International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.47, No.2, SPRING 2016

SPECIAL ISSUE :

The Farm Machinery Industry in Asia and Research Activities

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International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.47, No.2, Spring 2016

Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

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Printed in Japan

This is the 167th issue since its maiden issue in the Spring of 1971

EDITORIAL

The world population exceeded 7.4 billion and it is predicted to exceed 9 billion by 2038. Recently Chinese government decided to stop the population control measure (one child policy) which had continued for long time and shifted the policy that people can have at least 2 children. This shift change was caused by the sense of crisis that the burden of young people is getting increased due to the acceleration of elderly population increase and that the economic growth of entire country becomes threatened because of the decrease of working population in near future. The peak of population that was predicted to be 1.4 billion will be 4 or 5 hundred million plus due to this policy change in China.

In India, the ratio of young people is increasing and a large population growth is predicted.

In case that world population increases more than we expect, is it still possible to do sustainable agriculture? It is a really big concern.

Increase of land productivity is mostly needed. For that, timely and precise operation in agriculture is essential. As I have told many times, development of agricultural mechanization is really essential for sustainable agriculture. For promoting agricultural mechanization, development of agricultural machinery industry is needed. In emerging countries like China and India, great big productions of agricultural machinery have already been shown. Also in other countries agricultural machinery industry is growing more than before.

In this issue, we focused on agricultural machinery industry in Asia. Asia will occupy about 60 % of world population in future. It is not exaggeration that Asia is the most important area for agriculture. To achieve agricultural mechanization, agricultural machinery industry must be developed in each country. It means that agricultural machinery industry in Asia is now occupies a very important position. Introduction of new technology, like use of AI and technology of agricultural robot is being developed rapidly for promoting agricultural mechanization in Asia from now on. Latest technology like smartphone has spread rapidly all over the glove including developing countries. I suppose improved agricultural machinery will also spread in the same way. With the aim of achieving sustainable agriculture, we have to deepen the international cooperation through agricultural mechanization.

Yoshisuke Kishida
Chief Editor

March, 2016

CONTENTS
AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.47, No.2, Spring 2016

ASIA and the PACIFIC REGION

Agricultural Mechanization Situation in Asia and the Pacific Region

by

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Abstract

The Asian 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 2014 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 agricultural 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.

Asia and the Pacific region has the largest area under irrigation and the use of electric and diesel pumpsets has increased significantly and will continue to increase. There is a need to provide technical and financial support for development of irrigation infrastructure and R & D efforts for irrigation systems to improve water and fertilizer use efficiency.

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 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. There is a need for favorable government policies to support these service providers by providing them financial support and training.

There is a need for favorable government policies to expand the man-

ufacturing sector in all countries. 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.

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.

Introduction

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 percent 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 percent 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 percent) 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 **Fig. 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 percent growth in the agricultural economy results in a 6 percent increase in spending by the poorest 10 percent of the population. Far less income filters down to the poor from the growth of other sectors of the economy (World Bank, 2008).

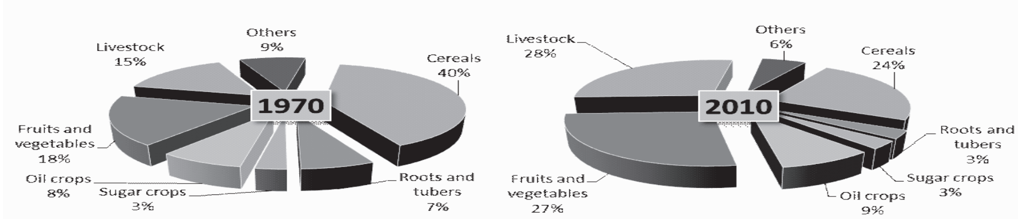
Decreasing Share of Agricultural Labor and Increasing Urbanization

The percent share of agriculture in the total work force has been

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

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



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.

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

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	1,008	524
China	10	44	46	34	30	36	6,807	785
India	18	25	57	50	21	29	1,504	697
Indonesia	14	46	40	35	20	45	3,500	1,018
Korea	2	39	59	6	24	70	25,977	27,097
Malaysia	9	41	50	13	28	59	10,514	9,687
Nepal	35	16	49	67	11	22	694	265
Pakistan	25	22	53	44	22	34	1,300	1,080
Philippines	12	31	57	31	16	53	2,765	1,129
Sri Lanka	11	32	57	32	26	42	3,280	1,041
Thailand	12	43	45	42	20	38	5,780	1,160
Vietnam	18	38	44	47	21	32	1,911	476
Japan	1	26	73	5*	25	70	40,000	46,000
U.S.A.	1	20	79	1	17	74	50,000	50,000

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

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.

Increase in Land and Labor Productivity

As shown in **Fig. 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 agrochemicals 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.

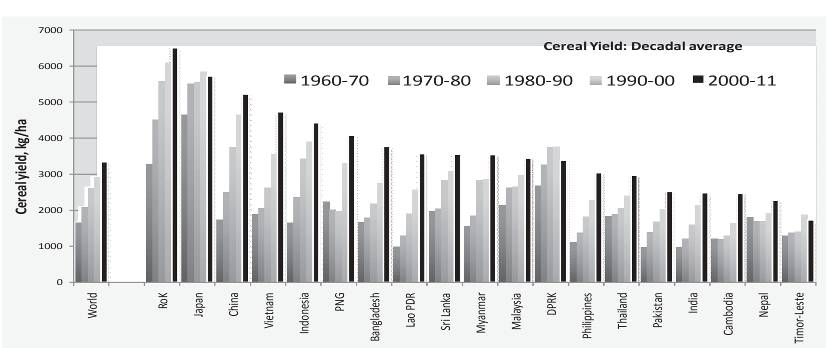
Agricultural mechanization reduces the drudgery in performing agricultural tasks by farm workers, overcomes time and labor bottlenecks thus enabling performance of tasks within optimum time period.

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

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

Country	Yield (Kg/ha)
Bangladesh	4,191
Indonesia	4,886
Malaysia	3,920
Cambodia	2,925
Japan	4,911
Pakistan	2,718
China	5,706
Korea	7,038
Philippines	3,341
India	2,883
Lao PDR	4,045
Thailand	3,065
Vietnam	5,383
Myanmar	3,880
World	3,708



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.*

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

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 5,000 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.

Present Status of Agricultural Mechanization in Asia Pacific Countries

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

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, interculture, 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.

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.

Electric motor

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

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.

Four-wheel, Two Axle tractor (4WT)

Four-wheel, two axle tractors are mainly used to power equipment for tillage, sowing/planting, interculture, 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.

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.

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

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	1,729	Nil	130	0.3	1.83
Cambodia	0.3	9.5	0.5	152	1.0	256	Nil	4,580		1.32
China	814	5,270	6,981	17,523	7,255	22,068	39,588	1,421,000	2.0	5.7
India	1,200	5,430	31	440	12,900	28,000	4,500	38,000	0.75	2.02
Indonesia	4	2.8	17	71					0.3	
Rep. Korea	31	278	739	640	326	350	32,900	78,854		10.6
Malaysia	2.5	8	2.1	35	70	N/A	44	1,700	0.24	0.2
Nepal	6	30	1	12	23	550	Nil		0.22	
Pakistan	231	573	5	2	288	1,050	1,300	9,000	0.75	1.1
Philippines	6		32		107				0.39	
Russia	1,366	260	N/A	N/A	79.4	5.2	407,800	67,900	2.67	1.48
Sri Lanka	15	1.5	24	2.8	52			1,099	0.43	
Thailand	45	334	583	1,750	851	2,320	2,250	15,000	0.89	2.5
Vietnam	5.2	170	20	380	168	2,170	0	20,000	0.61	1.7

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**.

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.

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.

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

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

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 (**Table**) based on the reports of the participants to CSAM meetings held during 2014 (CSAM, 2014).

Challenges

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.

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

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.

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.

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.

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: 1) 2 Wheel-Single Axle tractors for wet tillage, transportation, water pumping and threshing; 2) 4 Wheel-Two Axle tractors for dry tillage, transportation, planting and seeding, interculture, spraying, harvesting and threshing; 3) Electrical motors and Diesel engines for irrigation pump sets and many post harvest processing operations; and 4) 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 pumpsets 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.

Acknowledgement

The material for this paper is based on the consultancy report submitted in 2015 to Center for Sustainable Agricultural Mechanization (CSAM), “Agricultural Mechanization Situation in Asia and the Pacific Region”. Based on the same report a paper was also presented at the Club of Bologna (CoB) meeting in Milan, Italy on 21 September 2015. Authors acknowledge the support of both CSAM and CoB.

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INDIA

Agricultural Machinery Industry in India

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Abstract

Indian tractor industry, comparatively young by world standards have expanded at a spectacular pace during last six decades. Consequently it now occupies a place of pride in India's automobile industry and now it produces highest number of tractors in the world. In terms of growth, India's growth is unmatched even with countries of long history of tractor manufacturing. The spectacular achievement reflects the maturity and dynamism of tractor manufacturers and also the policies adopted by the government to enable it to effectively meet the demand. The tractor industry in India has made a significant progress in terms of production and capacity as well as indigenisation of technology. It is a typical sector where both imported technology and indigenous developed technology have developed towards meeting the overall national requirements. The different sources of power are available on the Indian farm for doing various mobile and stationary operations such as mobile power viz. human, draught animals, tractors, power tillers and self-propelled machines; and stationary power i.e. diesel/oil engines and electric motors. Food grains productivity in India has increased from 0.710 t/ha in 1960-61 to 2.21 t/ha in 2013-14, while farm power availability has increased from 0.296 kW/ha to 2.02 kW/ha during the same period. Thus, food grains productivity is positively associated with unit power available for Indian agriculture. During the past five decades, a large number of farm tools, implements and machines have been developed for different farm operations such as land levelling, seed bed preparation, sowing and planting, weeding and hoeing, plant protection, harvesting, threshing, dehusking, decorticating, etc. There are about 250 medium to large scale units, 2,500 small scale industries, 15,000 tiny industries and more than 100,000 village level artisans in India. Most of them are under un-organized sector except the tractor industries.

Introduction

India is a country with various landforms ranging from lofty mountains to ravine, deltas and also including high altitude forest of Himalayas, sprawling grasslands of Indo-Gangetic plains, peninsular plateaus of South East and South West India and many other geological formations. The climate of India is full of extremities; and most prone sector to rainfall variations, either deficit or excess, particularly when it coincides with susceptible/critical crop growth stages. Due to presence of a wide range of geological and climatic conditions, Indian agriculture is diverse and complex with both irrigated and dry land areas, capable of producing most of the food and horticultural crops of the world. India has an estimated 142 million ha cultivated area of which about 57 Million ha (40 %) is irrigated and remaining 85 Million ha (60 %) is rain-fed (Singh *et al*., 2015). With increasing level of industrialization, creation of special economic zones, urbanization and development of housing sector there is possibility of decline in the arable land. Rice, wheat, maize, sorghum, and millet are the five main cereals grown in India. Along with this the pulses, oilseeds, cotton, jute, sugarcane, and potato are the other major crops. Pulses include mainly gram (chickpea) and pigeon pea and oilseeds include mainly groundnut, mustard and rapeseeds, soybean, and sunflower.

India ranks second worldwide in farm output but the economic contribution of agriculture to India's GDP is steadily declining with the country's broad-based economic growth (Singh, 2015). In India, 63 percent holdings are below 1 ha accounting for 19 percent of the operated area while over 86 percent holdings are less than 2 ha accounting for nearly 40 percent of the area. Fragmentation of operational farm holdings is yet another major concern in this respect and the average size of holdings has shrunk from 2.82 ha in 1970-71 to 1.1 ha in 2010-11. India is the second largest producer of wheat and rice and third largest producer of pulses, sugarcane, roots and tuber crops, vegetables, coconut, dry fruits, agriculture-based textile raw materials, inland fish and eggs (Singh *et al*., 2015). The country has produced 263 million tonnes (MT) of food grains during 2012-13 surpassing all earlier records. Record production has been achieved in the case of rice (104.3 MT), wheat (93.9 MT), cotton (35.2 million bales), and sugarcane (357.7 MT).

Availability of adequate farm power is very crucial for achieving the required level of mechanization. Modern methods such as precision farming, increase in the area under irrigation, conservation tillage, strong management and diversification in agriculture requires more power. Similarly, power required for the production sector for seeds, fertilizers, plant protection chemicals and production of machinery have to be increased. Among various inputs for intensive agriculture, farm mechanization has made significant contribution in increasing agricultural production and productivity through timeliness in operations, efficient application of inputs, conserving soil and water resources; and reducing losses, pollution and drudgery apart from increasing cropping intensity. Mechanization in association with improved crop inputs have shown improved yields by 10-15 %. Amidst growing concerns about man power availability and shrinking profitability of agriculture as enterprise, the need has been felt for appropriate, affordable and energy efficient equipment and technology for cost effective production and processing of crops focused at increased yield, reduced cost of cultivation, prevention of losses and value addition through location specific management practices. The farmers have realized these advantages and mechanization is in an increasing trend in many parts of the country. However, the type of equipment suitable for cultivation and the rate of introduction of new equipment are to be considered with multidisciplinary approach specific to the site needs.

Till 1950, very few farmers possessed prime movers like tractors, engines and motors. Heavy agricultural tractors and machinery were imported by Government organizations mainly for land reclamation and development of large farms. The picture changed quickly during the early sixties with introduction of high yielding varieties of wheat and rice which needed irrigation facilities. Beginning was made with the use of stationary power sources such as engines and eclectic motors for pumps, tube wells, and threshers. In the late fifties, India's first power thresher was innovated in Punjab (India) in 1957 and then after animal operated seed drills, diggers weeders etc (Anonymous, 2006). Mechanization of a crop or operation always began from Punjab and spreads to adjoining states and then to whole country. The farmers soon realized that the traditional water lifts which were driven by draught animals or operated manually could not meet the water requirement of high yielding varieties of wheat and rice. Therefore lift operation was quickly mechanized through use of diesel engines or electric motors powered pumps. This made a sharp increase in wheat production and farmers suffered heavy losses because crop could not be harvested within normal harvesting period during late sixties and early seventies. Large scale adoption of threshers operated by electric motors, diesel engines and tractors that followed in early seventies onwards was a result of the need to complete threshing operation quickly. Following this, came the extensive use of tractors for tillage and transport and use of tractor operated and self-propelled harvesting equipment.

Farm mechanization in India has come a long way during the last 60 years and still there is tremendous scope as it is required in every unit operation of agricultural production, post harvest, food processing and rural living. Farmers, policy makers and developmental agencies now realize that for raising farm productivity at reduced unit cost of production, mechanization is essential. With increasing labour wages and agriculture produce market prices, farmers, specially, the medium and large ones are looking for labour saving devices to remain competitive. As demand for farm mechanization is escalating and it is almost becoming the today's farm necessity, mechanization has come to centre stage with the globalization of world markets. Even though farm mechanization shows an increasing trend, there are wide ranging disparities in the levels of mechanization across states. Northern states such as Punjab, Haryana and western Uttar Pradesh have achieved a faster growth in mechanization; mechanization in Western and Southern states of the country viz. Gujarat, Maharashtra, Rajasthan and certain areas of Tamil Nadu, Andhra Pradesh etc, has increased with the increase in area under irrigation and also with the growing awareness among farmers.

