Innovations in agricultural mechanization for food security in Asia

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1. Introduction

1.1 *Food security- a major challenge in many countries*

At present the World is facing multiple challenges of feeding growing populations, alleviating poverty, protecting the environment, and responding to climate change. If the population growth is not checked, it may perpetuate hunger and malnutrition and reduce economic growth. During the period 2010 to 2012, thirteen percent of the population of Asia and the Pacific region experienced severe forms of hunger and malnutrition. However, while this proportion has fallen from 22 per cent during the period 1990 to 1992, still as of 2012, about two thirds of the World's under nourished people lived in the Asia and Pacific region (FAO, 2013). The world is facing perhaps the greatest challenge of how to feed two billion more people by 2050. This, combined with increasing incomes in the developing world and growing needs for energy, is likely to lead to increased demand for agricultural products at an unprecedented rate. The global demand for food is expected to increase by 60 per cent by 2050 (OECD-FAO, 2012).

The green revolution which occurred in the region in the 1960s and 70s focused mainly on farm production aspects and the post-harvest sector was considered after bumper harvests began to choke the post production infrastructure leading to massive losses. It was only in the early 1980s when there was a concerted effort, initially focused on storage, to tackle the post-harvest constraints. Post-production systems will have to be strengthened to ensure food security and also to enhance the growing export opportunities for countries of the region with surplus production capacity (Mrema and Rolle, 2012).

Asia has the largest land area in the world, comprising about 45 billion ha (30 per cent) of the global land area with more than 50% of the world population and with only 36% (504 million ha) of the world's arable land. Agriculture provides livelihood and is a culture. Cereals, fruits and vegetables and livestock production continues to be the main activity and rice and wheat remain the staple food crops in Asia. Over 90 percent of the world's rice supply comes from Asia. Due to increased incomes food habits are changing and the agricultural production systems are changing to meet those demands. During 1970s cereals constituted 40% of agricultural production in monetary terms and by 2010 contribution of cereals reduced to 25%. During the same period the share of fruits and vegetables and livestock production increased from 18% and 15%, respectively in 1970 to 27% and 28%, respectively by 2010 shown in **Figure 1** (Briones and Felipe, 2013).

Worldwide in 2013, 842 million (12%) people were reported to be chronically hungry and 2.2 billion (15%) people were near or living in multidimensional poverty (UNDP, 2014). According to the World Bank (2014) projections (**Table 1**) the population of South Asia will continue to grow through 2050 where about half of the World's under nourished population lives at present.

Agriculture is the most effective route to reducing poverty in many of the poorest parts of the world. One per cent growth in the agricultural economy results in a 6 per cent increase in spending by the poorest 10 per cent of the population. Far less income filters down to the poor from the growth of other sectors of the economy (World Bank, 2008).

1.2 *Decreasing share of agricultural labor and increasing urbanization*

The percent share of agriculture in the total work force has been decreasing in all countries. The decline in absolute number of workers in agriculture sector is related to development of industry and service sectors of a country. The absolute number of workers in agriculture sector started to decline in Japan in 1955 and in Republic of Korea in 1977. By now the absolute number of workers in agriculture sector is decreasing in most of the countries.

Urbanization is driven by three factors: natural population growth, rural to urban migration and reclassification of rural areas into urban areas. In 2012, 1.96 billion (46%) people of Asia and the Pacific region lived in urban areas. By 2020 urban population is expected to reach 50% (UNESCAP, 2014). Benefits of living in urban areas are effective delivery of critical services such as transport, health and education as well as higher wages. This is making less labor available for farming as more people, especially the young, move to cities to look for jobs outside of the agricultural sector. Shortage of labor and rising rural wages are forcing farmers in Asia to adopt labor-saving technologies, i.e. farm mechanization. Also with increasing feminization of agriculture due to the propensity of more men migrating to urban areas than women, there is an increasing demand for labor saving technologies as well as gender specific interventions in farm mechanization.

1.3 *Decreasing share of agricultural sector in GDP faster than decrease in agricultural labor force*

According to World Bank (2013), worldwide during 2012 agriculture sector employed 36% of work force and its contribution to world GDP was only 3%. While services and industry sectors employed 41% and 20%, respectively and their contributions to world GDP were 70% and 27%, respectively. The share of agriculture sector in GDP is extremely low compared to labor force employed in this sector. During 2012 contributions of three sectors, namely, agriculture, industry (including manufacturing) and services are given in **Table 2**. Even for developing countries in East Asia and the Pacific the contribution of agriculture sector in economy is very low (11%) and it is 18% for South Asia while agriculture sector employs about one third of the workers in East Asia and the Pacific and about half of the workers in South Asia (**Table 3**). Due to very low income of farm workers many of them are migrating to urban areas. This has resulted in shortage of labor and rising rural wages resulting in increase in mechanization. When the agriculture is highly mechanized the difference in GDP per person in agriculture and other sectors becomes negligible, for example, Republic of Korea, Japan and USA (**Table 3**).

