly practices. Fertilizers replaced organic soil quality management, while herbicides and pesticides provided an alternative to crop rotation as a means of controlling weeds, pests and diseases (Tilmann, 1998). However, as described earlier, the GR had serious negative consequences. It is now imperative to introduce sustainability into the future productivity increases required. The **Save and Grow** paradigm (FAO, 2011a, 2016a) advocates stewardship of fragile natural resources, combined with intensification of crop production through greatly enhanced land husbandry methods, including conservation agriculture. The sustainable increase in productivity is just one important aspect of raising smallholder incomes and developing new opportunities for mechanization; there is also a need for sustainable commercialization of farm products. Smallholders can increase commercialization opportunities by adopting equipment for on-farm value addition or improved transport to market. Increased access to more sustainable and lucrative forms of commercialization will raise incomes and provide further opportunities for mechanization.

New opportunities for Agricultural Mechanisation development.

In many parts of our country, despite the challenges discussed above earlier, there are numerous opportunities for mechanization development in the near future. Following decades of decline in per capita food production, there is now a new climate of optimism combined with a modified international investment landscape. The agriculture sector is projected to become economically sustainable because of the rapid expansion of urban centres and the associated demand for agricultural products, in addition to the increases in international food commodity prices. The new situation will provide opportunities for the adoption and expansion of agricultural mechanization for many reasons and those are:

- Increasing AgriculturalWages.
- New sources of farm machinery more suitable to IndianConditions.
- Need for more innovative and energy-efficient sustainable mechanization concepts in line with the FAO "**Save and Grow**"paradigm.
- Climate-smart and conservation agriculture – the need for environmentally sustainablemechanization.
- New need for sustainable business models for mechanization inIndia.

Investing in Agricultural Mechanization.

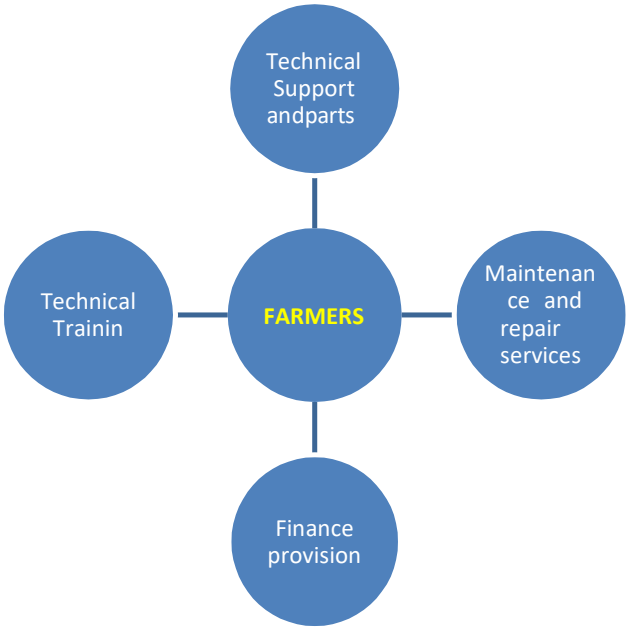
The recommendations that emerged focused on facilitating support for both private and public sector investment flows into the development of agricultural mechanization in India. The main objectives included the reduction of primary land preparation using hand tools substantially and their

replacement with a combination of draught animal power and tractors. The principal recommendations may be asfollows:

- Establish national committees on agriculturalmechanization.
- Create an enablingenvironment.
- Increase investment in agricultural mechanization through separate Budgetallocation.
- Capacitybuilding.

Figure 3

Stakeholders in the farm machinery support network for smallholder farmers



- Establish a code of practice for agricultural machinerysuppliers.
- Create regional networks of agriculturalmechanization.

While some recommendations will be more relevant than others, depending on the situation, the deliberations of this high level international group of experts highlight the importance ofextending mechanization services to smallholderfarms.

IV. THE WAY FORWARD: SUGGESTEDACTION

There are numerous examples of in-depth analysis of the agricultural mechanization scenario in our country. There are some recurring themes:

1. Farm power and mechanization are essential inputs if agricultural productivity and production are to increase and manage to feed the world's burgeoningpopulation.

2. The intensification of crop production must be sustainable: its environmental footprint must be as low as possible, and in any case lower than the rate of naturalrenewal.

3. Top-down solutions are rarely successful; all stakeholders need to be considered from the outset and the private sector must lead the development process on theground.

4. The role of the public sector is to provide an enabling environment for the private sector to perform without unnecessaryobstacles.

5. A holistic, value-chain approach is necessary for agricultural mechanization, going beyond green production and into post-harvest, processing and marketingactivities.

We can summarize as: "*If agricultural mechanization efforts are to succeed in India, there is an urgent need for all concerned, be they farmers, supporters, planners or policy makers, to understand and contribute to agricultural mechanization efforts across the entire farming system and with a value chain perspective*".