Tractor and Its Manufacturering History in India

War surplus tractors and bulldozers were imported for land reclamation and cultivation in mid 1940's. In 1947 central and state tractor organizations were set up to develop and promote the supply and use of tractors in agriculture and up to 1960, the demand was met entirely through imports. There were 8,500 tractors in use in 1951, 20,000 in 1955 and 37,000 by 1960 (Singh *et al.*, 2009; 2009a; 2011). Use of tractor for agriculture in India started during the '50s with annual introduction of about 8,000 imported units. Indigenous manufacture of tractor in India started in 1961 by 5 manufacturers with aggregate capacity of 11,000 units (**Table 1**). Annual production was 880 units in 1961, and rose to over 5,000 units by 1965. Subsequent to green revolution in mid sixties, the farmers increasingly realized the advantages of tractorisation for timely completion of operations. Availability of improved farm technology, government policy support, rise in awareness and resource availability among the farmers generated additional momentum to demand of tractor consequently stepping up of indigenous production to meet the requirement. Since late sixties, new manufacturers entered the market. By the seventies, annual production was around 20,000, and grew rapidly with sustained agricultural credit being offered by the government. In the early eighties, the growth fluttered due to fluctuation in credit allocation resulting into survival of eight manufacturers by 1986. During remaining part of the decade, sale of tractor again gained momentum to an average of about 75,000 units per year and continued in the nineties with production of more than 150,000 units per year. Six new manufacturers were established during 1971-80 (**Table 1**). Escorts Ltd. began local manufacture of Ford tractors in 1971 in collaboration with Ford, UK and total production climbed steadily to 33,000 in 1975 reaching 71,000 by 1980. Credit facilities for farmers continued to improve and the tractor market expanded rapidly with the total in use passing the half million mark by 1980. A further five manufacturers began production during 1981-90 but only one of these survived in the increasingly competitive market place. Annual production exceeded 75,000 units by 1985 and reached 140,000 in 1990 when the total in use was about 1.2 million. Then India –a net importer up to the mid-seventies– became an exporter in the 1980s mainly to countries in Africa.

Since 1992, it has not been necessary to obtain an industrial license for tractor manufacture in India. By 1997 annual production exceeded 255,000 units and the national tractor population passed the two million mark. India now emerged as one of the world leaders in wheeled tractor production. Five new manufacturers have started production since 1997. In 1998 Bajaj Tempo, already well established in the motor industry, began tractor production in Pune. In April 1998 New Holland Tractor (India) Ltd launched produc-

Table 1 History of tractors' manufacturers in India.

Manufacturer	Collaborator	Year
Eicher Tractors Ltd.	Gebr, Eicher Tractor. West Germany	1961
Gujarat Tractors Ltd.	Motokov -Praha. Czechoslovakia	1963
TAFE	Messey Ferguson. UK	1961
Escorts Ltd.	Moloimport Arazawa Zaklady Mechaniczne. Ursus Poland	1964
Mahindra and Mahindra	International Harvestor. UK	1965
Escorts Tractor Ltd.	Ford. U.K.	1971
Hindustan Machine Tools	Motokov -Praha. Czechoslovakia	1971
Kirloskar Tractors Ltd.	Klochner-Humboldt Deutz. Germany	1974
Punjab Tractor Ltd.	CMERI.INDIA	1974
Pittie Tractor Ltd.	Own know-how	1974
Harsha Tractor Ltd.	Moto Import. Russia	1975
Auto Tractor Ltd.	British Leyland. U.K.	1981
Pratap Steel Rolling Mill	Own know-how	1983
VST Tillers Tractors	Mitsubishi. Japan	1983
United Auto Tractor Ltd.	Uzina Tractorul. Romania	1986
Asian Tractor Ltd.	Own know-how	1989
Bajaj Tempo Ltd Presently, Force Motors	Own know-how	1987
International Tractors	Own know-how	1998
Larsen and Tourbo Ltd. now John Deere	John Deere USA	1999
New Holland Tractor	New Holland Tractors. Italy	1999
Greaves Ltd. now two firms SAME and Deutz-Fahr	Same Deutz- Fahr. Italy	1999

tion of 70 hp tractors with matching equipment. Larsen and Toubro established a joint venture with John Deere, USA for the manufacture of 35-65 hp tractors at a plant in Pune.

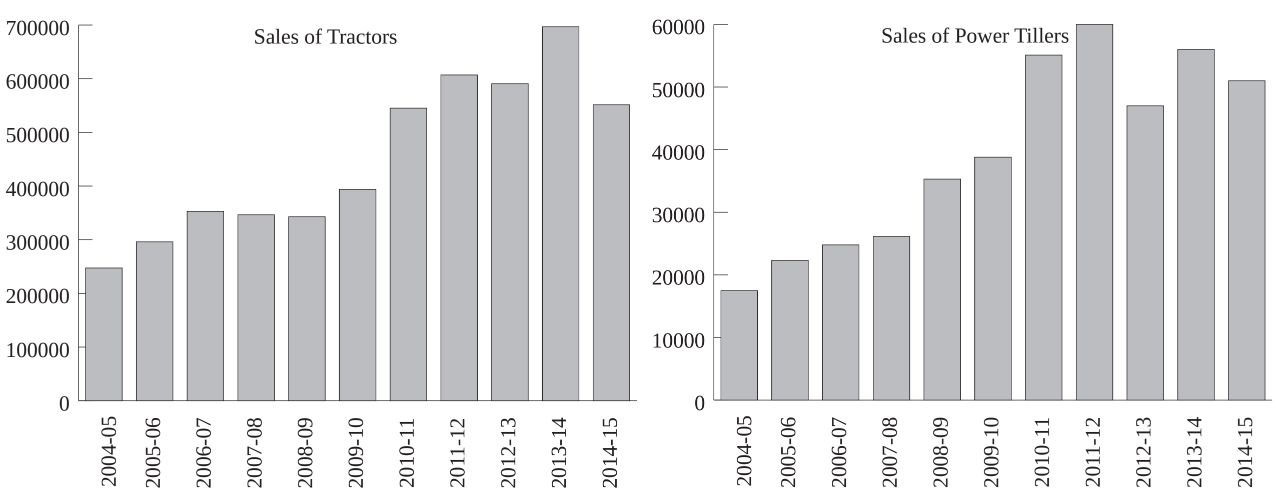
M/S VST Tillers and Tractors Ltd was the only company that manufacture tractors of below 20 hp ranges and rest of the companies were selling the models of 21-30 hp, 31-40 hp, 41-50 hp and > 51 hp tractors. Later many companies such as Captain Tractors Pvt. Ltd.; Mahindra & Mahindra; International Tractors Ltd; Kubota Agriculture Machinery Pvt. Ltd; Kerla Agro Machinary Company Ltd.; White Wagon Tractors Pvt. Ltd.; Trishul Tractors Pvt. Ltd.; Farmer Tractors Pvt. Ltd.; D.K.Diesels Pvt. Ltd; Jayant Agro Industries; Vandana Green Tech Pvt. Ltd; Apollo Earthmovers Ltd.; Madhav Agro Industries; Kishan Agrotech Industries; Shree Shyam Agrotech; Krushiraj Mini Tractor; Angel Farm; Gayatri Tractors and many more started manufacturing small tractors less than 20 hp.

In India, it has been more of tractorization, while farm mechanization in the sense of small machinery has largely been un-tapped but now the scenario has changed. The Indian tractor industry is the largest in the world and accounts for one third of global production. The sale of tractors has grown at a CAGR of 11 % from 247,531 in 2004-05 to 551,463 in 2014-15 (Singh *et al.*, 2014; Singh, 2015a; Kale, 2015); **Fig. 1**. Similar is trend for power tillers (**Fig. 1**).

Within the country, sale of different hp range of tractors indicates that the highest share is of 31-40 hp tractors (46.2 %) followed by 27.62 % of 41-50 hp, 13.83 % of 21-30 hp, 11.61 % of above 51 hp and 0.75 % less than 20 hp tractors. Sale trend of tractors less than 20 hp range revealed that the Maharashtra has highest share (65.1 %) followed by Gujarat (19.8 %), Karnataka (6.9 %), Tamil Nadu (2.7 %) and Madhya Pradesh (2.2 %). State-wise sale of tractor was analyzed for observing the current sale trend of different hp range of tractors throughout the country (**Fig. 2**). Of total sale of tractors in the country, Uttar Pradesh is having the largest share (15.1 %) followed by Madhya Pradesh (13.85 %), Rajasthan (11.82 %), Maharashtra (10.32 %) and Gujarat (7.36 %). Sale of tractors of above 51 hp range was found highest again in Punjab followed by Uttar Pradesh, Maharashtra, Madhya Pradesh and Haryana. This indicates the farmers' inclination towards high range of power. Tractor export started with 4,567 units (2.38 % of total sale) from year 2003-04. It has been observed that about 8 to 10 % tractors are exported every year since 2003-04 onwards (**Fig. 3**). Current trend of export of different range of tractors shown in Fig. 4 showed that the demand of high hp range of tractors (above 51 hp) was maximum (56.4 %) followed by 41-50 hp range (27.5 %), 31-40 hp range (11 %), 21-30 hp (4.8 %) and less than 20 hp (0.3 %) of the total tractors export.

Power Sources on Indian Farms

The different sources of power available on the Indian farm for doing various mobile and stationary operations are mobile power viz. human (men, women), draught animals (bullocks, buffaloes, camels, horses and ponies, mules and donkeys), tractors, power tillers and self-propelled machines (combines, dozers, reapers, sprayers etc.); and stationary power i.e. diesel/ oil engines (for pump sets, thresh-



Source: Singh *et al.* (2014); Singh (2015a); Kale (2015); Tractor Manufacturers' Association (TMA); Power Tiller Manufacturers' Association (PTMA)

Fig. 1 Tracor and power tiller sales data for last 11 years.

Table 2 Farm power sources in India

Year	Population of farm power sources, million					
	Agricultural Workers	Draft animal power	Tractors	Power tillers	Diesel engines	Electric motors
1960-61	131.10	80.4	0.037	0	0.23	0.20
1970-71	125.70	82.6	0.168	0.0096	1.70	1.60
1980-81	148.0	73.4	0.531	0.0162	2.88	3.35
1990-91	185.30	70.9	1.192	0.0323	4.80	8.07
2000-01	234.10	60.3	2.531	0.1147	5.90	13.25
2010-11	263.00	53.50	4.207	0.3213	8.20	16.50
2011-12	266.08*	53.0	4.553	0.3621	8.30	16.70
2012-13	269.20*	52.8	4.858	0.4021	8.35	16.80
2013-14	272.00*	52.0	5.237	0.4409	8.45	17.00

*Estimated

Source: Singh (2015a); Singh *et al*. (2014); Singh *et al*. (2015); Live Stock Census; Tractor Manufacturers' Association (TMA); Power Tiller Manufacturers' Association (PTMA)

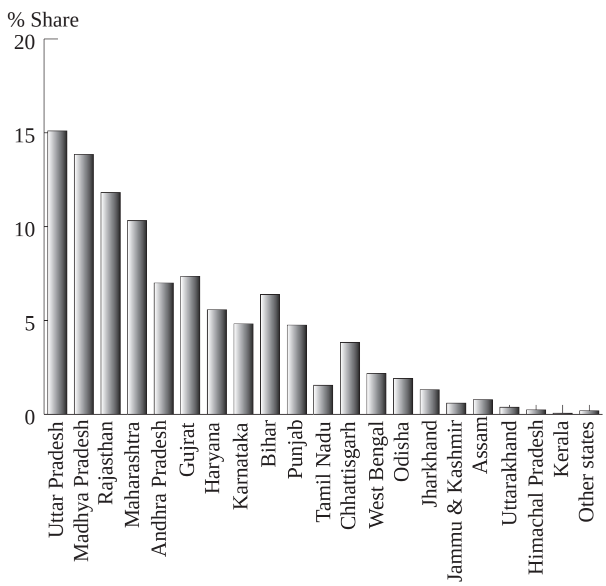


Fig. 2 Share of tractor sales in different states during year 2013-14.

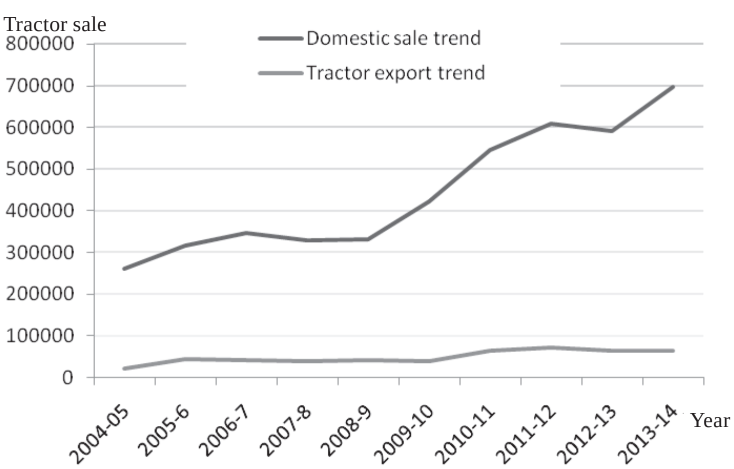


Fig. 3 Export and domestic sale of tractors.

ers, sprayers and other stationary operations) and electric motors (for pump sets, threshers, sprayers and other stationary operations). Agriculture has been the main occupation of the rural people and largely dependent on use of animate power sources. Human energy is predominantly used for all operations in agriculture. While the population of agricultural workers as percentage of rural population has gone down from about 69.4 % in 1951 to about 55 % in 2013-14 but in absolute terms, due to increase in overall population, the number of agricultural workers available in rural areas has increased from 131.1 million in 1960-61 to 272 million in 2013-14 and thereby registered an annual compound growth rate of 1.38 % (**Table 2**). These agricultural workers are engaged in different farm operations and depend on agriculture for their livelihood, even when they are not fully employed throughout the year. Due to too much involvement of labour in different farm operations, the cost of production of most of the crops in our country is quite high as compared to developed countries. Human power availability for agriculture had been 0.043 kW/ha in 1960-61 and reached to 0.096 kW/ha in 2013-14 registered an annual compound growth rate of 1.53 % (**Fig. 5**). Share of agricultural workers in total power availability in 1960-61 was 14.7 % reduced to

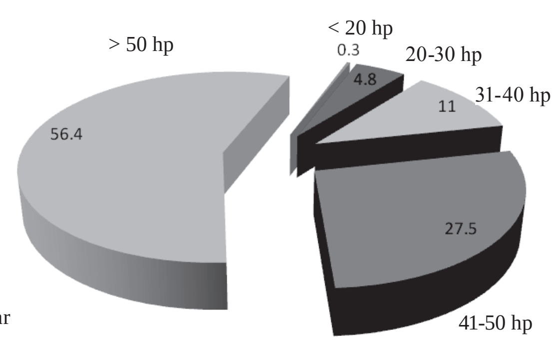


Fig. 4 Percent share of tractor's export in different hp range.

4.66 % in 2013-14 (**Fig. 6**). Time series trend suggests that share of power from agricultural workers to total power available will further reduced in near future.

Draught animals, particularly bullocks, are still the predominant source of mobile power on about 60 % of the cultivated area consisting of about 85 million ha. While earlier a pair of animals was being used for about 1200-1800 hours annually, their average annual use has now come down to about 300-500 hour only, that too for tillage, sowing, weeding and rural transport. It has been observed that on an average a tractor is replacing about 5 pairs and power tiller about 2 pairs of animals. Draught animal population, mainly derived from bovines, was 80.40 million in 1960-61 and reduced to 52 million by 2013-14 with a negative annual compound growth rate of -0.82 % (**Table 2**). Share of draught animal power was 78 % of the total farm power in 1960-61 reduced to 7 % only in 2013-14 (**Fig. 6**). Draught animal power availability in India decreased from 0.229 to 0.14 kW/ha between 1960-61 and 2013-14 (**Fig. 5**).