The agriculture sector in developing countries in Asia and the Pacific region also employs more people than in other sectors, industry and services. Contribution of agriculture to GDP is much smaller and thus average annual earnings of farm workers are much lower compared to workers in other sectors. For example, in India, agriculture employs about 50% labor force and its contribution to GDP is about 14% only. Thus the average annual earnings of non-agricultural workers are about 6 times that of agricultural workers in India. Similarly, these are about 4.5 times in China, 3.3 times in the Philippines and about 5.3 times in Thailand.

1.4 *Increase in land and labor productivity*

As shown in **Figure 2** the cereal yields in most countries have increased very significantly. The cereal yields (**Table 4**) in many countries in the region are higher than average yield of cereals in

the world while in other countries these are lower (FAOSTAT and World Bank, 2013). The output per worker in agriculture sector rose by 2.2% per annum during 1980-2010.

Approximately 80 percent of water in the region is used for agriculture. With the rapidly increasing demand for water by industrial and municipal users, competition for water is becoming increasingly fierce. Global climate change has potential grave consequences for food production and, consequently for global food security. Agricultural production systems in most developing Asian countries are highly vulnerable to risks of climate change and have little capacity to cope with its impact. Water shortages, low water quality, increasing temperatures, rise in sea-level, floods and more intense tropical cyclones are real risks that will lead to the deterioration of farming environments in many areas of the region. These trends require the development and implementation of sustainable cropping systems which include innovative crop management practices and efficient post-production systems that are resilient to climate change to minimize risks. Agricultural mechanization using efficient machines improves the utilization efficiency of inputs like fertilizers and agro-chemicals and reduces negative impact on environment. Similarly use of micro-irrigation techniques, not only improves water use efficiency significantly but also reduces deep percolation of water with which fertilizers like nitrates leach and pollute ground water. Application of fertilizer with drip irrigation (fertigation) improves fertilizer use efficiency and thus reduces amount of fertilizer needed to be applied, again reducing the negative chemical impact on the environment. The use of conservation tillage and minimum tillage methods improves soil health, reduces soil erosion and reduces cost. Thus appropriate and sustainable agricultural mechanization plays a major role in making agriculture sustainable.

Agricultural mechanization reduces the drudgery in performing agricultural tasks by farm workers, overcomes time and labor bottlenecks thus enabling performance of tasks within optimum time period.

1.5 *History of mechanization in Asia*

Until 1950s traditional methods of using animate (human and animal) power were used in all crop production operations throughout Asia. However, three regions of Asia, namely, north east, south, south east experienced somewhat different developments in agricultural mechanization. In the north east, Japan was the first to mechanize as a result of rapid industrialization immediately after the Second World War. Republic of Korea followed due to its own industrialization and access to technologies from Japan. The two-wheel tractor or power tiller developed in Japan became the mainstay of agriculture in these countries which are being replaced by four-wheel tractors. China, during 1953-57 acquired about 5000 tractors of 15 hp each from former USSR. The first tractor factory was also constructed with assistance from USSR and in 1976 mechanization started to expand rapidly.

In South Asia the first tractor to India was brought in 1914. In 1930's pump-sets were introduced. In the 1940's high hp crawler tractors were imported under the aegis of Central Tractor Organization mainly for land development and to eradicate obnoxious weed *kans* grass. There were only about 8,000 tractors in 1950. Manufacturing of irrigation pump-sets started in late 1950's and tractor manufacturing stared in 1961. Among the Southeast Asian countries, Thailand made considerable progress in the 1980s by introducing locally made two-wheel tractors, stationary threshers and low lift water pumps, also mostly powered by two-wheel tractor engines. Before that Thailand was mainly using four-wheel imported tractors assembled locally, assembly of which was discontinued later. Malaysia introduced large four-wheel tractors and combines in the 1970s and 1980s under MUDA Agricultural Development Authority.

Singh and Chancellor (1975), based on a yearlong survey, found that agricultural output for categories of farms was related to energy inputs, irrespective of ownership of farm power sources (owned or rented) and the size of land holding had no effect on yield. Farmers with better management (i.e. timely operations, like sowing, irrigation, weeding, fertilizer and pesticide application; and proper amounts and right techniques of application) had higher yields than those with poor management. Further, Singh (2001) reported that the economics of ownership of most tractors in India had been justified by custom hiring for on-farm work as well as for off-farm transport and construction activities. The use of tractors in transport activities accounted for about 60% of average annual use of 600 hours. Many small farmers also started purchasing tractors due to the opportunity of custom hiring. Similarly, the ownership of many other farm machines and equipment, like pumps for tube-wells, seed-drills and planters became economically viable due to renting out to other farmers. However, ownership of large threshers, laser land levelers and combine harvesters is mainly justified by custom work.

2 Present Status of Agricultural Mechanization in Asia Pacific Countries

2.1 Main power source-equipment systems used in operations

At present, countries across the region differ widely with respect to how they make use of following main sources of farm power in performing various on- farm and off-farm operations.