Following are suggested for the rapid and sustainable Agricultural Mechanisation:

Integration of Agricultural Mechanization in Pan-India Policy Frameworks: There is a need to sensitize and raise awareness at pan-India level of the potential of agricultural mechanization for development. It is essential to develop appropriate policies, supranational in nature and refocused at regional level.

Sustainable Agricultural Mechanization strategies: Mechanization should not be limited to on-farm practices; economies of use can be enhanced by incorporating off-farm applications. Moreover, agricultural mechanization is successful when there is an effective demand for farming outputs (including on- and off-farm value addition). In order to achieve sustainability, it is essential to consider the entire agro food chain, including financing of the necessary capital investments (FAO, 2014b). It should be noted that mechanization technologies for agro food chains contribute to waste avoidance, help maintain rural infrastructure and provide employment opportunities. Sustainable mechanization involves an increase in production combined with conservation of the natural resources (in particular soil and water). It is vital that future mechanization models conform to FAO's **Save and Grow** paradigm. According to Save and Grow, agriculture must be productive and profitable for the farmer, while contributing to the conservation of resources and the delivery of ecosystem services. As the negative effects of climate change are increasingly apparent, the large-scale application of conservation agriculture is essential to maintain food production. The practices involve soil protection, water conservation, and precise and efficient energy use and input application. It is vital to reduce the emission of GHGs during agricultural production, while sequestering carbon in untilled soil and preserved forest areas. For a consistent and coherent change in the use of agricultural mechanization, it is necessary to formulate and implement a plan, especially since major changes are required for sustainable agricultural mechanization. During the formulation process, reference should be made to the FAO guidelines (FAO, 1988) and it is important that the approach adopted isboth

participatory, to hear the views of the multiple stakeholders, and systematic, given the complexity of agricultural mechanization. During the process, participatory workshops should be organized to involve the spectrum of interested actors from all along the agro-food value chain, beginning with an inaugural workshop. Formulation comprises four major steps:

Figure 4

Progressive steps in the formulation of an agricultural mechanization strategy

- **Step 1** involves a thorough analysis of the situation, with experts focused on their particular specialization.
- **Step 2** entails a second participatory workshop to gather views on the existingsituation.
- **Step 3** is the strategy and action plan formulation, aligned with national development goals and policies refined during a thirdworkshop.
- **Step 4** involves further definition of the plan with preparation of a portfolio of project profiles. The results are presented at a final participatoryworkshop.

Throughout this process, the concept of sustainability is the absolute priority.

Sustainable Agricultural Practices for Smallholders: Agricultural mechanization can make an important contribution to the improved use of natural resources and the overall "greening" of agriculture, in particular at smallholder level. Mechanization technologies enable smallholders to enhance yields through the adoption of intensification, conservation agriculture, and other climate-resilient, labour- and energy-efficient, and gender-friendly practices. Importantly, mechanization also enables a rational and efficient approach to farming in the long term, increasing the prospect of sustained profitability over time and leading to increased ecosystem resilience and long-term sustainability of smallholder systems.

Specific Business Models for Smallholder up scaling: Smallholders are commonly relegated to the margins of agro food value chains and they do not easily find their niche in modern food systems. The identification and specification of appropriate business models for smallholder mechanization can provide numerous opportunities for improved access to and integration in agro food value chains with more reliable supplies, increased volumes of produce, timely deliveries and value addition.

Economic Advantages of Mechanization for Smallholders: It is important to identify models that not only provide economic benefits to famers, but which can be self-generating in the development of the smallholder sector. There is ample evidence that farmers who – thanks to mechanization – achieve quality and good yields, and consequently higher revenues, tend to spend their new wealth rather than re-invest it in the farm business. Small scale farmers must receive guidance on how investments in equipment repair and maintenance and in other productive revenue-generating assets can reinforce their economic standing. For example, investment in equipment that serves a range of functions is a wise move: not only can services be sold to other farmers, but the different operations offer good potential to provide for positive economic outcomes.

Social advantages derived from Mechanization: Agricultural mechanization has the potential to produce social opportunities (and outcomes) for small-scale farmers. It can reduce the risk of low yields thanks to increased cropping intensity and timely planting, weed control and harvesting, and can facilitate storage, resulting in better food security and improved nutrition for the farm family. Mechanization enables small-scale farmers to diversify their income sources, as they cease to rely on only crops for income and gain access to revenues from services offered to other local farmers. This in turn can reinforce social relations in local communities and provide for greater social harmony and well-being. Poor infrastructures and lack of transport are important constraints in remote rural areas. Agricultural mechanization can provide transport for rural people and rural produce, improving mobility and creating opportunities for commercialization. There are also potential opportunities for a change in gender relationships, as smallholder farm families become more enabled and have more time to search for off-farm employmentopportunities.