For meeting the increased demand of mobile power for timely farm operations and increased intensity of cropping, additional power is available mainly from tractors and power tillers. Self-propelled reapers and combines also provide mobile power specially for harvesting operations. Tractor population in India has grown from 0.037 million in 1960-61 to 5.237 million units in the year 2013-14 at an annual compound growth rate of about 10 percent (**Table 2**); (Singh *et al*., 2014; Singh, 2015a). Farm power availability from tractor has consequently increased from 0.007 kW/ha in 1960 to 0.218 kW/ha in 1990 at an annual compound growth rate of 12.14 % (**Fig. 5**); **Table 3**. The growth rate in the next decade decreased to 8 %. Farm power availability in the year 2000 was 0.47 kW/ha, reaching to 0.97 kW/ha in 2013-14 at an overall growth rate of 9.80 %. Power tiller, or two-wheel tractor, came in India with import of two units from Japan in 1961.There are mainly 2 manufacturers of power tillers in the country producing about 6 models in the range of 8-12 hp. In addition to these, there are many others who are importing power tillers and selling in the country. Contribution of tractors and power tillers was only 2.54 % of the total farm power in 1960-61 increased to about 50 % in 2013-14 (**Fig. 6**). Sale of tractors and power tillers has constantly increased during last 10 years with some exceptions (**Fig. 1**).

Stationary power sources in agriculture comprise of diesel engines and electric motors used for lifting irrigation water, operating threshers and other stationary machines. The populations of these prime movers have increased tremendously since the green revolution. Diesel engine population in the country increased about 37 times between 1960-61 and 2013-14 (**Table 2**), while the annual compound growth rate had been 10.66 % during the period 1960-61 to 1990-91, with increased availability of electricity it reduced to 7.04 % during the period of 1990-

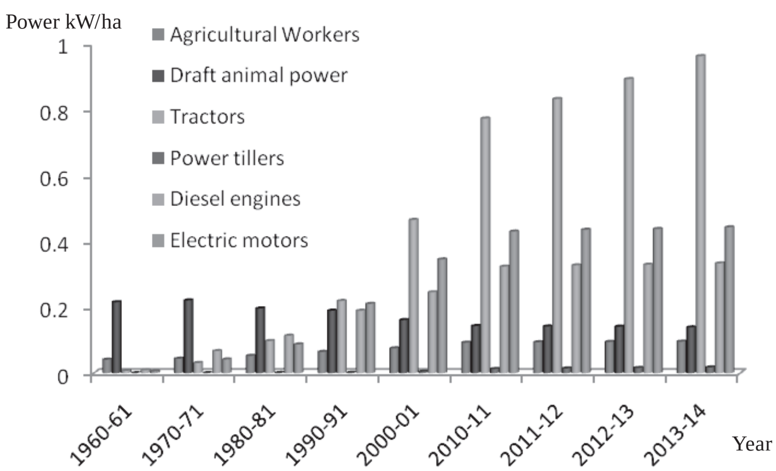


Fig. 5 Power available from different power sources on Indian farms

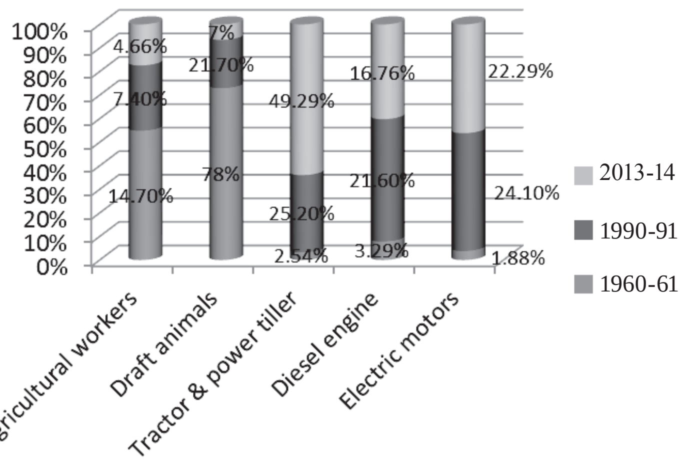


Fig. 6 Share of different power sources in total power availability

Table 3 Power available from different sources in India

Year	Power available from different power sources, million kW*					
	Agricultural Workers	Draft animal power	Tractors	Power tillers	Diesel engines	Electric motors
1960-61	5.8	30.6	1.00	0	1.298	0.74
1970-71	6.21	31.39	4.38	0.054	9.52	5.92
1980-81	7.46	27.89	13.86	0.091	16.13	12.39
1990-91	9.17	26.94	31.11	0.181	26.88	29.86
2000-01	10.7	22.9	66.06	0.642	34.86	49.03
2010-11	13.15	20.33	109.80	1.799	45.92	61.05
2011-12	13.30	20.14	118.23	2.028	46.48	61.79
2012-13	13.46	20.06	126.80	2.252	46.76	62.16
2013-14	13.60	19.76	136.70	2.469	47.32	62.90

Note: 1 Human = 0.05 kW; draught animal = 0.38 kW; tractor = 26.1 kW; Power tiller = 5.6 kW; Electric motor = 3.7 kW; Diesel Engine = 5.6 kW
Source: Singh (2015a); Singh *et al.* (2014); Singh *et al.* (2015)
*Power per unit area is total power available in million kW divided by total cultivated area (142 million ha)

91 to 2013-14. Farm power from diesel engines increased from 0.009 kW/ha in 1960-61 to 0.247 kW/ha in 2000-01 and 0.335 kW/ha in 2013-14 (**Table 3**; **Fig. 5**), registered an annual compound growth rate of about 7 %. Electric motor population has also increased 85 times between 1960-61 and 2013-14 at an impressive annual compound growth rate of 8.7 % (**Table 2**). Farm power availability consequently increased exponentially from 0.005 kW/ha to 0.445 kW/ha (**Fig. 5**).

For adoption of higher level of technology to perform complex operations within time constraints and with comfort and dignity to the operators, mechanical power becomes essential. Thus, the extent of use of mechanical power serves as an indicator of acceptance of higher level of technology on farms. Over the years the shift has been towards the use of mechanical and electrical sources of power and in 1960-61 about 92.30 % farm power was coming from animate sources (**Fig. 7**). In 2013-14 the contribution of animate sources of power reduced to about 11.80 % and that of mechanical and electrical sources of power increased from 7.70 % in 1960-61 to about 88.20 % (**Fig. 7**). It is apparent from **Table 4** that the cropping intensity increasing with increase in per unit power availability. It was 114 % with power availability of 0.32 kW/ha during 1965-66 that increased to about 142 % with increase in power availability for 2.02 kW/ha in 2013-14. Net sown area per tractor shows the reverse trend during the same period, which observed 2,162 ha/tractor in 1965-66 reduced to 27 ha/tractor in 2013-14. Between 1960-61 and 2013-14, the growth rate in power was 3.81 % to reach 2.02 kW/ha. Food grains productivity in India has increased from 0.710 t/ha in 1960-61 to 2.21 t/ha in 2013-14. Thus, food grains productivity is positively associated with unit power availability in Indian agriculture (**Fig. 8**). The relationship between food grains productivity and unit farm power availability for the period 1960-61 to 2013-14 were estimated by linear function, with highly significant value of coefficient of determination (R2). This indicates that productivity and unit power availability is associated linearly. It is also evident that farm power input has to be increased further to achieve higher food grains production, the composition of farm power from different sources to be properly balanced to meet of its timely requirement for various farm operations.

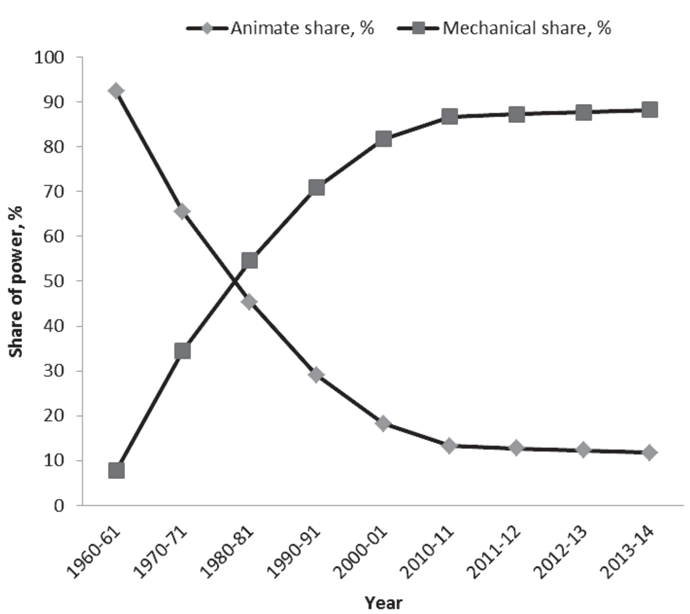


Fig. 7 Animate and mechanical power scenario in Indian agriculture

Development of Agricultural Machinery in India

Improved tools, implements and

Table 4 Cropping intensity and power availability on Indian farms

Year	Cropping intensity (%)	Food grain productivity (t/ha)	Power available (kW/ha)	Power per unit production (kW/t)	Net sown area per tractor (ha)
1965-66	114.00	0.636	0.32	0.50	2,162
1975-76	120.30	0.944	0.48	0.51	487
1985-86	126.80	1.184	0.73	0.62	174
1995-96	130.80	1.499	1.05	0.70	82
2005-06	135.90	1.715	1.49	0.87	45
2010-11	140.50	1.930	1.78	0.92	34
2011-12	141.50	2.079	1.87	0.90	31
2012-13	140.90	2.129	1.94	0.91	29
2013-14	142.00	2.111	2.02	0.96	27

Source: Agricultural Statistics at a Glance, Agricultural Census; Singh (2015a)

machines have always been means for advancing agriculture since prehistoric period. Incidences of famines and starvations compelled Governments to pay attention to agriculture. They imported and tried western animal drawn farm equipment and implements like mould board ploughs, harrows, cultivators, seed drill/planters etc. A few indigenous manufacturers adopted some of these implements. Traditional Hal (wooden wedge plough with its regional variation), Bakhar, Dufan and Tifan, wooden plank for leveling continued to dominate and are still used by marginal and small farmers (Anonymous, 2006). Major developments have occurred in post-independence period more so after on-set of Green Revolution in late 1960s. In the year 1961-62, when the High Yielding Varieties (HYV) started picking up the country started producing tractors and also imported to meet local demands. Year-by-year the demand of tractors increased. Similar trends were observed in the number of different types of tillage equipment, seeder & planters, plant protection equipment, harvesting & threshing equipment and tractor trailers.

Attempts were made in mid 60s and 70s to develop threshers, which not only have higher output-hp ratio but was able to handle a variety of crops including paddy. Hammer mill type of threshers were the first to be introduced but have now become obsolete in view of their high power requirements. Both spike tooth type and chaff cutter type threshers are still very popular in India. Spike tooth type threshers have low grain crackage but can handle only very dry crop with grain moisture content of about 9-10 %. On the other hand, chaff-cutter type threshers have advantages like low energy requirements, uniform size 'bhusa' and capability to handle crop of higher moisture content. However, grain crackage is reported to be higher in the chaff-cutter type of threshers. IRRI-PAK thresher was developed on the basis of axial flow principle. Conventional rasp bar and spike tooth type threshers used in grain combines allow the crop materials to pass through the concave as well as over the concave. But threshers incorporating straw bruising features, as are being used in India, allow the crop to pass through the concave only. Straw in these threshers cannot passes through the concave until it has been reduced to a size, which will permit its passage through it. Three types of such systems have been mainly used namely: hammer mill, spike tooth and chaff cutter.

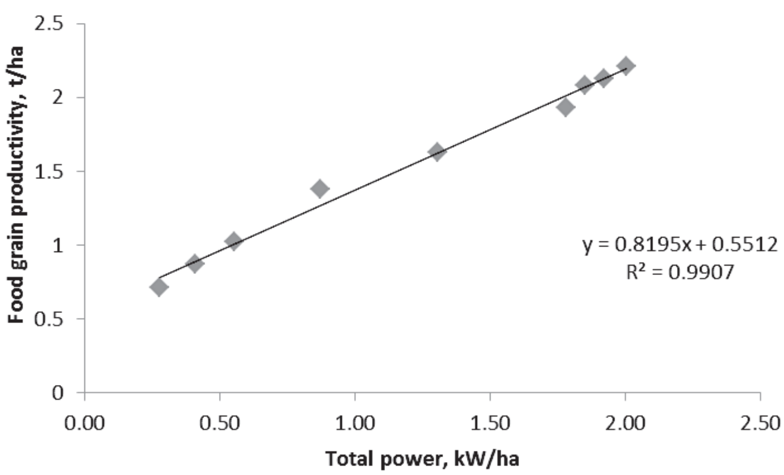


Fig. 8 Food grain productivity and power availability relationship in Indian agriculture

State Agricultural Universities and Indian Council of Agricultural Research (ICAR) Institutes took lead in agricultural mechanization in the country. Establishment of Central Institute of Agricultural Engineering (CIAE) Bhopal by ICAR was a major step which took initiatives to organized R&D in the area of agricultural mechanization and allied issues. ICAR launched a number of All India Coordinated Projects involving State Agricultural Universities and NGOs such as Farm Implements and Machinery; Energy Requirements in Intensive Agriculture which was rename as Energy Requirements in Agriculture Sector; Power Tillers; Utilization of Animal Energy with

Enhanced System Efficiency; Renewable Energy Sources; Optimization of Ground Water Use through Wells and Pumps; Agricultural Drainage; Harvest and Post-Harvest Technology that contributed a great deal in adoption, development, demonstrations, commercialization and pilot introduction of farm tools and equipment. Thereafter, linkages were developed with State Departments of Agriculture and Directorate of Agricultural Engineering, agricultural machinery manufacturers furthering the cause of farm mechanization. Department of Agriculture & Cooperation (DAC), Government of India took initiative in promoting agricultural mechanization and in this direction the Department established four Testing and Training Institutes in the country. The DAC also launched various promotional schemes providing subsidy to the farmers/users, and bank loans. It is well established that agricultural mechanization in India is driven by the needs and demands of the farmers and now it is essential input for modernizing production agriculture.

Medium and large farm holders can use improved agricultural machinery on ownership as well as on custom hire basis. Small farm holders due to their limited resources contribute to low productivity of land as they depend on traditional equipment and methods of crop cultivation. Because of the low productivity of their lands, they also use low amount of crop inputs and do not adopt high yielding varieties of the seeds. The Government of India realizes the importance of agriculture to the development of the nation and hence has adopted several initiatives and programmes for this sector's continuous growth. Notable among them are Rashtriya Krishi Vikas Yojana (RKVY); National Food Security Mission (NFSM); National Horticulture Mission (NHM); Gramin Bhandaran Yojana; Integrated Scheme of Oilseeds, Pulses, Oil palm, and Maize (ISOPOM), and lately the Sub-Mission on Agricultural Mechanization (SMAM) etc (Kale, 2015).

The scenario of farm mechanization has certainly changed as the Indian agricultural equipment market has experienced a rapid growth with expected strong potential for future growth as well. There has been a surge in demand over the past few years for tractors, power tillers, combine harvesters, rotavators, threshers and rice transplanters. The current market for tractors is 450,000-500,000 and power tillers 50,000-60,000 units. The combine harvesters market is estimated at 3,000-4,000 units annually. It is estimated that the annual requirement for rotavators, threshers and power weeders is 100,000-120,000; 60,000-80,000; and 35,000-40,000 respectively. The sale of machinery like MB plough (45,000-50,000), laser guided land leveler (2,500-3,500) and planter (15,000-25,000) are growing fast on custom hiring mode even though cost is higher, since the demand is more. Availability of these implements with respect to the numbers/1000 ha of net cultivated area has been continuously increasing during last 40 years. The overall level of Farm Mechanization in India is about 40-45 % (i.e. tillage about 40 %, seeding & planting about 30 %, plant protection about 35-45 % and harvesting & threshing about 60-70 % for rice and wheat and less than 15 % for other crops). India's small farms usually do not present an economic condition to permit the extensive use of agricultural machinery. Given the constraint of limited days' usage of machinery, the operational and capital costs may be optimized for the farmers by making the machinery available to the farmers on custom hiring. Thus, even small farmers may be able to get the benefit of agricultural mechanization. Setting up custom hiring services will be able to provide the machinery on need basis to the small and medium farmers.