1. Human labor
2. Animal power
3. Engine (petrol/diesel)
4. Electric motor
5. Two-wheel, single axle tractor (2WT)
6. Four-wheel, two axle tractor (4WT)
7. Self propelled machines

2.1.1 Human Labor

Manual labor is predominantly used in many countries for broadcasting of seeds and fertilizers; sowing; transplanting of rice and vegetable seedlings; spraying using knapsack sprayers; weeding, inter-culture, ridging, leveling and bund making using hand tools; reaping of crops using sickle; plucking of fruits; plucking and harvesting of vegetables; bundling of harvested crops including fodder crops, transportation of inputs (seeds, fertilizer, etc.) to field and harvested crops to threshing floors; threshing of crops by beating (including against a log); transportation of produce to drying floor and homestead; bagging and loading on transport vehicle.

Human operator is needed to operate all animal powered implements and mechanically (including electrically) powered implements and equipment.

2.1.2 Animal Power

In many countries animal draught power is still being used for tillage, sowing, inter-culture, irrigation (water lifting), threshing (trampling), and transport operations.

Engine (Petrol/Diesel)

Most of the engines are diesel engines and are used to power stationery machines like water pumps, threshers, winnowers, cleaners, graders and processing machines.

2.1.3 Electric Motor

Electric motors are used to power stationery machines like water pumps, threshers, winnowers, cleaners, graders and processing machines.

2.1.4 Two-Wheel, Single Axle Tractor (2WT)

Two-wheel, single axle tractors are mainly used for tillage and transport operations. A 2WT equipped with a rotary tiller is commonly known as Power Tiller. With a belt and pulley mechanism engines of these 2TWs are also used to power stationery machines like water pumps and threshers.

2.1.5 Four-Wheel, Two Axle Tractor (4WT)

Four-wheel, two axle tractors are mainly used to power equipment for tillage, sowing/planting, inter-culture, weeding, ridging, bund making, leveling, spraying, reaping and harvesting, and transport operations. Using PTO shaft (with a belt and pulley mechanism) these 4TWs are also used to power stationery machines like water pumps, threshers and other machines.

2.1.6 Self Propelled Machines

The most common self propelled machine in use in the region is combine harvester for grain crops, mainly wheat and rice. Other self propelled machines which are gaining popularity mainly by custom-hire operators are rice trans-planter and sugarcane harvester. Corn (maize) pickers, forage harvesters and cotton pickers are also being introduced by custom-hire operators.

2.2 Availability of power sources

The land and water resources in Asia and the Pacific region are already fully exploited and with only significant inputs of energy we can improve the use of these resources to increase food production. Agricultural mechanization plays a pivotal role as machines make it possible to apply and use inputs like seeds, fertilizers and chemicals and water at appropriate place and time in desired quantities in an efficient way.

The experience of the region shows that mechanization of processing and pumping has tended to precede the mechanization of crop care and harvesting operations. The use of irrigation pumps has increased exponentially in the region: in India the use of pumps grew from 6 million in 1980, to 28 million in 2010. In Bangladesh, the use of pumps grew from 0.3 million in 1996 to 1.3 million in 2010; while in Cambodia, it increased from 0.06 million in 2001 to 0.17 million in 2010. In certain areas, excessive use of pumps has also led to the overdrawing of groundwater, and as a result, countries of Asia and the Pacific Region have recently been facing depleted water tables. Japan, Russia and Korea have already mechanized most of the operations. Malaysia, Thailand, China, India, Pakistan, Sri Lanka, Bangladesh, Vietnam have mechanized land preparation and transportation operations using 4W and 2W tractors and milling, water pumping and threshing using stationery engines and electric motors. In Thailand, Indonesia, Vietnam, Cambodia, Philippines, Bangladesh and Nepal 2W tractors (in stationery mode) are also used to power irrigation pumps. For harvesting combines are being used extensively in Malaysia and gaining popularity in Thailand, China, India and Pakistan. Combines are also being used to limited extent in Philippines, Cambodia, Bangladesh and Nepal.

The use of animal draft power has declined significantly in all countries since 1990s. In India the number of draft animals in use declined from over 85 million in 1975 to about 50 million in 2010 and is projected to decline to 18 million by 2030 (Singh, 2013). Of the total power 2.0 kW/ha available during 2013, the share of animal draught power was only 5% compared to 46% share from tractors and 27% share from electric motors. In Bangladesh, the cyclones of the 1980s killed most of the draft animals and these were replaced by 2WT. Similarly in China it is projected that

draft animals will be completely replaced by 2025 (Renpu, 2014). The animal draft power is still being used to varying extents mainly for land preparation and transport operations in all countries except Japan and Korea. The use of animal draft power is still quite common in Nepal, Cambodia, Indonesia, Philippines, India, Bangladesh, Vietnam, Pakistan, Fiji, Papua New Guinea and Thailand. With the exception of Japan, Russia and Korea rice transplanting, seed broadcasting, transplanting of vegetable seedlings, weeding and inter-culture, spraying (with knapsack sprayer) fertilizing, reaping of crops, picking of fruits, harvesting of vegetables, winnowing, cleaning, grading and sorting are mostly done manually. The number of 4W tractors, 2W tractors, irrigation pumps and combine harvesters and power available in selected countries is given in **Table 5.**