Mechanization and Gender: The feminization of agriculture offers a series of opportunities for increased agricultural mechanization at farm level and in the agro food value chain that are economically, environmentally and socially sustainable. Women tend to be proficient in natural resource management. Given the prevailing conditions of climate change and natural resource degradation, it is important to combine women's knowledge with the employment of appropriate machines designed for use by women farmers in order to make food production more environmentally sustainable. Reducing drudgery for women and speeding up farm and household operations are just two of the potential advantages of appropriately adapted and culturally and socially sensitive mechanization. However, there are numerous constraints limiting women's adoption of technologies, not least their lack of access to and control of resources, combined with cultural norms, values and assumptions (van Eerdewijk and Danielsen, 2015). Interventions to support the adoption of mechanization need to address local norms and values; this may in turn facilitate access to resources. Studies show that if women's access to productive resources were on par with that of men, farm yields would rise by 20–30 percent (FAO, 2011b). It thus makes sense to consider how women can access or have control of resources invested inmechanization

Enabling women's access to mechanization – the "feminization" of mechanization – requires a theory of change that is not only based on technological aspects, but which addresses a wider spectrum of constraints faced by women. Once these constraints have been addressed, the focus should be on technology. First and foremost, young girls must have access to education. Once this is achieved, active engagement in the discussion of local norms and assumptions is vital, encouraging group formation and collective action, and facilitating access to and control over resources. The focus can then turn to women's needs in terms of technologies and their related design parameters, with the objective of providing women-centredlabour-saving mechanization technologies at production and other stages in the agro food valuechain.

Institutional and Organizational arrangements for increased Smallholder Mechanization: Smallholders who group together – for example, in producer organizations – have improved access to agricultural mechanization opportunities. Increased access to various sources and types of financing, more sharing of knowledge, improved bargaining power, increased value addition and greater opportunities to optimize agricultural mechanization and realize its full potential will all contribute to improving commercial farming, enabling further integration into modern agro food systems.

Increased integration into Agro food Value Chains: Agricultural mechanization is a cornerstone forsmallholder integration into modern food systems. Mechanization not only applies at farm level, butithasanimportantroleinvalueaddition,forexampleinimprovedpost-harvestoperations,and

processing and marketing activities. Furthermore, it saves time between harvesting and consumption, allowing more time for marketing.

Increased Agricultural Mechanization with Private Sector development: By fostering private sector development within the context of agricultural mechanization, it is possible not only to increase the manufacturing base for agricultural mechanization in India, but also to provide opportunities for more Cooperation among manufacturers, dealers and institutions. Private sector development can support smallholder enterprises at field level, with farmers providing mechanization hire services to other farmers. This leads not only to higher farm yields, but to greater demand for vehicles, equipment and tools at national level, creating a mutually reinforcing virtuouscircle.

Development of Knowledge Sharing Platform at National and International level: Common lessons learned during development and the sharing of experiences can create a knowledge sharing platform for improved agricultural mechanization in India. This can lead to technology and know-how transfer in terms of machinery, tools and equipment, in addition to sharing of experiences about the application of models that do or do not work at national and local level. The sharing of policies and strategies for agricultural mechanization – both successful and not – can further enhance the collaboration, fostering more specific and targeted policies andstrategies.

Field-based Capacity Building and Capacity Development for Agricultural Mechanization: Field-based methods of capacity building and capacity development for agricultural mechanization need to be integrated with experienced and well tested training methodologies. Agricultural mechanization can be integrated at field level into Farmer Field Schools (**FFS**) and Farmer Business Schools (**FBS**). This not only provides a sound basis for smallholder competency development in agricultural mechanization, but acts as a source of data and information to feed into development projects, R&D organizations (national and international, public and private) and educational institutions, such as vocational secondary schools and universities across the country.

Regional Centres of Agricultural Mechanization with due emphasis on Dizitisation: Regional Centres of excellence be across the nation be established regional centres of excellence that can guide national policy towards sustainable agricultural mechanization. In close collaboration with farmers, other value chain actors, manufacturers, relevant private sector stakeholders and national government organisations, these centres of excellence can engage in R&D, machinery testing and training, wherever deemed appropriate and useful for the private sector. It is vital that the centres focus on the stakeholders' interests to ensure that they do not research concepts (farming methods and machinery) that then remain at the prototype stage. At the testing stage, it is important to keep in mind the machinery's potential users. An interesting model to study is the Asian United Nations Centre for Sustainable Agricultural Mechanization (UN–CSAM) (UN–CSAM, 2016).

V. CONCLUSION

Mechanisation covers all levels of farming and processing technologies, from simple and basic hand tools to more sophisticated and motorisedequipments. It eases and reduces hard labour, relieves labour shortage, improves productivity and timeliness of agricultural operation, improves the efficient use of resources, enhances market access and contribution to mitigate climate related hazards. Sustainable mechanisation considers technological, economic, social, environmental and culturalaspectswhencontributingtothesustainabledevelopmentoffoodandagriculturesector.

Mechanisation plays a key role in enabling the growth of commercial agriculture food systems andthe efficiency of post harvest handling, processing and marketing operation, and as such can be a major determinant in the availability and accessibility of food, the food prices paid by urban and rural poor, as well as contributing to increased household **foodsecurity**.

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