Major Thrust Towards Farm Mechanization in 12th Plan

As such there is no Agricultural Mechanization Policy in India. In order to lay special emphasis on farm mechanization and to bring more inclusiveness, a dedicated Sub-Mission on Agricultural Mechanization (SMAM) for the XII Plan (2012-17) has been launched by Govt. of India (Kale, 2015). SMAM puts 'Small & Marginal Farmers' at the core of the interventions with a special emphasis on 'reaching the unreached', i.e. bringing farm mechanization to those villages where the technologies deployed are decades old. Besides, the mission is also catering to 'adverse economies of scale' by promoting 'Custom Hiring Services' through 'the rural entrepreneurship' model. The Mission is catalyzing an accelerated but inclusive growth of agricultural mechanization and providing assistance for promotion and strengthening of agricultural mechanization through training, testing and demonstration; Post harvest technology and management; Procurement of selected agriculture machinery and equipment; Establishment of farm machinery banks for custom hiring; Establishing hi-tech productive equipment centres to target low productive agricultural regions and assistance for increasing farm mechanization. To make the cost of machinery affordable and to make them available to all farmers, Govt. has launched a credit-linked subsidy scheme for establishment of farm machinery banks and hi-tech high productive equipment hub for custom hiring for increasing the reach of farm mechanization to small and marginal farmers and to the regions where availability of farm power is low.

All-India Agricultural Machinery Manufacturers' Association (Amma-India)

There are about 250 medium to large scale units, 2,500 small scale industries, 15,000 tiny industries and more than 100,000 village level artisans in India. Most of them are under un-organized sector except the tractor industries. There was no ways to pass on Govt. benefit schemes to these industries. The All-India Agricultural Machinery Manufacturers' Association (AMMA-India) was established in the year 2010 on January 17 at the behest of Department of Agriculture and Cooperation (Mechanization and Technology Division), Ministry of Agriculture, Govt. of India. This represents the machinery manufacturers of agriculture and allied sectors. The main objectives of association are: i) augmenting and intensifying agricultural mechanization related activities in different agro-climatic zones; ii) promoting scientific development and technological up-gradation of need based agricultural machines and power sources; iii) providing technological coordination, management and advisory back-up to the members of AMMA-India; and iv) providing effective liaison with Government organizations, NGOs and agencies sponsoring national and international fairs/meets and to establish institutional relations for implementation of appropriate policies and initiatives to promote growth of agricultural mechanization. Presently, 448 agricultural machinery manufacturers including tractor industries are the members of this association. Association is working very closely with central as well as state Govts. for implementations of various Govt. schemes for the benefit of users/farmers and manufacturers. For more details one can visit www.ammaindia.in. This association is registered under society act and also the member of UN-CSAM 'The Regional Council of Agricultural Machinery Associations in Asia and the Pacific (ReCAMA)'.

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INDIA

Present Status and Future Prospects of Agricultural Machinery Research in India

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India supports 17 % of the world's human population and 15 % of the livestock with a meager 2.5 % of the world's geographical area and 4% of its water resources. Food grain production of the country has touched 264.4 Mt during 2013-14 (FAO, 2014) from a mere 51 Mt in 1951-52. The country has attained self-sufficiency in food grain production and also has sufficient buffer stock. The horticultural production in India has surpassed even the grain production in recent years. India could be the world's largest economy by 2050 and by this time the country would have 1.6 billion people. It is estimated that the contribution of agriculture in national GDP would come down to about 3 % and the work force in agriculture would be about 25%. Many of these agricultural workers would have additional non- agricultural source of income to supplement their needs. Agriculture would remain important in the livelihood of a considerable section of India's population for several decades to come although with a reducing share in the country's GDP. With the growth of economy of any country, the labour force shifts from agriculture i.e. primary sector to manufacturing of goods i.e., secondary sector and later on to service sector i.e., tertiary sector. In India also, in the process of development, the labour force have considerably shifted from agriculture to other sectors which necessitated more dependency on agricultural machinery. In fact, the overall development in production agriculture has been closely linked with progress of agricultural mechanization.

Indian agriculture, pre-independence, was mainly labor based. During 1950 agriculture received 98 percent power from animate sources i.e., human and animal and 2 percent from in-animate sources i.e., mechanical and electrical power. The intervention of mechanical power started in 1930s with manufacturing of diesel engines for irrigation and other purposes. Tractors were introduced later on in late 1940s when Central Tractor Organization (CTO) was established. Few high horse power tractors were imported mainly for land development and eradication Kans, an obnoxious weed. The indigenous manufacturing of tractor started in 1961. M/s Eicher Tractor Ltd. manufactured 880 tractors in 1961, first time in the history of India, which kicked off the process of mechanization in India using tractors. These tractors were suitable for land tilling, irrigation and transportation. As a result, these three operations got mechanized at large scale. In fact, 1960s was worst period of food scarcity in India known as ship to mouth stage. This worst situation became the emanation point of the best- so birth of green revolution during this period only. The history of modern agriculture in India i.e., green revolution is contemporary to development of mechanization in the country. The critical input like HYV seeds, fertilizer and plant protection chemicals would not have been applied efficiently and timely without use of efficient tools and equipment. The timeliness of operations, removal of drudgery to increase is labour productivity could not be attained without mechanization in the regions of green revolution.

As a general trend, farm operations requiring high power inputs and low controls (tillage, transport, water pumping, milling, threshing, etc.) are mechanized first and those requiring medium levels of power and control (seeding, spraying, intercultural operations, etc.) are mechanized next. The operations requiring high degree of controls and low power inputs are mechanized last (transplanting, planting of vegetables, harvesting of fruits and vegetables, etc.). This happens so because any work, which is power intensive, can be done faster mechanically and at a lower cost. Whereas, converting human knowledge into machine knowledge is difficult and costly. Growth of the mechanization in India has also followed the same general pattern found worldwide. India could be the world's largest economy by 2050 and by this time the country would have 1.6 billion people..

Renewed Emphasis on Mechanization

Indian agriculture is beset with several challenges. Drudgery, natural uncertainties, relatively low productivities, low profitability and climate change are all driving the present day youth away from agriculture. Prime Minister of India has given a call: more crop per unit of land; more crop per drop of water and farmers feed us we must enrich them. All these can be achieved through engineering interventions. Among the other challenges before Indian agriculture is to attract people, particularly youths towards agriculture. The one way to attract youths towards agriculture is the introduction of appropriate mechanization. This will give a status to farmer and abridge the social gaps. Tilling by walking behind a bullock drawn country plough may be taken as disrespect; but operating a laser land leveler by sitting in the driving seat of a tractor, the same young man or woman may feel honored.

Diminishing agriculture workforce is a reality. The younger rural work force is getting more inclined towards non - agricultural sectors which are more remunerative and also offer an attractive urban life setup. The result is that the average age of workforce engaged in agriculture is increasing. Unless agriculture becomes remunerative, young people will not be attracted to it and unless young people manage the agriculture, it will not be profitable. Technology, skills and the policies must lift the weakest farm holder above the national per capita income threshold. It is in this context that engineering inputs to agriculture in India have begun to be appreciated.

Current Status of Mechanization

During last couple of decades, farm power, an indicator of farm mechanization, registered increase due to enhanced contribution from electrical and mechanical sources. There seems to be a nexus between irrigation, mechanization level as exhibited by situations in the states like Punjab, Haryana and western Uttar Pradesh where farm power availability ranges between 1.75 -3.5 kW/ha and irrigation level between 73 to 85 percent with grain productivity in higher range. In contrast states like Odisha and Chhattisgarh with 0.6 kW /ha power availability, irrigation with 21-33 percent and the productivity in the lowest range. The state of agricultural mechanization in the country may be characterized with large variations in terms of power availability varying from 0.60 kW/ha in Odisha to 3.5 kW/ha in Punjab. The average farm power available is about 1.5 kW/ha comprising of more than 85 % from mechanical and electrical sources and less than 15 % from animal power and human labour. Tractor production started in 1961 and presently, India is largest producer of tractors in the world with annual production of 0.7 million. Power tillers are becoming popular in low land flooded rice fields and hilly terrains. Diesel engines and electric motors are main stationary power sources with total estimated quantity of 7.5 million and 10 million units, respectively, in different horse power ranges mainly for pumping and to some extent in threshing and milling of flour and dal. Healthy growth in population of tractors has resulted in corresponding growth in implement manufacturing. After liberalization and with development of research prototypes of machines manufacturing got a big boost particularly in Haryana, Punjab, Rajasthan, Madhya Pradesh and Uttar Pradesh and Gujarat. Combine harvesting of wheat, paddy and soybean is well accepted by farmers. The tractor powered combine harvesters costing only 25-30 % of the self-propelled combine was real innovation of manufacturers of Punjab and this machine can be owned by farmers individually. The self-propelled combines are largely owned by custom-hiring contractors. In addition, machinery is a must to harness available moisture at the time of tillage and sowing, hence dry land areas also registered growth in availability of farm machinery. For enhancing productivity in dry land areas, farm machines like rotary tiller, ferti-seed drill, raised bed planter and laser leveler and aquaferti-seed drill may prove a boon by enhancing water use efficiency of whatever little water/ moisture is available.

Gaps in Agricultural Machinery Research in India

Farm mechanization in India has picked up and moving towards a level of maturity touching the annual sales of machinery to over Rs. 800 billion The level of mechanization in India is still lower than United State (95 %), Western Europe (95 %), Russia (80 %), Brazil (75

%) and China (57 %) (Renpu, 2014). The average farm power availability in the country is still at a low level as compared to China, Korea and Japan. Unlike other agricultural sectors, farm mechanization sector in India has a far more complex structural composition. These challenges pose a serious impediment to the growth of the agricultural machinery in particular and agriculture in general. The key gaps in agricultural machinery research in India are as follows:

1. India has a large number of small and marginal land holdings and the mechanization thereof is a difficult task. The average farm size in India is small (< 2 ha) as compared to the European Union (14 ha) and the United States (170 ha). Due to small size of land holdings, it is difficult and not advisable for the farmers to own normal size power machinery system unless custom hiring is not to be taken up by such farmers. That is why emphasis is on research and development of machinery for mechanizing 1.0 hectare farm.

2. Indian farmers are not able to acquire high cost and energy efficient farm machinery as these are capital intensive. Therefore, custom hiring service facility is gaining foot hold to provide these farm machineries to the farmers. Research for development of appropriate custom hiring model is another area of priority.

3. The increased use of heavy equipment and power resources will also increase the area with sub soil compaction. Other problems arising due to soil compaction, like water logging, poor infiltration of water, reduced aquifer recharge rates, further deteriorate the soil health, ultimately resulting in reduced crop productivity. A comprehensive research on soil compaction and technological solutions is needed.

4. Land is going to be a scarce resource with urbanization and industrialization, a techno-economic feasibility of speciality agriculture such as vertical farming, hydroponics, soilless agriculture, ocean farming, cultivation in problematic soils is the need of the hour.

5. The inadequacy of farm power and machinery with the farmers is the major constraint for increasing agricultural production and productivity. The average farm power availability needs to be increased to minimum 2.5 kW/ha to assure timeliness in heavy field operations like sub-soiling, chiselling and deep ploughing.

6. For operations like dryland farming, paddy transplanting, sugarcane harvesting, potato harvesting, accelerated compost making, cotton picking, spraying tall plants, there is an urgent need to design, develop and adopt machinery suitable to Indian farming conditions.

7. The scope of mechanization increases with intensive cropping pattern. Cropping pattern decides the extent of mechanization required for timely operations and achieving optimum results. With quick change in cropping patterns due to shrinkage of natural resources makes the job more difficult for achieving a set level of farm mechanization.

8. The green revolution witnessed in the 1960’s catapulted the country from a “begging bowl to the bread-basket”. It is estimated that indiscriminate use of fertilisers and excessive irrigation have resulted in 12 million ha of land becoming water logged and 14 million ha rendered saline. A problem of soil erosion due to water is seen on 141 million ha and due to wind on 11.5 million ha. The current whole-field management approaches ignore variability in soil-related characteristics and seek to apply crop production inputs in a uniform manner. With such an approach, the likelihood of over-application and/or under-application of inputs in a single field cannot be avoided that result into higher cost of operation as well. Development of indigenous and affordable systems and devices for precise application of inputs is a challenge.

9. Matching equipment for tractors, power tillers and other prime movers are either not available or farmers make inappropriate selection in the absence of proper guidance, resulting in fuel wastage and high cost of production. Research for development of appropriate model for selection of appropriate power machinery system is required.

10. Mechanization of hill agriculture is abysmally low though 20 % of cultivated land is under hill agriculture with very small plot size on undulating terrain. This situation has to be improved by developing and promoting package of technology for mechanization of hill agriculture to achieve higher productivity.

11. Fertilizer use efficiency on Indian farms is poor. Development of applicators for liquid fertilizer like Urea Ammonia Nitrate (UAN), Urea Super Granules (USG), and Neem coated urea (NCU) are must.

12. Conservation agriculture is must for regaining deteriorating soil health, enhancing carbon sequestration, improving soil hydro thermal regime, and saving environment from excessive crop residue burning in particularly in rice wheat cropping system. Appropriate combine equipment which can facilitate sowing of next crop at the time of harvesting or during crop residue management must be developed.

13. The quality and after sales service of farm machinery are the other concerns in India. Most of the small scale manufacturers do not have the expertise and resources for standard designs of equipment that poses a big challenge to farm mechanization. The quality of farm implements and machinery manufactured by small scale industries

in the country is generally not of desired standard resulting in poor-quality work, longer down time, low output and high operational cost. Machinery standardization and Facility for quality testing of agro machinery is need of the hour.

Status of Agricultural Machinery Research in India

In India research and development efforts and approaches in agricultural machinery have been directed towards finding cost-effective solutions to location-specific problems of agriculture. National Agricultural Research System (NARS) comprising of Indian Council of Agricultural Research (ICAR), New Delhi and State Agricultural Universities primarily looks after the need of research and development activities, need based region specific technologies and specific-problem related issues. Some of the research institutes under the aegis of Central Scientific Industrial Research (CSIR), New Delhi are also engaged in research and development of agricultural machinery. Some of the achievements due to these efforts can be summarized as given below:

1. Development of improved machinery such as laser land leveller, self-propelled sprayers, precision seeders and planters, transplanters for rice and vegetable seedlings, multi-crop threshers, harvesters for cereals and sugarcane etc. for efficient farm operations and resource conservation, gender-friendly tools for reduction in the drudgery of women farm workers, and recommendations for minimizing accidents in agriculture.

2. Technologies related to renewable energy technologies, region and commodity specific equipment and processes for post-harvest loss reduction and value addition have also been developed.

3. Developed and commercialization of technologies related to dry land agriculture like aqua-fertiseed drill, Hydrogel applicator, complete animal feed block making machine, rapid compost making machine, machines related to vegetable mechanization , gadgets suitable for safe operation of chaff cutter and smart solar operated equipment.

4. Development of precision machinery and strategies for carrying out timely and efficient agricultural operations in irrigated, rain-fed and hill agriculture, horticulture, livestock and fisheries production.