2.3 Local production and imports of farm machinery

The AP Region has emerged as the largest market in the world in terms of agricultural machinery sales – projected to have sales of about USD 50 Billion in 2015 (World Bank, 2010). In 2012 the globally the output value of agricultural machinery industry was about US$120 billion of which China accounted for about US$50 billion and India about US$ 15 billion.
The 4W tractors (two axles) are mainly produced in China, India, Japan, Korea and Pakistan. Other countries in the region import tractors from countries within the region as well as from countries outside the region. The 2W tractors (single axle) or power tillers are mainly produced in China, India, Japan, Korea, Thailand, Philippines, Indonesia, and Vietnam. Other counties in the region like Bangladesh, Nepal, Sri Lanka, Cambodia, and Laos import 2W tractors mainly from China. Laos and Cambodia also import 2W tractors (power tillers) from Thailand. Mainly Japan, China, Korea and India are producing combine harvesters in large numbers. Thailand also produces locally made track type combines mainly to harvest rice from wet fields. Other countries in the region import combines from these countries in the region as well as from the countries outside the region. Most counties in the region are producing engines (petrol/diesel) and electric motors with the exception of Laos, Cambodia, Nepal, Fiji and PNG. Similarly most of the countries are producing implements and equipment powered by 4W and 2W tractors and water pumps and threshers. However some countries still rely on imports from China, India, Thailand, Japan, Korea and some countries outside the region.

2.4 Level of mechanization for different operations

The level of mechanization for different operations varies significantly from crop to crop and in big countries it varies from region to region in the same country. The level of mechanization for different operations also varies significantly for the same crop.
In 2013 in China，the national comprehensive mechanization level, comprising of crop tillage, planting and harvesting reached 59.5%; with tillage at 76.0%, planting at 48.8% and harvesting at 48.1% as given in **Table 6** (MOA China, 2014). Among crops wheat had the highest level of comprehensive mechanization at 93.7%, followed by rice at 73.1% and maize at 59.5%. For tillage, tractor plowing for wheat was 98.9%, for rice it was 95.1% and for maize it was 76.0%. The level of mechanical sowing for wheat was 86.7%, for rice only 31.7% and for maize it was 84.1%. Similarly, the level of mechanical harvesting for wheat crop was 93.8%, for rice 80.9% and for maize it was only 51.6%. Even for the same crop and the same operation the level of mechanization varies in different parts of China.

2.5 Common custom hire services

Initially the ownership of machinery was with big farms/farmers and they provided very little custom hire services. With shortage of labor many medium farmers owned machines for their own

work and custom hired these machines to other farmers. Now in most countries custom hire services are being provided by the entrepreneurs, both farmers and non-farmers. The size of machines owned by service providers is relatively larger compared to those owned by farmers for their own work. Many enterprises providing custom hire services own multiple sets of various machines and some enterprises provide services at far away distances from their home base. In China Combine Service Enterprises (CSEs) in 2011 were operating in 12 provinces. They shifted from Chinese Futian combines to more reliable Japanese Kubota combines. CSEs have evolved in small co-operatives of 5-10 CSEs for maintenance and coordination. Combines are up to 8 months away from home. In India combine services providers travel up to 600 km over a period of 2 months to harvest mainly wheat crop. Under a Sub-Mission on Agricultural Mechanization the Government of India is promoting 'Custom Hiring Centers including hubs for hi-tech & high value farm equipment' to offset the adverse economies of scale arising due to small landholding and high cost of individual ownership.

Common custom hire services provided by farmers, entrepreneurs and service enterprises to farmers not owning some equipment are given below based on the reports of the participants to CSAM meetings held during 2014(CSAM, 2014).

Transportation: 4WT and 2WT trailer: all countries; Animal cart: Nepal, Cambodia, Laos
Milling: Engine and motor: all countries
Water pumping: Engine, motor, 2WT pump: most countries
Threshing (Wheat): 4WT thresher: India, China, Pakistan, Nepal
Threshing (Rice): 4WT and 2WT thresher: most countries; Diesel engines: Thailand
Harvesting (Wheat): Combine harvester: China, India, Pakistan
Harvesting (Rice): Combine harvester: China, Malaysia, India, Thailand, Sri Lanka
Tillage (Dry): 4WT: most countries
Tillage (Wet): 2WT: most countries
Land leveling: 4WT laser leveler: India, Pakistan, Cambodia
Seeding: 4WT seed drill: China, India, Pakistan, Thailand
Transplanting (Rice): China, India
Maize shelling: India, Bangladesh, Philippines
Harvesting (Sugarcane): Thailand, India

3. Challenges

3.1 Small land holdings

About 90% of the World's more than 500 million small farms (<2ha) are in the Asia and the Pacific region. The average size of land holdings in Asia is only about 1 ha. Average size of holdings for the countries in the AP Region are: Bangladesh: 0.5 ha; China: 0.54 ha; India: 1.2 ha; and Nepal: 0.7 ha. In most countries even these small holdings are made up of a number of small plots scattered in different locations. Many of these plots have limited access to relatively large size farm machines like combine harvesters and even tractors. Due to small size of land holdings majority of the farmers have low investment capacity and cannot afford to buy even small machines like 2W tractor or power tiller. Due to shortage of labor such farmers rent equipment on hire from service providers. Consolidating the holding of a farmer at one or two places will increase the size of operational plot. It will be easier to use a relatively big equipment at reduces cost of operation.
Due to increased incomes food habits are changing and the agricultural production systems are changing to meet those demands. During 1970s cereals constituted 40% of agricultural production in monetary terms and by 2010 contribution of cereals reduced to 25%. During the same period the share of fruits and vegetables and livestock production increased from 18% and 15%, respectively

in 1970 to 27% and 28%, respectively by 2010. As income from growing grain crops is very limited, for their survival and sustainability small holder farmers are diversifying into labor intensive, but more profitable activities like production of fruits and vegetables, fish and livestock. The produce being perishable (milk, meat, fruits, vegetables, fish, etc.) makes these farm activities highly risky. So far there has been very limited mechanization of production and post-production activities related to production of fruits and vegetables and livestock and fish. There is a need to provide mechanization services for production and post-production activities, and reliable post harvest handling, processing and marketing infrastructure and services to ensure reasonable returns to farmers.

3.2 Limited manufacturing capacity

Only a few countries in Asia and the Pacific region like Japan, China, India and Korea have well developed industry for the manufacture of agricultural equipment and these countries are also exporters of equipment. Pakistan, Thailand, Vietnam and Indonesia also have agricultural equipment manufacturing industries. However, these countries import certain critical components from other countries. Countries like Bangladesh, Sri Lanka, and Philippines import prime movers like tractors, engines and motors and farm implements and equipment like plows, harrows, seed drills, sprayers, threshers, irrigation pumps and milling machines are produces locally. A few countries like Nepal, Cambodia, Laos, Fiji, PNG and Mangolia have very limited manufacturing industry and import most of their farm equipment. Although, Malaysia has a well developed industry but due to limited demand it imports most of the farm equipment.

Manufacturers who are exporting their products to developed countries maintain high quality of products. However, keeping the limited purchasing power of farmers in mind, many of the equipment manufacturers produce products of relatively poor quality to keep the cost low. Poor quality equipment do produce poor quality work, give poor fuel economy and use of such equipment results in injuries and fatal accidents.

3.3 Shortage of power and fuel

Most countries in the region face shortage of power due to which there are frequent shut downs. Many days the industrial workers sit idle for long hours in factories for non availability of power. This reduces productivity of workers and increases the cost of manufactured items. Many times, interrupted power supply also affects the quality of product. Small and Medium Enterprises (SMEs) cannot afford to put up a power generation plant. However, some big industries have put up power generation plants using fossil fuels but many of these industries face shortage of fuel. Due to expensive fuel the electricity generated is also more expensive which in turn increases the cost of items manufactured. Shortage of power also affects the crops as certain operations like irrigation are not done at the most appropriate time resulting in reduced yields. As petroleum fuel is mainly available in cities and town and on main roads, the owners of farm machines have to travel quite a distance to get it which also adds to cost. Many times fuel is also in short supply or not available for a period of time. Reliable supply of electricity to industries is essential to produce quality products at reasonable cost.

3.4 Need for institutional framework at regional level

The region has made great progress over the past six decades in transforming farm power situation from almost 95% from animate sources in 1960s to over 50% from mechanical sources by 2010 in many countries. Four main types of power sources are emerging i) 2WT; ii) 4WT; iii) Electrical and Diesel pump sets for irrigation; and iv) Motorized equipment for harvesting and Post-harvest operations. The use of draft animals is likely to be insignificant by 2030 in the region. While animal draft power is indigenous to a country and implements are also locally produced, many countries in

the region do not have manufacturing facilities for producing mechanical power sources and associated equipment.

In case of imported equipment major problems are insufficient after sales and extension services. The operators are not adequately trained and there are limited trained technicians to repair the imported machines. Imported machines are normally supplied with selected spare parts based on the experience in the country of origin. However the breakdowns are related to operator skills, care and maintenance, field and environmental conditions which may not be the same in both countries. If the machine breaks down during the working season and the required spare part is not available, the machine sits idle and farm work suffers resulting in significant loss. The country which imports machines from outside must make sure that there is a good dealership network providing necessary after sales and extension services. This also applies to remote areas (like islands) for the machines produced within the country.

Asia Pacific region is emerging as a leading global player in the manufacture and use of mechanization inputs. The challenge is how to incentivize manufacturers to R&D and produce quality machinery at affordable cost. Like in North America and Europe the academic and research institutions should work in close collaboration with private sector. South-south collaboration in R &D to achieve economies of scale through regulatory framework for patenting and licensing of technologies at regional level should be encouraged. A large manufacturing base in the region and trade in mechanization technologies requires a regional mechanism for standards and testing of these technologies. ANTAM (CSAM-UNESCAP) offers this opportunity by supporting establishment of testing centers and harmonization of testing protocols across the region to facilitate trade in mechanization technologies regionally and globally.