5. Increasing work efficiency for human, animal and mechanical systems and reduction of occupational hazards in agricultural operations.

6. Energy management and utilization of conventional and non-conventional energy

sources in agricultural production and processing activities.

7. Utilization of surplus agricultural residues for decentralised power generation.

8. Reduction of post-harvest losses, value addition to agricultural produce, processing and utilization of by-products.

9. A dedicated Sub-Mission on Agricultural Mechanization (SMAM) for the XII Plan (2012-17) has been launched with an estimated outlay of US$ 350 million for the plan period by Machinery & Technology Division (M&T), Department of Agriculture and Co-operation, Ministry of Agriculture of Government of India. SMAM will put 'Small & Marginal Farmers' at the core of the interventions with a special emphasis on 'reaching the unreached', i.e., bringing farm mechanization to those villages where the technologies deployed are decades old. Besides, the mission also proposes to cater to 'adverse economies of scale' by promoting 'Custom Hiring Services' through 'the rural entrepreneurship' model.

Future Prospects of Agricultural Machinery Research

Future agricultural machinery research will be driven by unavailability of human labour, higher targets of food production and economic feasibility of mechanization adoption. There is a growing trend of contract farming which will demand mechanization of agricultural operations for high value vegetable, fruits and flower crops. In addition, custom hiring of agricultural machinery will be a common scene by 2050, necessitating the research efforts in direction of developing bigger machineries and equipment. Machinery trafficks and resulting soil compaction will be a problem area. Basis and strategic research in this area to alleviate as well as prevent further soil compaction would become absolutely necessary. Soil tillage and seeding machinery would also be looked upon as a basic input (like seed, water, fertilizer) and will be monitored and controlled in precision farming.

Some of the vital areas giving opportunities to the research of agricultural machinery in India are:

• Development of agricultural machinery suitable for different agro ecological regions keeping in view the rich biodiversity in the country in terms of crop, soil, climate and cropping systems.

• Need of innovative small ergonomically designed powered agricultural tools for urban and peri-urban clientele. Research on comfort and safety of agricultural workers.

• Visionary schemes of Government of India like Make in India, Digital India, Prime Minister Agricultural Irrigation Plan (PMKSY), Agricultural development plan (organic farming), Soil Health Card Scheme will boost agricultural machinery research in India.

• Skill India vision will provide trained manpower in agricultural technologies which in turn, will require research on newer innovative technologies in agriculture.

• Stronger economy leading to technological leadership.

• Big boost in FDI and Make In India schemes of Government of India will pave way for international companies to establish manufacturing centres with advance research and development facilities for research on agricultural machinery.

The strategies to achieve the targets can be summarized as given below:

1. Both physical and intellectual components of infrastructure need to be created in the form of state-of-art laboratories and specialized human resource. The infrastructure together with efficient operating procedures would create a fertile ground to sustain the growth for the future. The energy conservation and energy efficiency will play an important role in the national energy strategy, and particularly renewable energy will become a key part of the solutions and is likely to play an increasingly important role for augmentation of grid power, providing energy access and reducing consumption of fossil fuels. Centre of excellence in bio energy, centre of excellence for precision farming / robotics in agriculture, agricultural mechanization development centres (AMDCs), farm mechanization clearing house, expert systems and virtual demonstration are to be instituted.

2. New materials are required for fabrication of machine, structures and resource conservation. Advances in material science would lead to development of hybrid and functional materials based on metals, non-metals and polymers. Agricultural machinery research will have to define the functional requirement of a material's interaction with soil/ water/ food/ agro-chemicals/ other environmental factors, individually and in any combination.

3. Mechatronics for agricultural applications would be more common feature in production and post-production machineries. A multi-disciplinary engineering approach for precision in controls, gender neutral, operator safety, ergonomics, food quality and safety, environmental monitoring, warning and prevention systems would be in demand by tech-savvy and alert farmers.

4. Biosystems modeling, simulation and amelioration will find a vital role in future agriculture due to introduction of superior computing powers, availability of real time reliable data and sensitivity of consumers to the issues of environmental impact of agriculture. The study of bio- systems is going to be an extremely important area in future to determine better ways of living on the Earth.

The future research in agricultural machinery in India will be in the area of precision machines, conservation agriculture, functional foods, energy in agriculture and climate resilient agriculture.

1. Adaptation of sensors and robotics in pre and post-harvest agriculture for decision making, control, quality retention and efficiency.

2. Development of methods and machines for retaining and efficient reuse of water.

3. Sensors based in-situ monitoring and management of soil-water-plant interaction for enhancing input use efficiencies.

4. Use of nano-materials and nano-sensors for improvement of input efficiency and real-time assessment of crop needs.

5. Mechanization of controlled climate agriculture.

6. Development/ adaptation of agricultural machines for efficient use of resources, combating extreme climatic conditions, conserving environment and working in special or difficult terrains.

7. Variable input applicators based on real-time variability assessment, e.g. application of inputs like major and minor soil nutrients, plant growth regulators, plant protection chemicals etc. using same machine in a single pass.

8. Organic solar cells, bio sensors and power packs. Efficient and feasible energy storage devices (particularly for electricity) will govern its use for mobile energy demands in agriculture.

9. Redesigning the machines to suit alternative energy sources such as bio-diesel, fuel cells, solar chips, portable energy sources and multi-fuel options

10. Mobile based smart information system for sending very quick solution to farmers' problems related biotic and abiotic stresses to crops.

11. Adoption and impact assessment of agricultural machinery for resource conservation under permanent bed cultivation.

12. Environmental impact assessment of different energy conversion processes for efficient utilization of surplus crop residues. Efficient conversion of crop residues through entrained gasification system.

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INDIA

Agricultural Machinery Industry in India

by
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INDIA

About AMMA- India

The Agricultural Machinery Manufacturers' Association (AMMA-India) was formed at the behest of Secretary, Agriculture and Co-operation, Ministry of Agriculture, Govt. of India and Secretary, Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Govt. of India and Director General, Indian Council of Agricultural Research (ICAR).

The mission statement of AMMA-India is

"AMMA-India is committed to the growth of Indian Agricultural Machinery Industry in such a way that it is able to assist the farmers in achieving sustainability and profitability through appropriate farm mechanization"

With the continuous efforts of AMMA-India, farm mechanization now is a key area in policy framework of Central as well as state Governments. Accordingly, Sub Mission on Agricultural Mechanization (SMAM) has been envisaged for implementation from XII plan onwards with the aim at catalyzing an accelerated but inclusive growth of agricultural mechanization in India.

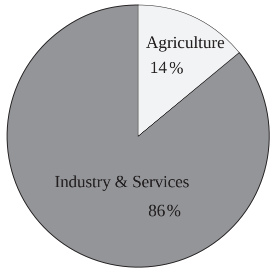
Introduction

India is a country with various landforms ranging from lofty mountains to ravine, deltas and also including high altitude forest of Himalayas, sprawling grasslands of Indo-Gangetic plains, peninsular plateaus of South East and South West India and many other geological formations. The climate of India is full of extremities; and most prone sector to rainfall variations, either deficit or excess, particularly when it coincides with susceptible/critical crop growth stages. Due to presence of a wide range of geological and climatic conditions, Indian agriculture is diverse and complex with both irrigated and dry land areas, capable of producing most of the food and horticultural crops of the world. India has an estimated 142 million ha cultivated area of which about 57 Million ha (40 %) is irrigated and remaining 85 Million ha (60 %) is rain-fed. Rice, wheat, maize, sorghum, and millet are the five main cereals grown in India. Along with this the pulses, oilseeds, cotton, jute, sugarcane, and potato are the other major crops.

India ranks second worldwide in farm output but the economic contribution of agriculture to India's GDP is steadily declining with the country's broad-based economic growth. In India, 63 percent holdings are below 1 ha accounting for 19 percent of the operated area

	India
Total population	1.21 billion (2011) 17 % of population of world Majority (69 %) of people live in rural areas
Population growth rate	1.5 % annually
Employment	52 % workers in Agriculture 14 % of GDP
Land area	297.3 million ha (2.4 % of world)
Water	1,200 mm annual rainfall Agriculture accounts for 80 % of water needs; 60 % from ground water. Only 4.2 % of world water

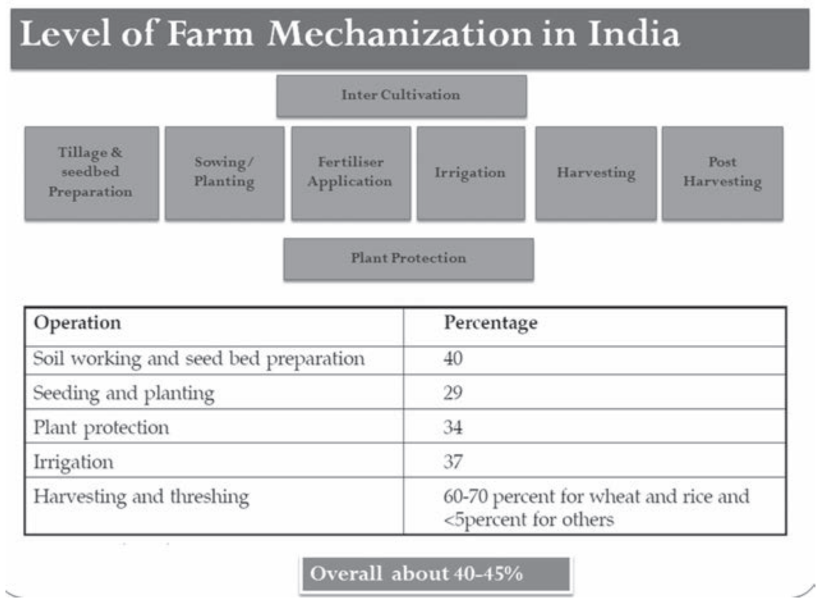
Indian Agriculture



while over 86 percent holdings are less than 2 ha accounting for nearly 40 percent of the area.

Farm mechanization in India has come a long way during the last 60 years and still there is tremendous scope as it is required in every unit operation of agricultural production, post harvest, food processing and rural living. Farmers, policy makers and developmental agencies now realize that for raising farm productivity at reduced unit cost of production, mechanization is essential.

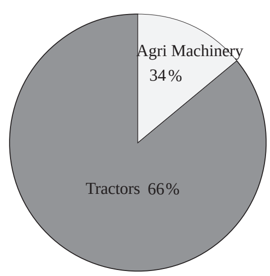
Level of Farm Mechanization in India

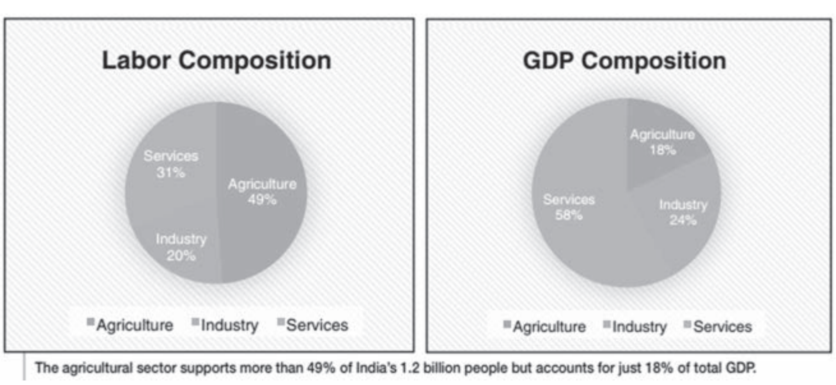


Operation	Percentage
Soil working and seed bed preparation	40
Seeding and planting	29
Plant protection	34
Irrigation	37
Harvesting and threshing	60-70 percent for wheat and rice and <5percent for others

Indian Agricultural Machinery Industry

250 Medium to Large Scale Units
2,500 Small Scale Industries
15,000 Tiny Industries
100,000 Village level Artisans
32,000 Crore Industry, CAGR growth 5 %





Tractor and its Manufacturing in India

Agricultural tractors, which represent 96 % of total ag equipment production, are expected to continue to grow at a steady pace of 5%. Combines and other agricultural machine production should increase in a similar way at a 5 % CAGR. The key growth driver is increased mechanization and the shift from low- to higher-horsepower machines as farmlands consolidate.

When looking at the top 10 engine suppliers today, we see that the market has remained fairly stable and is dominated by domestic players. Going forward, however, we expect that many manufacturers will collaborate to improve their product ranges. India is also a good base from which to export engines to the surrounding markets of South Asia and the Middle East.

The agricultural equipment manufacturing market remains concentrated, with the top five companies representing 83% of the market, as seen in the accompanying chart. We are expecting aggressive marketing and product strategies to be implemented in line with the changing market dynamics.

Domestic engine suppliers make up a large segment of the ag machinery markets in India. The top five suppliers of agriculture equip-

Manufacturing Units in India

Equipment manufacturers	No. of units
Agricultural tractors	13
Power tillers	2
Irrigation pumps	600
Plant protection equipment	300
Combine Harvester	48
Reapers	60
Threshers	6,000
Seed Drills and planters	2,500
Diesel oil engines	200
Plough, cultivators, harrows	5,000
Chaff cutter	50
Rural artisans (hand tools)	> 1 million

ment in India represent more than 80 % of the market.

Today, 96 % of engines operating in the agriculture segment are below 60 kW. The market forecast is to trend toward higher outputs in the next decade, though the pace of this trend is relatively slow. Most manufacturers are beginning to announce new, more powerful machines. Mahindra recently announced plans to launch more than six new models under the Mahindra and Swaraj brands in the next three years.

Summary

In summary, agriculture equipment production in India is expected to remain flat in 2015, but the market will grow at a 5 % growth rate in the next five years. Overall, the market remains concentrated, although introduction of new government regulation and the shift to higher output machines will help boost growth in the medium and long term. Unit volumes of agricultural equipment produced in India will continue to rise in the next five years, with India representing 12 % of global equipment production by 2020.

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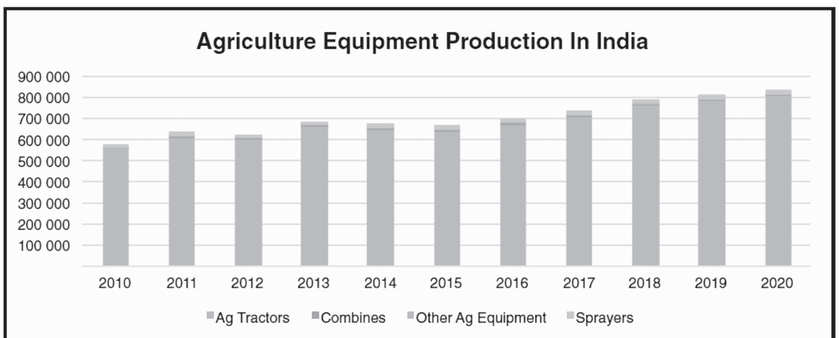
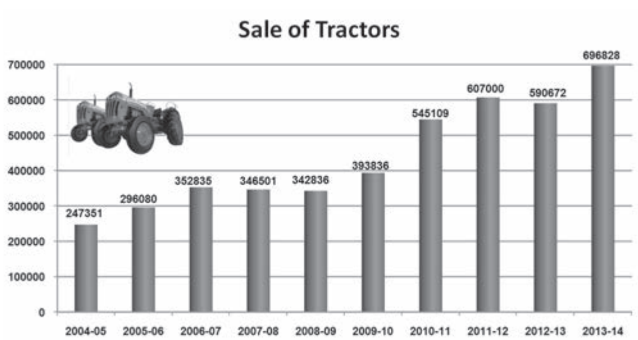
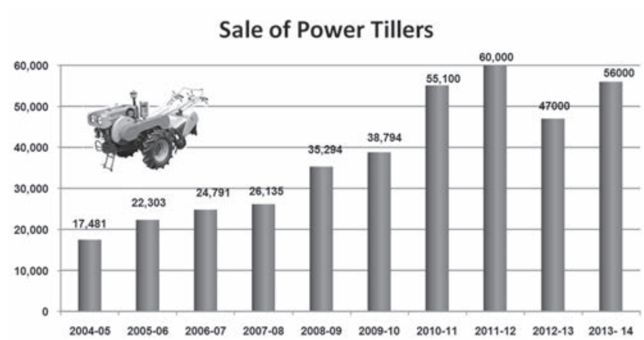


Tractors represent the vast majority of total agricultural equipment production in India.

Top 10 Agriculture Engine Suppliers In India (2015)
Mahindra & Mahindra Ltd.
Simpson & Company
Swaraj Engines Ltd.
Escorts Ltd.
Deere & Co.
Sonalika Group
FPT Industrial
TAFE (Tractor and Farm Equipment Ltd.)
Same Deutz-Fahr
Kubota Corp.





Agriculture Equipment Market Share by OEM Parent (%)

Mahindra Group	38
Amalgamations Group (TAFE & Eicher)	20
Escorts Group	9
Deere & Co.	8
Sonalika Group	8
CNH Industrial N.V.	5
V.S.T. Tillers Tractors Ltd.	2
Same Deutz-Fahr Group	2
Kubota Corp.	2
ASPEE	1
Indo Farm Equipment Ltd.	1
Force Motors Ltd.	1
Green Field Material Handling Pvt. Ltd.	1
Others	3

PAKISTAN

Farm Mechanization: Historical Developments, Present Status and Future Trends in Pakistan

by

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Abstract

Total cropped area of Pakistan is 27.48 million hectares which is 34.4 percent of total land area. Annual population growth rate of Pakistan is around 1.5 %. Current population of Pakistan is about 199 million and this makes Pakistan the 6th most populous country in the world. Rapid urbanization due to increasing population has reduced the cultivable land in the country. Limited land, increasing population, high cost of crop production and rising demand for food are key challenges for the agriculture sector in Pakistan. This situation has forced government to pay serious attention upon modern agriculture based on mechanized farming. Seed bed preparation, wheat and paddy harvesting and pesticide application have attained reasonable level of mechanization, while use of machines for remaining field operations is quite limited. Beside established potential of mechanized nursery transplanting, this is still done manually. Cattle farming, fish pond farming and postharvest processing of fruit and vegetable are emerging businesses and are important prospective areas for mechanization. Current level of farm power availability is 0.52 hp/ac (1.29 hp/ha) while over five hundred small and medium sized manufacturers are working in Pakistan with key issue of low quality and lack of standardization. This aspect indicates great potential for joint venture of Pakistani manufacturers with high-tech international manufacturers to produce good quality farm machine at Pakistan for domestic and international market with competitive prices.

Introduction

Pakistan got independence from the British Regime in 1947 and was declared a sovereign Nation. At the time of independence, most of farm operations were performed with bullocks, farm productivity was very low and basic food need of the country was met through import or foreign aid. Gradually bullock power was replaced with tractors. Supplemented with tube-wells, area under cultivation, yield, production and cropping intensity of crops increased to a level that the country has not only become self-sufficient in most of its agricultural needs but it is exporting several agricultural products including wheat, rice and cotton. Rising population, shrinking agricultural land, increasing demand for food, extensive land degradation and inadequate infrastructure appear to be key concerns of the agriculture sector in Pakistan (Bhutto and Bazmi, 2007). This situation has forced the experts and policy maker to pay due attention on agricultural mechanization.

Agricultural mechanization necessitates the provision of mechanical power for undertaking the various agricultural operations. The extent of accessible mechanical power marks the level of productivity as well as production. Pakistan has recently realized the need for a highly mechanized agricultural sector and is in the process to develop agricultural mechanization policy of the country.

This manuscript summarizes the status of area, yield and production of major crops, tractor industry and available tractor power, agricultural machinery industry, agricultural machinery census, farm mechanization, land resources development services, water resources development services, water management services, soil and water conservation services, agricultural mechanization Research, agricultural engineering education, protected agriculture and cattle and fish farm mechanization.

This document gauges the future prospects of mechanized farming and recommendations are also framed for the policy makers of Pakistan and propose potential of co-operations between the stakeholders in the agricultural sector of Pakistan and in Japan.

Area, Yield and Production of Major Crops

Total cropped area in Pakistan is around 27.48 million ha out of which wheat alone covers 42 %, followed by cotton and rice 14 % each, fodder 9 %, maize and sugarcane 4 % each. Remaining cropped area is occupied by other crops (AC, 2010). Wheat crop covers the largest area followed by cotton, rice and sugarcane. Punjab province covers 69 % of the cropped area of the country and is considered food basket of Pakistan. According to the World Bank report (2005), land and water productivity in Pakistan's Punjab is 2-3 times lower compared to those at international benchmark as shown in **Table 1**.

In-spite of having World's best alluvial soils, diversified weather conditions with most appropriate day-night temperature, Pakistan is facing constraints like low growth rate, high post-harvest losses, poor quality of produce and exorbitantly high marketing costs. To cope up with these issues, Government of the Punjab is promoting compliance certification regime (Global GAP, HACCP, BRC and IFS etc.) for the production and processing units of agriculture and livestock.

In order to meet the increasing requirement of food with increasing population and decreasing land, Pakistan needs to put serious attention upon agricultural mechanization. Mechanization of cattle farm, fish ponds, and mechanization of orchards are appearing as important business in the country. Rice transplanting, processing of fruit and vegetable to reduce postharvest losses and to increase export need immediate attention. High cost of imported machines is a serious challenge faced by different stake holder in Pakistan. Hence, improvement of local manufacturing industry with the collaboration of developed world shows great potential in Pakistan. Pakistan is welcoming foreign investment and making special policy changes for improvement of infrastructure.

Area under fruit and vegetable is around 1.06 million ha while under fruit only is 0.83 million ha. The subsector, Fruits and Vegetables etc. (horticulture) contributes 11 % to the total value addition in agriculture sector. Reports indicate that Pakistan is facing 24.5 % postharvest losses in all fruit with the worth of US$ 314 million (MNFSR, 2013).

Production of fruit and vegetable is also below as compared to world leaders. Importance for the pruning of fruit trees has been felt and it cannot be achieved to the desired level due to non-availability of efficient machines in the country. Similarly fruit picking is mostly manual and seriously need state of the art fruit picking and sorting system. Post-harvest losses can be managed with the introduction of specific systems and machines. Good management of fruit tree requires machines for tree trans-planting, tree pruning and fruit picking. These all machines are very limited and its need

Table 1 Present yield, potential yield and yield gap of major crops

Crop	World's Highest Yield (ton/ha)	Pakistan's' Potential Yield (ton/ha)	Pakistan's' Avg. Yield 2011-12 (ton/ha)	Yield Gap (ton/ha)	Yield Gap (Times)
Wheat	France (7.50)	6.81	2.83	4.98	1.37
Seed Cotton	China (4.00)	4.33	2.19	2.14	2.02
Sugarcane	Egypt (120.00)	300.00	56.00	244.00	1.23
Maize	France (9.90)	9.20	3.81	5.39	1.71
Rice	USA (7.40)	5.15	2.04	3.11	1.66

Source: FAO Statistical yearbook 2012

is emerging on high pace.

Soil conditions, experience of farmers and researchers and natural climatic conditions are very supportive for the production of good quality vegetables in Pakistan. Vegetable picking, grading, processing, and packing have not been mechanized. Government has supportive policy for the export of agricultural produce while competing international market requires conforming set standards which are possible with high tech handling system. This situation indicates emerging potential for the introduction of state of the art farm machines for vegetable picking, grading, processing and packing.

Tractor Industry and Available Tractor Power

Tractor manufacturing industry in Pakistan started with the establishment of Rana tractors (now Millat Tractors Limited) in 1964 and an assembly plant was set up in 1967 to assemble tractors imported in semi-knocked down (SKD) condition. Local manufacturing of the tractors under government approved deletion program started in 1981 and five firms were licensed to manufacture tractors. The manufacturers of Belarus, Ford and IMT tractors went out of business and now only two manufacturers are actively involved in local manufacturing of tractors. M/s Millat Tractors Ltd. Lahore and M/s Al-Ghazi Tractors Ltd. Dera Ghazi Khan are producing 8 models of tractors in the range of 50 to 100 hp. Both of the companies have well established manufacturing/assembling plants and network of distribution and after sale service throughout Punjab and Pakistan. M/s Millat Tractors Ltd. is producing 45,000 units annually while M/s Al-Ghazi tractors Ltd., has installed capacity of over 30,000 tractors on single shift basis. Besides these two major tractor manufacturers, few other manufacturers are also producing and marketing locally assembled and imported tractors on a limited scale.

Assuming all tractors before 1994-95 deleted, as per Agric. Statistics of Pakistan (2010-11), tractor produced and imported from 1994-95 to 2010-11 were 717,673. After accounting for estimated deletion @ 10 % i.e. 7,1767 tractors, working population of tractors was 645,906. Assuming average tractor power of 55 hp/tractor, total available power was 35,554,830 hp. Based on total cropped area of 27,480,000 ha (67,875,600 ac) available tractor power is 1.29hp/ha (0.52hp/ac) as compared to 3.56 hp/ha (1.4hp/ac) as considered appropriate for mechanization (Kendel, 2015). Present tractor production level is 60-70,000 per year whereas, required tractor production level shall be 150,000 per year to achieve desired level of farm power. In order to enhance tractor power, government is providing tractors to the farmers against subsidized cost.

Agricultural Machinery Industry

Over five hundred manufacturers of agricultural machinery are producing and marketing farm machines in Pakistan. These manufacturers have dispersed cluster in different provinces. In Punjab province, cluster of agricultural machinery manufacturers exist in the cities of Chakwal, Daska, Lahore, Faisalabad, Okara, Mianchannu, Multan and Rahim Yar Khan. In Sindh province, Hyderabad, Khayerpur, and Nawabshah have farm machinery manufacturing facilities. Peshawar, Mardan and Dera Ismail Khan are major farm machinery producing cities in Khyber Pakhtunkhwa (KPK) province.In Balochistan,Quetta, Hub and DeramuradJamalycitiesarethe potential places for manufacturing a few basic implements; so, Baluchistan mostly import farm machines from Punjab and Sindh provinces or from international market.

Large scale manufacturers have qualified; experienced and skilled work force with reasonable manufacturing facilities. Large scale manufacturers are capable to produce good quality farm machine/implements. On the other hand, mainstream of the manufacturers are small, illiterate and lack in modern manufacturing techniques. Agriculture Machinery lacks standardization which is resulting in loss of energy, inefficient farm operations, wastage of money & time, undue compaction, and postharvest losses etc. Production of good quality machines needs infrastructure, experienced workforce and good economic condition of end users. Availability of machinery standards, accessibility of required raw material with specific grades and availability of formally trained workers are the common difficulty faced by the manufacturers. Beside multiple challenges, Pakistan is producing good quality machines and exporting various farm machines to neighbouring countries in Asia as well as in Africa.

Agricultural implements and machinery manufacturing industry in Pakistan started with the establishment of Esakhel Estate Farm, Kot Samaba, District Rahim Yar Khan during early 50’s which played a vital role in promotion and dissemination of farm mechanization in Pakistan by importing the very first tractor in the country during 1954 and establishing a manufacturing unit for production of implements for mechanized farming with the collaboration of John Deere from USA. The Esakhel Estate Farm provided training to the farmers of the area and also provided repair and maintenance services for the tractors and implements.

During 1959, there were only 15

farm machinery manufacturers in the country. The number increased to 500 in 1984. The increasing trend of manufacturers during the period of 1978 to 1984 was due to the liberal government policies such as rebate in import duty for raw materials and exemption of income tax (Khan and Farooq, 1993). However, a setback has been observed in this industry by closing/reducing production by medium sized manufacturers due to withdrawal of above government incentives. Local farm machinery industry is producing a wide range of farm machinery except for the complex one like transplanters for vegetables and paddy, combine harvesters, sugarcane harvester, cotton picker, corn picker, fodder cutters cum choppers, balers for silage, hay balers, tedder rakes, mango pruner, carrot washer, fruit and vegetable grader etc.

In order to improve quality of locally made farm machines, US-AID provided training to the manufacturers. Several agricultural engineers have also been trained for productivity enhancement by countries like Japan, Netherland, China, USA and Canada.

Agricultural Machinery Census

The latest census of Agricultural machinery in Pakistan was to be conducted in 2014 but it has been delayed. The available data of the 2004 census as displayed in the **Fig. 1**, indicates increasing tendency of farm machine from 1983 to 2004. **Fig. 1** also shows that among reported farm machines, population of cultivator (369,866) is the highest followed by trolley (242,655) and wheat thresher (137,270). Proportional analysis of the figure for the period of twenty years (1984 to 2004) was carried out. The analysis suggests that among considered list of the machines, the highest annual proportional increase appeared in the population of ridger and the lowest increase in the population of thresher.

Farm Mechanization

Farm mechanization in Pakistan is not yet fully adopted and even today some farmers' especially small ones are using manual tools and bullocks to perform different farm operations. Due to low available farm power and poor economic condition of the farmers, existing level of farm mechanization in Pakistan is also quite low. For example, land preparation, pesticide application and wheat threshing are mechanized to greater extent while farm operations like cotton picking and rice transplanting are mostly done manually, in-spite of the fact that several efforts have been made in the past to mechanize these operations. During early 90's, two cotton picking machines were imported from USA and during 1994 one cotton picker was also imported from Uzbekistan. Similarly, root washed type rice transplanters were imported from Korea in 1978 and mat type nursery transplanters were imported from Japan during 1998.

For land preparation, primary as well as secondary tillage implements are used. Chisel plow, M.B. plow and Disc plow are main types of primary tillage implements while Disc harrows, cultivators, rotary tillers (rotavator) etc., are commonly used for secondary tillage. Conservation tillage practices such as zero tillage, stubble tillage and mulch or stubble tillage are also practiced on limited scale. Seedbed Preparation implements commonly used include clod breaker, cultivator and plank (sohaga). Use of rotary tiller and disc harrow for seedbed preparation is expanding.

For sowing of wheat in fields without stubbles, rigid tine type seed drills and coulter type seed drills are used while for sowing in stubble fields, zero-tillage drill, happy seeder and rocket seeders have been developed. Similarly for sowing of wheat, bed and furrow seed drills are also gaining popularity. For sowing of row crops like cotton, maize, sunflower, groundnut and others, horizontal plate multi-crop planters are commonly used. Similarly, pneumatic planters, inclined/vertical seed plate planters are used on a very limited scale. For planting of sugarcane, sugarcane set planters are also used on a limited scale. Similarly, for sowing of potato seeds, vertical cup planters are commonly used.

Pesticides application machinery commonly being used includes knapsack sprayers, tractor operated

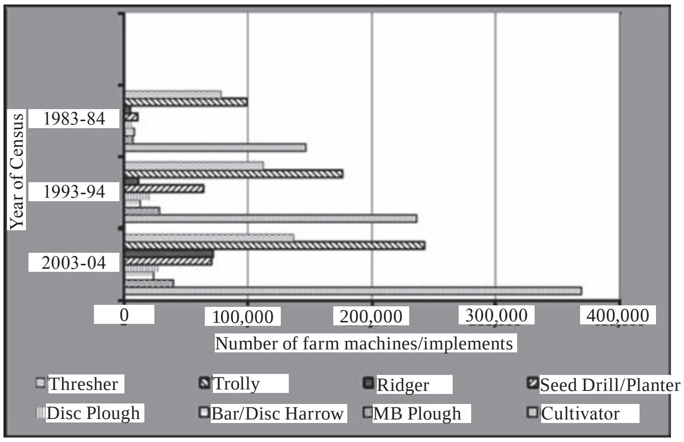

Fig. 1 Increase in the population of farm machines /implements from 1983-2004.

boom sprayers and hand held sprayers. Power knapsack sprayers (mist blower and piston/plunger pump type) are also used. For spraying of orchards, canon type mist blowers are also used. On a very limited scale hand held ULV sprayers are also used.