4. General findings and recommendations for Asia and the Pacific region

The region has made great progress over the past six decades in transforming farm power situation from over 90% from animate sources in 1960s to over 60% from mechanical sources by 2013 in many countries. Four main types of mechanical power sources are becoming popular: i) 2Wheel-Single Axle tractors for wet tillage, transportation, water pumping and threshing; ii) 4Wheel-Two Axle tractors for dry tillage, transportation, planting and seeding, inter-culture, spraying, harvesting and threshing; iii) Electrical motors and Diesel engines for irrigation pump sets and many post harvest processing operations; and iv) Self propelled machines like combine harvesters for grain harvesting, trans-planters for rice and vegetable crops, fodder harvesters and sugarcane harvesters. The use of draft animals is likely to be insignificant by 2030 in the region. While animal draft power is indigenous to a country and animal drawn implements are also locally produced, many countries in the region have limited manufacturing facilities for producing mechanical power sources and associated equipment. The removal of non tariff barriers to trade in the region will contribute significantly to reduce the cost of machines to farmers.

Present level of mechanization and crop yields in many countries are quite low. There is labor shortage during peak periods and available agricultural labor is getting older and proportion of female labor is increasing. More labor saving and ergonomically appropriate equipment are required to facilitate the work of women and elderly agricultural workers.

In all developing countries the percentage of labor in agriculture is very high compared to contribution of agriculture sector to GDP, resulting in relatively very low incomes of farmers and other agricultural workers. Mechanization helps in increasing yields by timely conduct of operations, efficient placement and application of inputs (seeds, fertilizers, pesticides and water)

and decreasing drudgery. Governments should have policies to promote mechanization for growth in agriculture, improved incomes of agricultural workers and improved food security.
Land holdings in many countries are small and fragmented. Consolidation of fragmented holdings helps in organizing resources and inputs more efficiently and provides easier access to farm machines even on small holdings. Governments should have policies to consolidate fragmented holdings.

Asia and the Pacific region has the largest area under irrigation and the use of electric and diesel pump-sets has increased significantly and will continue to increase. Due to increased demand for water from other sectors of economy, availability of water for agriculture is expected to decline. There is an urgent need to provide technical and financial support for development of irrigation infrastructure and R & D efforts particularly for controlled irrigation systems to improve water use efficiency and fertilizer use efficiency in irrigated agriculture.

Mechanization technologies were first adopted by the large farmers followed by medium scale farmers. Ownership of many farm machines is not economic for farmers if these machines are utilized only on their own holdings. The large numbers of owner farmers are the ones who are able to provide mechanization and other services to the more numerous small holder farmers. Increased and improved efficiency of utilization of machines available with farmers through custom hiring to neighbor farmers and or through larger operational holdings makes ownership of machines economic and profitable. In some countries the availability of credit at subsidized rates has been catalytic to the rate at which farmers – especially the small and medium scale ones – were able to procure agricultural machinery and implements. In addition, assured support prices for the farmers' produce, as well as the availability of off and on farm custom hire possibilities where agricultural machinery could be used, further enhanced the profitability of acquiring agricultural mechanization inputs by farmers. Even a very small farmer or an entrepreneur with no land can have a profitable business as a custom hiring service provider. There is a need for favorable government policies to support these service providers by providing them financial support and training.

In many countries the large numbers of owner farmers played a critical role in facilitating the creation of a viable agricultural machinery and implement distribution and services sector. The high level of effective demand for agricultural machinery and equipment led to the creation of a competitive and viable manufacturing industry such that Japan, Korea, China and India have become globally leading players in this sector including becoming exporters. There is a need for favorable government policies to expand the manufacturing sector in all countries. Items of high demand like simple tools, implements, sprayers, irrigation pumps, threshers, etc. should be produces locally. Manufacturing processes need improvements to produce quality machines with improved safety standards. There is need to develop and / or adopt low energy consumption machines and practices like no-till drills / planters and conservation agriculture.
Governments in many countries are providing support services for research and development; testing and standards; and for human resources development in support of agricultural mechanization. The agricultural engineering programs established in universities have been instrumental for the success of agricultural mechanization in these countries. A new breed of experts is required to implement new emerging technologies for sustainable agricultural mechanization. This requires strengthening of both public and private sectors institutions. There is need to revise curricula of colleges and universities to introduce new concepts like conservation agriculture (CA), precision farming, etc. Trainings of operators, farmers and technicians are necessary for successful implementation of new emerging technologies for sustainable agricultural mechanization. There is a need for favorable government policies to expand these support services

to meet the needs of mechanization. In some cases regional training programs may offer economies of scale which may be organized with assistance from CSAM.

Business and enterprise friendly policies, laws, and regulations as well as physical and institutional infrastructures which encourage commercial activities and entrepreneurship in farming, input supply, produce handling, processing and marketing as well as in manufacturing have been and remain, the key factors to success of agricultural mechanization in most countries.

In recent years the efforts related to agricultural mechanization at regional and international level have increased. The Center for Sustainable Agricultural Mechanization (CSAM) and the Asia - Pacific Network for Testing Agricultural Machinery (ANTAM) should play major roles in facilitating regional cooperation in policy assistance, information sharing, collaborative R&D, harmonization of standards and testing procedures, capacity building, technology transfer and trade and investment facilitation.

References

[1] **Briones R, Felipe J.,** 2013. Agriculture and Structural Transformation in Developing Asia: Review and Outlook ADB Manila.