Harvesting of wheat and rice is conventionally done using hand sickles. Tractor mounted reaper windrowers and combine harvesters are also used to a greater extent. Threshing of wheat is mostly done with the help of stationary threshers which are powered through tractor PTO, engine or electric motors. Threshing of basmati rice is generally done manually, but on a very limited scale head feeding type threshers are also used. For threshing of coarse grain rice, whole crop threshers are also available.

For promotion of farm mechanization, provincial governments are providing selected machines to the farmers on cost sharing basis. Some of the machines which were distributed include sprayers, tractors, seed drills, planters, tillage implements, laser land levellers etc.

Land Resources Development Services

According to the Statistical Bureau of Pakistan (2013-14), about 8.27 million ha are lying as cultureable waste land. For development of cultureable waste land, tractor mounted front blade and bulldozers are commonly used (PBS, 2015). Tractor mounted front blades are available through private sector while bulldozers are available from the provincial Agricultural Engineering Departments. Provincial Agricultural engineering formations are providing bulldozers for development of cultureable waste land on subsidized rates.

Water Resources Development Services

Pakistan agriculture is mostly irrigated for which world's best canal system exists but it hardly provides 50 % of the irrigation water. In order to supplement canal irrigation, over 1,000,000 tube wells are being used which are powered through electricity or diesel engines. For groundwater development, provincial Agricultural Engineering formations as well as private sector is providing well boring machinery including manually/power winch operated percussion type boring plants and reverse rotary power drilling rigs. Direct rotary power drilling rigs are mostly provided by the private sector.

Beside well boring, groundwater exploration/divining services are also available through Punjab Agriculture Department. For groundwater exploration/divining, electric resistivity meters and for placement and location of pipes and filters, geo-loggers are used.

Water Management Services

Canal irrigation system of Pakistan provides about 50 % of the irrigation requirements. According to reported data, over 50 MAF of irrigation water is wasted through conveyance and during application. Improvement in farm layout and adaptation of irrigation scheduling technology to decide the quantity of irrigation and the time of irrigation are essential activities in process. Keeping in view the water scarcity, Government is attaching highest priority to water management and is providing different water saving technologies to the farmers on cost sharing basis through the provincial Water Management wings. The water saving services being made available include lining/improvement of water courses, laser land levelling equipment and high efficiency irrigation systems including sprinkler and drip irrigation systems.

Soil and Water Conservation Services

Soiland water run-off is a great challenge for the rain-fed agriculture of Pakistan where lands are mostly rolling. Zia *et al.* (2003) reported that 11.17 Mha (27.59 Mac) of land is affected by soil erosion and 3.5 Mha are affected by wind erosion. . In order to curtail soil erosion and run-off water loss, provincial soil and water conservation services are playing important role. The services being provided to the farmers for this purpose include provision of bulldozers to construct storage ponds/mini-dams, terracing and dikes making. Similarly, construction of check dams, retraining walls, water disposal outlets and tree plantation is done on cost-sharing basis.

Agricultural Mechanization Research

Agriculture mechanization research is carried out at federal as well as at provincial levels. Agricultural and Biological Engineering Institute (ABEI) is working at federal level while Agricultural Mechanization Research Institute (AMRI) and Agricultural Mechanization Cell are working in the provinces of Punjab and Sindh respectively. Both the institutions have played important role in local development of appropriate and low cost farm mechanization technologies. Some of the technologies developed by ABEI include reaper wind-rower, zero tillage drill, stubble mulch machines such as happy seeder and rocket seeder, bed and furrow seeders, sunflower threshers, paddy threshers and mobile seed cleaner graders. Some of the machines developed by AMRI include soil ripper, sulphuric acid applicator, wheat drill, wheat thresher, crop root stalk puller shredder, bed and furrow planter, coulter drill, sugarcane planter, potato planter, weed eradication equipment, fertilizer spreader, fertilizer placement drill, fodder mower, fodder chopper, seed cleaner cum grader, self-propelled hydraulic, air assisted boom sprayers, carrot washer and mango hot water treatment plant etc. Most of the machines developed by AEBI and AMRI are being produced and marketed by the manufacturers.

Agricultural Engineering Education

Agricultural engineering education in Pakistan is imparted by several universities and colleges including University of Peshawar (province of KPK), University of Agriculture Faisalabad, Pir Mehar Ali Shah Arid Agriculture University, Rawalpindi and Agriculture college of the Baha-ud din Zakariya (BZU) University, Multan (province of the Punjab) and Agriculture University Tandojam (province of Sindh). All the universities are offering BSc, MSc. And PhD degree programmes.

Protected Agriculture

Although Pakistan is blessed with the four seasons due to which fresh fruits and vegetables are available throughout the year but the farmers are also growing off-season vegetables in plastic covered tunnel type greenhouses. These tunnels don’t have any environment control system and only provide shelter from frost and help produce vegetables about 45-60 days earlier than the field sown vegetables. Reportedly, about 20,000 ha of land is under tunnel farming.

Conventional greenhouses with environment control systems for irrigation, temperature, light and carbon-dioxide are practically not-existing. Anyhow, one unit of hydroponic greenhouse has been established by one of the Dutch company and was later handed over to Government of the Punjab for research and demonstration purpose.

Renewable Energy Resources

Use of renewable energy resources in farm mechanization is increasing with the passage of time. Several hundred solar and biogas operated tube wells are being used in the country. Similarly, one 12 MW electricity power plant operated with biomass is functional while three others are being set up.

Cattle and Fish Farm Mechanization

Multiple Agricultural businesses are developing and require local and international collaboration. Emerging requirements for mechanization have been noticed for cattle farming, milk and meat processing, fish pond mechanization.

Provincial and federal government have set vision to expand cattle farming in Pakistan. In cattle farming two separate options are gaining popularity: one is dairy farming to meet the demand of milk and the other is animal fattening to encounter the need of meat (beef). The dairy farms are located in the peri-urban areas of the major cities while farms for animal fattening are scattered all over. Most of these farms are established without scientific planning for construction of buildings, roads, water supply and drainage and assessment for requirement of farm machines to support the cattle farming operations.

In Pakistan, around 57 million dairy animals (cows and buffaloes) have worth of nearly RS.1.5 trillion and contributing to the national economy to the tune of RS.1.2 trillion per annum (Qureshi, 2008). This makes the country 5th largest producer of milk in the world but only 3.0 % of produced milk is being processed (LDDB, 2015). A few milk processing plants have been installed in the country and serious shortage of milk chillers in the milk pocket can be a potential reason for small proportion of milk processing. Increase in milk plants with expansion of chillers network offer a good investment.

Pakistan Government has recognized the remarkable potential for growth in livestock farming and has taken initiatives by introducing legal framework to make it more investment friendly. To promote this business; Dairy Development Board and Pakistan Dairy Development Companies have been established and Pakistan has allowed duty free import of all related farm machines (LDDB, 2015).

Cattle feed mills can hardly accommodate less than 5 % of the requisite secure feed essentials. The mandate for livestock feed of various types for dairy, fattening, bulls, etc. is categorically increasing resultantly cattle feed industry is expected to grow. Fodder seeding/planting machines are in the phase of local development and adaptation. Beside great demand, limited sets of forage harvester, silage balers and wrappers are in use. High cost of imported machines is one of the challenges faced by livestock farmers.

Rapidly increasing demand for red meat such as mutton and beef in the country has made feedlot fattening a prospective investment. Setting up of slaughter houses and model butcheries with grading system offers good added value. Accordingly, in Pakistan, there is a tremendous scope to institute state of the art slaughter house by-product plants for better profitability through export.

Pakistan has marine and inland fishery resources with the estimated potential of 1 million tonnes of fish/year from the marine subsector only (FAO, 2009). Beside marine subsector cultivation of pond fish has established as an alternate farming business. According to an estimate, the total area covered by fish ponds is about 60,500 ha and about 13 000 fish farms have so far been established across Pakistan, and the average farm size is 5 to 10 ha (FAO, 2009).

Pond fish farmers are facing multiple challenges such as aeration of pond to maintain desired level of dissolved oxygen, catching fish during cold weather, removal and management of fish waste. A few Fish Pond Paddlewheel Aerators, Toring Turbines and Aero-tube fish pond aeration systems have been introduced in the country on very limited scale. Farmers use conventional net for fish catching. Fish waste management is poorly addressed and this potential resource is not being properly utilized.

Recommendations

Following recommendations are made:-

1. Provincial Agriculture Machinery Boards (PAMB) should be established in Pakistan to introduce, implement and monitor the recommendations for the adaptation of modern mechanization techniques.
2. Agricultural mechanization extension services should be established as a separate wing in all provinces of Pakistan.
3. Manufacturing standards of agriculture machines and implements should be developed with the collaboration of federal and provincial stake holders.
4. Health and safety standards should be developed for the user/operator of agriculture machinery.
5. Develop mechanism to check and verify agriculture machinery standards being implemented.
6. Capacity building of manufacturers/users of agricultural machinery about operation, maintenance and health & safety standards.
7. Japan may establish regional farm machinery manufacturing units in Pakistan by making joint venture with the local manufacturers.
8. Japan may make these centers as hub to market farm machines in developing countries of Asia as well as Africa.

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BANGLADESH

Status of Demand and Manufacturing of Agricultural Machinery in Bangladesh

by

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Abstract

This paper presents briefly the current status of agricultural machinery manufacturing sector in Bangladesh. Both public and private institutions are involved in manufacturing agricultural machines and equipment including spare parts of all types. Some statistical information on import of agricultural machinery and their market size have been presented. Constraints affecting manufacturing have also been discussed.

Introduction

Bangladesh is situated on a deltaic plain with a system of meandering rivers subject to flooding, and a small hilly region in east and south-east. The country has an area of 147,610 square kilometers including 13,830 square kilometers of water bodies. Bangladesh is an agricultural country whose main farm produces are rice, jute, potato, vegetables, fishes and poultry. Over 88 % of farms belong to marginal and small holding categories (**Table 1**) which is a limiting factor for agricultural mechanization.

Bangladesh transformed its agricultural sector into a productive farm economy during the last three decades. Farm power (human, animal or mechanical) for crop establishment, irrigation, harvesting, processing, and transport has become a critically important input for agricultural production. Irrigation is now practically fully mechanised as more than one million diesel and electric pumps lift ground and surface water. Survey reports indicate that by 2011 about 80 % of the land was tilled with two-wheeled 'power tillers' and 4-wheel tractors while marginal farmers had access to these machines through private contractor services. Custom hiring system in Bangladesh started with Power Tiller (2WT) and Tractor (4WT) in early seventies and at present it is gaining momentum. In the past rice was milled with

Table 1 Different Categories of Farm Holdings in Bangladesh

Farm holding sizes	Percent
Marginal farm holdings (0.05-0.49 acre)	38.63
Small farm holdings (0.5-2.49 acres)	49.85
Medium farm holdings (2.5-7.49 acres)	10.35
Large farm holdings (above 7.50 acres)	1.17
Total	100.00

Source: BBS (2013)

the foot operated 'dheki' but today mechanised rice hullers and mills have taken over this task. Institutions and enterprises involved in fabricating farm machinery are described below.

Manufacturing Institutions

Agricultural Machinery Manufacturing Association of Bangladesh (AMMA-B): This is a private sector association that works for profitable growth of this sub-sector and to identify problems, constraints and opportunities of the farm machinery industry in Bangladesh. AMMA-B was established in 2005 (BAMMA, 2011). The Association is also trying to unite all the manufacturers exclusively involved in the manufacture and marketing of farm machinery to work for a common cause and benefit. It has more than 68 members. AMMA-B provides information and services to its member and acts as a platform for the members to develop the industries.

Agricultural Machinery Manufacturers

There are about 250 private agricultural machinery manufacturers in the country (ITDG-Bangladesh, 2003). MAWTS in Dhaka, Alim Industries in Sylhet, Farida Engg. Works and Kamal Machine Tools in Bogra, Janata Machine Tools Ltd in Jessore, Aulad Engg. Workshop in Keshoregonj, Mahabub Engg. Workshop in Jamalpur, Uttaran Engg. Ltd in Dinajpur, Comilla Cooperative Karkhana in Comilla, RDRS Engg. Workshop in Thakurgaon are some of the well known private agricultural machinery manufacturers in the country. They manufacture locally developed agricultural machinery such as hydro tiller, IRRI power tiller, rice thresher, axial thresher, seed drill, urea briquette applicator, irrigation pumps, straw chopper, reaper, potato planter, maize sheller, rice huller, winnower, weeder etc.

Bangladesh Machine Tools Factory (BMTF) is the only public sector farm machinery manufacturer in the country. Managed by the Bangladesh Army, it produces a limited number of agricultural machinery on demand only. These are mainly, reapers, urea briquette applicator, maize sheller, and weeders.

Import of Agricultural Machinery

About a dozen of multinational and national business firms are promoting agricultural mechanization through import of large and medium categories of agricultural machinery, namely, tractor, power tiller (two wheeler), diesel engine, combine harvester, rice transplanter, reaper, rice huller, grain dryer, seed drill, disk plow, disk harrow, pumps, etc. ACI Motors, The Metal Pvt Ltd, Karnafuli Group, Corona Ltd, Chittagong Builders Ltd., Rahim-Afroz Ltd, RFL Ltd., Runner Group, Gatco Ltd, Mollik Brothers, Krishibid Farm Machinery and Automobiles Ltd are the main importers of the machines. Among all imported agricultural machinery the volume of import of power tiller (two- wheeler) ranks top of the list counting more than 45,000 per year and is decreasing steadily. Tractor (four wheelers, 45 to 60 hp) ranks next to power tiller, volume of import is at least 3,550 per year (**Table 2**). The Metal Pvt Ltd, ACI Ltd, and Karnafuli Group imported, respectively, 26 %, 22 % and 21 % of all the tractors during 2012-2015. These are imported mainly from India having zero tax/tariff. Power tillers (two wheelers) and diesel engines (6-12 hp) are mainly imported from China. **Table 2** shows the import statistics of agricultural machinery in Bangladesh. It also indicates that number of rice transplanter, reaper and the combine harvester are increasing steadily.

Growth of Local Manufacturing Industry

During the last couple of decades, rapid growth and transformation in agriculture has triggered expansion of rural non-farm activities, especially, manufacturing and services activities at the local level. These include manufacturing and trading of farm machinery and equipment spare parts, machinery installation, repair and maintenance services, inputs and grain trade, crop and food-processing, rural transport, rural trade and shop keeping, etc. Most of

Table 2 Import Statistics of Agricultural Machinery in Bangladesh

Product	Years									
	2015*		2014		2013		2012		2011	
	No.	Million USD	No.	Million USD	No.	Million USD	No.	Million USD	No.	Million USD
Tractor (4 wheel)	4,500	42.75	4,000	38.00	3,550	33.73	5,000	47.50	8,500	80.75
Rotary Tiller	2,000	4.20	1,800	3.78	1,600	3.36	1,500	3.15	2,000	4.20
Power Tiller (2-wheel Tractor)	45,000	49.50	50,000	55.00	55,000	60.50	60,000	66.00	65,000	71.50
Rice Transplanter	140	0.434	100	0.31	75	0.23	60	0.19	50	0.16
Reaper	550	0.83	250	0.38	100	0.15	50	0.075	24	0.04
Combine Harvester	40	1.12	20	0.56	20	0.56	10	0.28	10	0.28

Source: The Metal (Pvt) Ltd; *Up to November 2015 the enterprises are very small and belong to the 'non-formal' category.