[2] **CSAM Country Reports,** 2014. Country Reports from Asia Pacific Countries on Current Status of Agricultural Mechanization as presented to the CSAM/ANTAM consultations of 2014.

[3] **FAOSTAT,** 2014. Statistical database. Food and Agriculture Organization. Available on line at http://faostat3.fao.org/faostat-gateway/go/to/home/EAccessed , December 2014.

[5] **Fuglie K.O.**, 2012. Productivity Growth and Technology Capital in the Global Agricultural Economy. In: Fuglie K.O., Wang S.L., Ball V.E. (eds). Productivity Growth in Agriculture: An International Perspective, Oxfordshire, UK: CAB International.

[6] **Kienzle J., Ashburner J.E., Sims B.G.**, 2013. Mechanization for Rural Development: A Review of Patterns and Progress from Around the World. Integrated Crop Management. Vol. 20-2013. FAO. ISSN 1020-4555 2003 Tokyo Japan pp. 13 – 20.

[7] **FAO**, 2012. OECD-FAO Agricultural Outlook 2012-2021. Food and Agriculture Organization of the United Nations, Rome.

[8] **Renpu Bai** 2014. Analysis of Trends of Agricultural Mechanization Development in Peoples Republic of China. 2000 – 2020. CSAM – Policy Brief, January, 2014.

[9] **Singh G.,** 2001. Relationship Between Mechanization and Agricultural Productivity in Various Parts of India. In Agricultural Mechanization in Asia, Africa and Latin America, 32(2), Spring 2001.

[10] **Singh G.,** 2013. Agricultural Mechanization in India. In: Mechanization For Rural Development: A Review of Patterns and Progress From Around the World- J. Kienzle, J.E. Ashburner, and B.G. Sims, eds. Integrated Crop Management Vol. 20-2013.FAO. ISSN 1020-4555

[11] **Singh G.,** 2015. Draft Report on Agricultural Mechanization Situation in Asia and the Pacific Region submitted to CSAM-UNESCAP.

[12] **Soni P., Ou Y.,** 2010. "Agricultural Mechanization at a Glance: Selected Country Studies in Asia on Agricultural Machinery Development." Study Report Prepared For the United Nations Asian and Pacific Centre for Agricultural Engineering and Machinery (UN-APCAEM).

[13] **UNESCAP,** 2013. Statistical Yearbook for Asia and the Pacific 2013. http://www.unescap.org/stat/data/syb2013/ESCAPsyb2013.pdf Unorganised Sector. New Delhi.

[14] **World Bank,** 2008. World Development Report 2008.

[15] **World Bank,** 2012. Agricultural Innovation Systems: An Investment Sourcebook.

[16] **World Bank,** 2013. The World Bank Data on Indicators. http://data.worldbank.org/indicator

[17] **World Bank,** 2014. World Development Indicators 2014. The World Bank. http://data.worldbank.org/indicator

Figure 1 - Percent Composition of Agricultural Output (constant $) for Asian Countries, 1970 and 2010

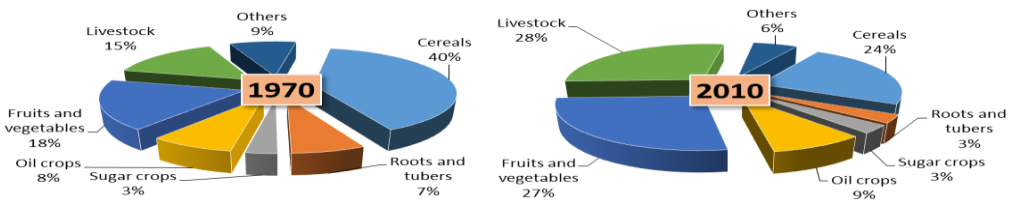
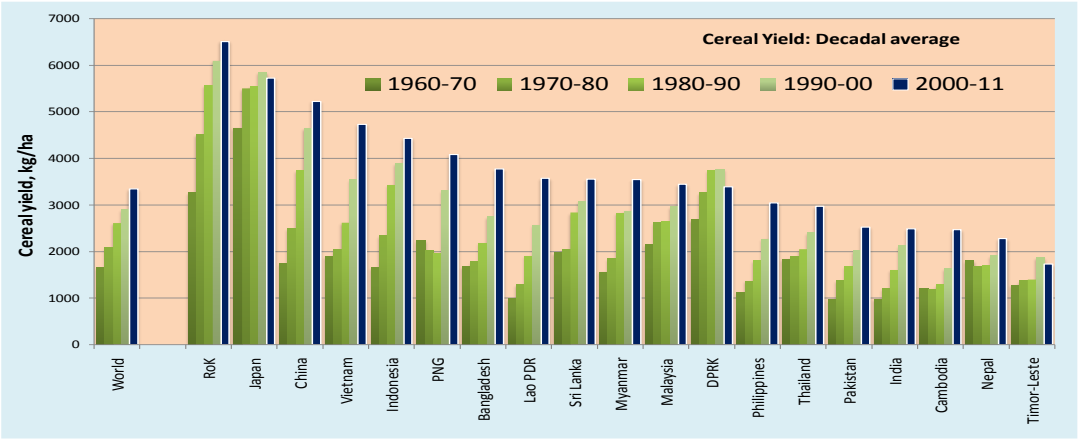


Figure 2 - Average of cereal yield over decades. Source: Soni (2014) calculation based on data from FAOSTAT and World Bank, 2013)



Cereal yield, *measured as kilograms per hectare of harvested area includes:wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat and mixed grains. Production data on cereals relate to crops harvested for dry grain only.*

Table 1 - Projected Population (Billion People). Source: World Bank, 2014

Region	**2020**	**2030**	**2040**	**2050**
East Asia & Pacific (Developing)	2.10	2.18	2.20	2.17
South Asia	1.81	1.99	2.13	2.21
World	7.67	8.37	8.97	9.47

Table 2 - Share of Agriculture, Industry (including manufacturing) and Services Sectors in GDP. Source: World Bank (2014)

	East Asia & Pacific (Developing)	South Asia	World
GNI per Capita ($, 2013)	5,536	1,474	10,584
Agriculture GDP (%)	11	18	3
Services GDP (%)	45	56	70
Industry GDP (%)	44	26	27
Manufacturing GDP (%)	30	14	16

Table 3 - GDP, Employment and Value Added per Person in Agriculture, Industry and Service Sectors of Selected Countries. Source: World Bank (2014)

Country	**Percent GDP**			**Percent Employment**			**Value Added per Person, $**	
	Agriculture	Industry	Services	Agriculture	Industry	Services	All workers	Agriculture
Bangladesh	17	29	54	39	21	40	829	505
Cambodia	36	24	40	49	20	31	1008	524
China	10	44	46	34	30	36	6807	785
India	18	25	57	50	21	29	1504	697
Indonesia	14	46	40	35	20	45	3500	1018
Korea	2	39	59	6	24	70	25977	27097
Malaysia	9	41	50	13	28	59	10514	9687
Nepal	35	16	49	67	11	22	694	265
Pakistan	25	22	53	44	22	34	1300	1080
Philippines	12	31	57	31	16	53	2765	1129
Sri Lanka	11	32	57	32	26	42	3280	1041
Thailand	12	43	45	42	20	38	5780	1160
Vietnam	18	38	44	47	21	32	1911	476
Japan	1	26	73	5*	25	70	40000	46000
U.S.A.	1	20	79	1	17	74	50000	50000

*Japan has a very large number of hobby (weekend) farmers who have regular job outside agriculture.

Table 4 - Cereal Yields in Countries of Asia and the Pacific Region (2011).
Source: World Bank (2013)

Country	**Yield (Kg/ha)**	**Country**	**Yield (Kg/ha)**	**Country**	**Yield (Kg/ha)**
Bangladesh	4191	Indonesia	4886	Malaysia	3920
Cambodia	2925	Japan	4911	Pakistan	2718
China	5706	Korea	7038	Philippines	3341
India	2883	Lao PDR	4045	Thailand	3065
Vietnam	5383	Myanmar	3880	World	3708

Table 5 - Number of 4W Tractors, 2W Tractors, Irrigation Pumps and Combine Harvesters and Power Available in Selected Countries. Source: Participants to Regional Meetings organized by CSAM-UNESCAP.

Country	**4W Tractors (000's)**		**2W Tractors (000's)**		**Irrigation pumps (000's)**		**Combine harvesters (Units)**		**Power kW/ha**	
	1990	2013	1990	2013	1990	2013	1990	2013	1990	2013
Bangladesh	5	60	10	700	220	1729	Nil	130	0.3	1.83
Cambodia	0.3	9.5	0.5	152	1.0	256	Nil	4580		1.32
China	814	5270	6981	17523	7255	22068	39588	1421000	2.0	5.7
India	1200	5430	31	440	12900	28000	4500	38000	0.75	2.02
Indonesia	4	2.8	17	71					0.3	
Rep. Korea	31	278	739	640	326	350	32900	78854		10.6
Malaysia	2.5	8	2.1	35	70	N/A	44	1700	0.24	0.2
Nepal	6	30	1	12	23	550	Nil		0.22	
Pakistan	231	573	5	2	288	1050	1300	9000	0.75	1.1
Philippines	6		32		107				0.39	
Russia	1366	260	N/A	N/A	79.4	5.2	407800	67900	2.67	1.48
Sri Lanka	15	1.5	24	2.8	52			1099	0.43	
Thailand	45	334	583	1750	851	2320	2250	15000	0.89	2.5
Vietnam	5.2	170	20	380	168	2170	0	20000	0.61	1.7

Table 6 - Mechanization level for main crops and their operations in China in 2013**.** Source: Department of Agricultural Mechanization, MOA, China

Items	**Comprehensive mechanization level (%)**	**Tractor plowing (%)**	**Mechanical sowing (%)**	**Mechanical harvesting (%)**
Crops	59.48	76.00	48.78	48.15
Wheat	93.71	98.90	86.69	93.82
Rice	73.14	95.09	36.10	80.91
Corn	79.76	97.67	84.08	51.57