Bogra has emerged as the largest agri-machinery industrial town in Bangladesh and manufacturing about 80 % of local machines and spare parts, especially irrigation pumps, threshers, maize shellers, piston, liner and numerous spare parts of small diesel engines and machines, and casting of machine components. Jessore is emerging next to Bogra. Other well known centers are located in Dhaka, Chittagong, Comilla, Tangail and Kustia districts. The significant shift in the supply of spare parts in the country underlines the growth potential of the local spare parts manufacturing sub-sector and potential for substitution of imported spare parts. At present, there are about 70 foundries, 250 agri-machinery manufacturing industry and workshops, 1500 spare parts manufacturing industries and workshops. In line with manufacturing of agri-machinery and spare parts, there are about 20,000 repair and maintenance workshops and about 500,000 mechanics are involved in repair and maintenance of engines and machines used in agricultural activities (Alam *et al.*, 2011). Spare parts of power tiller, diesel engine and centrifugal pump are both imported and locally produced. This saves a huge amount of foreign currency and decrease dependency on import. The spare parts sub-sector is employing a significant number of skilled and semi-skilled labour forces. However, this sub-sector is still lacking the attention of the policy planners of the country (Alam *et al.*, 2011).

Besides most common agri-machinery and spare parts production, a few items like drum seeder, push-pull weeder, potato harvester, potato grader, fish and poultry feed machine, rice grader, rice polisher, auto crusher machine, auto mixture machine, oil mill, chira/puffed rice mill, rice huller, hot mixture machine, cereal dryer, etc. are being manufactured in the country. This sub-sector remains unexplored and there is a huge potential for growth and employment generation.

Production of spare parts including piston and liner, clutch bush, governor bush, housing, silencer, chain cover, bush guide, etc. has a significant share in the domestic market as well as informal export market in Nepal, Bhutan and India. Some locally produced parts such as, centrifugal pump casing and impeller, engine fuel filter, rocker-arm, chain cover, pulley, etc. are good in quality and captured the local market by replacing imported items.

Market Status of Agricultural Machinery in Financial Terms

A study on current market size of agricultural machinery, conducted by Alam and Khan (2013) is presented in **Table 3**. It indicates that the annual estimated market size of agro-machinery and spare parts in the country is about USD 814.89 million with Tk. USD 110.50 million annual repairs and maintenance service market. Estimated total annual agro-machinery market size is about USD 925.39 million, of which local production market share is USD 423.00 million which is about 42.30 % of the total market size.

Table 3 Annual Market Size of Agri-machinery in 2011

Agricultural machinery	Market size/yr. (Million USD)
Power Tiller & Rotary Tiller	75.70
Tractor (4-wheel)	80.75
Engine (STW*, Thresher, Corn sheller)	270.00
Centrifugal Pump (STW* & LLP**)	17.50
Thresher (Open & Close drum, local)	41.50
Maize Sheller	1.81
Sprayer (local)	1.57
Sprayer (imported)	0.38
Weeder	0.68
Local Spare Parts	250.00
Imported spare parts	75.00
Sub-total	814.89
Repair & Maintenance	110.50
Total market size	925.39

*Shallow tube well; **Low Lift Pump

Constraints Affecting Manufacturing

Agricultural machinery manufacturing in Bangladesh still belongs to very small scale enterprises in the so called 'informal' industrial sub-sector. The major constraints faced by the relevant enterprises and organizations include inadequate linkage with R&D institutes, use of age-old machineries and technologies resulting in quality-compromised products, high price of raw materials, poor quality of raw materials, lack of skill and technical knowledge related to metal casting, heat treatment etc., lack of testing facilities for maintaining quality of products, lack of working capital, lack of non-interrupted supply of electricity, inadequate spaces for the manufacturing industries and inappropriate policy related to tariffs on imported raw materials.

For sustainability, this sub-sector needs preferential treatment and the Government of Bangladesh is considering the following points to mitigate the problems.

1. Establishment of 'Agro-machinery Production Zones (APZ)' on the outskirts of Bogra and Jessore towns to accommodate existing and potential agro-machinery industries and workshops;
2. Establishment of a 'Central Institute of Agricultural Engineering (CIAE)' for continuation of innovation through R&D on Government institutions and development partners initiative;
3. Establishment of National Standardization Committee for agri-

machinery, implements and spare parts;
4. Access to soft and flexible long and mid-term credit facilities for capital machinery and working capital;
5. Policy options for zero tariff/ nominal tariff on import of modern capital machinery and essential raw materials for agro-machinery production sub-sector;

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BANGLADESH

Research on Agricultural Machinery Development in Bangladesh

by

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Abstract

This paper briefly discusses the research on agricultural machinery development in Bangladesh and the institutions involved. More than two dozens of agricultural machinery have been developed by several public and private institutions with the support from international organizations. Research and development on agricultural machinery and equipment in Bangladesh is progressing at a pace slower than expected. The constraints and suggestions for improvement have also been addressed.

Introduction

Bangladesh has made a remarkable progress in producing cereal grains (rice, wheat, and maize) and to some extent, vegetables like potato, tomato, cauliflower, cabbage, egg plants, beans, etc. through use of improved seeds, use of needed agro-chemicals and mechanization for tillage, irrigation and threshing. Among many agricultural inputs, agricultural machinery plays an important role in promoting crop production to a targeted level to sustain self-sufficiency in cereal production in the country which has increased more than two folds over the last two decades to 38.0 million tons in 2013. The government has already attributed due importance to agricultural mechanization and machinery research in the National Agricultural Policy (MoA, 2013). In recent past, significant improvements have been made in the production and marketing of locally made agricultural machinery in the country.

Almost all centrifugal pumps being used in Shallow Tube Wells (STW) and Low Lift Pumps (LLP) are manufactured in the country. Similarly, rice and wheat thresher, maize sheller, hand and foot-pump sprayer, weeder, engine and machine spare parts are also being designed and manufactured locally. A few more items like drum seeder, push-pull weeder, potato harvester, potato grader, fish and poultry feed machine, rice grader, rice polisher, auto crusher machine, auto mixture machine, oil mill, chira/puffed rice mill, rice huller, hot mixture machine, cereal dryer machine etc. are also being manufactured in the country. Though these machines were basically designed and developed elsewhere, many underwent some adaptive development in Bangladesh.

Today, locally developed farm machinery such rotary tiller, hydro-tiller, irrigation pump, sprayer, closed drum thresher, maize sheller, potato planter, high speed rotary tillers (HSRT) and power tiller operated seeders (PTOS), versatile multi-purpose planter (VMP), power tiller operated bed maker-cum-seeder, seed-cum-fertilizer applicator, urea super granule (USG) applicator, reaper, mobile rice hauler etc. are being used by the Bangladeshi farmers. Adaptive research and development on theses machinery is also progressing to cope up with rapid social, economic and environmental changes in Bangladesh (Miah *et al.*, 2014; Hussain, 2015; Wohab, 2015).

Most of the R&D activities are aimed at adapting the machines and implement to local conditions of small farm holdings, replacing imported items with locally producible ones and finding innovative engineering solutions for the problems related to production and processing of local produces.

Research and Development Activities at Public Institutions

Bangladesh Agricultural Research Council (BARC)

The major objectives of the council are to identify priority areas of research under the guidelines of the national agricultural policy. As an apex body of National Agricultural Research System (NARS) supports all categories of R & D activities including funding for agricultural machinery development and agricultural mechanization in Bangladesh.

Bangladesh Agricultural Research Institute (BARI)

BARI, having nationwide research stations, is responsible for conducting research on all crops and its related agricultural machinery except rice, jute sugarcane, and tea, for which there are separate institutes. There is a separate unit of BARI known as Farm Machinery and Post Harvest Processing Engineering Division. A good number of agricultural machinery such as zero till drill, reaper, thresher, winnower, urea briquette applicator, potato planter, potato grader, onion cutter, maize sheller, and weeders has been developed by this division.

Bangladesh Rice Research Institute (BRRI)

BRRI, located in Gazipur has a well established department known as Farm Machinery and Post-Harvest Technology Division. Several field machines related to rice culture such as reaper, thresher, urea briquette applicator, rice dryer, winnower, dry and wet land weeder have been developed and disseminated.

Department of Agricultural Extension (DAE)

Department of Agricultural Extension is a well established and the oldest institution for promoting agricultural technologies to farm level and to bring farm level problems to research institutions for solution. It provides a vital link between the R&D institutes and the farming communities regarding the farming problems and the needs of research and development works.

Bangladesh Agricultural University (BAU)

The premier seat of higher agricultural education and research in the country covers all the domains of agricultural sciences having a separate faculty of Agricultural Engineering and Technology. Several farm machines such as reaper, rice dryer, solar dryer, seed-cum-fertilizer applicator, sprayer, etc. have been designed and developed here. In addition to donor funded research, post-graduate (M.S. & Ph.D) level research is being carried out in this subsector.

Rural Development Academy (RDA)

RDA is a public institution responsible for rural development in general. However, most of its development activities are focused on agriculture and agri-industries, including agricultural mechanization. This institute is also involved in doing limited adaptive research on agricultural machinery development and promotion in Bangladesh.

Activities at Private Institutions

Very limited adaptive research on agricultural equipment is also being carried out by several non-government institutes, namely, BRAC, Practical Action, ActionAID, and CARE. Agricultural machinery business firms like, ACI Motors, The Metal (Pvt.) Ltd, MAWTS, Alim Industries are also performing limited R & D activities in collaboration with public institutions.

Support from International Organizations

International organizations like International Rice Research Institute (IRRI), International Maize and Wheat Improvement Center (CYMMIT), USAID, SAARC Agriculture Centre, FAO, DFID, KOICA are providing technical and financial support in R & D activities to the public institutes in Bangladesh.

Constrains Affecting R&D Activities and Suggestions for Mitigation

The agro-machinery sub-sector is still recognized as a part of non-formal industrial sector. Very limited effort has been made so far to assess the market demand and supply, needs of improving coordination of R&D with fabrication and marketing and the needs of modernizing the technology involved in it. The private sector is not expected to establish a strong R&D program for farming and processing machinery in the near future;

The public sector institutions lack a master plan for mechanization of agricultural production and agro-processing activities based on national food and agricultural policies; irregular and uncertain funding and lack of sustainable collaboration among R&D capable institutions are hindering R&D activities today.

The following activities are suggested to help necessary R&D activities without much delay (Ahmmed, 2015).

1. Establishment of a 'Central Institute of Agricultural Engineering (CIAE)' for continuation of innovation through R&D with government and non-government organizations and development partners initiatives, along with a well equipped fabrication workshop and adequate funds for running a core program;
2. Formation of a high level National Agricultural Mechanization Committee for formulating and periodically updating Agricultural Mechanization Policy and guidelines for testing and standardization of agricultural machines, implements and spare parts;
3. Modernization of local foundries and workshops through collaboration and experience sharing activities among the Asia-pacific region and industrialized countries;
4. Strengthening capacity of agro-machinery entrepreneurs through transfer of proto-type machines and technologies among the industrialized countries of the Asia-pacific region and, visitation and training of proper personnel in countries which have achieved success in developing and producing farm machinery.

Conclusions

Research and development on agricultural machinery and equipment in Bangladesh is progressing at a pace slower than expected. Farmers want affordable and appropriate machines and implements to enhance production and productivity. Both ownership and custom hiring of farm machines are increasing in Bangladesh. Small size of farm holdings, high intensity of cultivation and need of soil conservation, reduction of harvesting and post-harvest losses and value addition to the produces demand accelerated R&D activities. The above mentioned suggestions are expected to invigorate needed R&D activities to meet the expectation of the agricultural sector of Bangladesh.

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THAILAND

Agricultural Mechanization in Thailand: Current Status and Future Outlook

by
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Abstract

Mechanization plays pivotal role in Thailand, where agriculture is rapidly transforming from subsistence farming to agribusiness model on the country's 46.6 % total land allocation to agricultural activities. With average farm size of 4.04 ha/household, Thailand is a host of 5.9 million farms on 23.9 million ha agricultural land or 46.6 % of the total land area. Nearly 50 % of the total agricultural land is cultivated for rice, 21.5 % for field crops, and 21.2 % for fruit or horticultural crops. Agricultural mechanization for rice production has been the most impressive when compared to other crops in Thailand. Central plain of the country is the highest and nearly full mechanized region. The number of agricultural tractors per 1,000 ha of arable land in Thailand has exponentially increased since 1960s; on an average there are above 50 tractors per 1,000 ha of arable land. Currently there are two modes of utilizing agricultural machinery: as an owner and/or through custom hiring service. There exists considerable variation across the regions in Thailand in terms of agricultural machinery utilization. Labor shortage and necessity to lower production cost in agriculture make mechanization an inevitable solution in the present agricultural landscape in Thailand. It is expected that the demand for agricultural machinery will continue to increase in coming decade. However, different regions require different mechanization solutions. There seem to be a growing market for 4-wheeled tractors under 30 kW, along with matching rotary implements- which would be replacing the existing power tillers in rice production systems of Central plain and Northern regions. This paper reviews the current status of agricultural development, agricultural mechanization and agricultural machinery industry in Thailand, and discusses the trends to present future outlook.

Keywords: Agriculture; Agricultural mechanization; Agricultural machinery industry; Status; Outlook; Thailand

General Background

Thailand is a tropical country

Table 1 Geography of Thai agriculture

Region	Key characteristics
Northern	Mountainous and low population density; Smaller landholding; Larger proportion of farmers specialized in high-value crops (fruits and vegetables)
Northeastern	The most agricultural region, with almost half of the Thai farmers; Less favorable agro-ecological conditions; Lowest agricultural productivity; Highest incidence of rural poverty; Smallest farm size per household but mostly owned by themselves
Central	Historic rice basket of Thailand; Having the most irrigated land; Commercial agriculture; High agricultural productivity but the lowest share of agriculture to its economy; Largest farm size per household; Highest rented holding area per farm
Southern	Rainfall spread all over the year; Highly suitable agro-climatic conditions; Low density of population; Specialized in rubber production

having three distinct seasons- hot and dry season (February to May), rainy, cooler season (June to September) and dry and cooler season (November to January). Topography and drainage define four main regions in the country; important characteristics of these regions are summarized in **Table 1**.

Agriculture is an important sector and remains the largest source of employment to Thai population, despite the fact that employment in this sector has been sharply diminishing- from 64 % in 1990 to 48.8 % in 2000 and currently 39.9 % (FAO, 2015). Being one of the world's net agricultural exporters, Thailand is a host of 5.9 million farms on 23.9 million ha agricultural land or 46.6 % of the total land area (OAE, 2015). **Table 2** presents the land utilization in the country during 2010-2013. Nearly 50 % of the total agricultural land is cultivated for rice, 21.5 % for field crops, and 21.2 % for fruit or horticultural crops (Mrema *et al*., 2014). With five important crops, in terms of cultivated area and value of production –rice (10.75 ha), maize (1.11 million ha), sugarcane (1.14 million ha), cassava (1.03 million ha) and soybean (0.16 million ha), field crops altogether constitute more than 60 % of the agricultural GDP (OAE, 2015). **Table 3** presents the agricultural land use of the country.

Irrigated area is limited and not equally spread throughout the country. Irrigation system is still in developmental phase that restricts growing more crops per season. Currently approximately 6.42 million ha agricultural land is irrigated (FAO, 2015). Approximately, 75 % of rice grown in rainfed areas and about 25 % rice is grown in the irrigated areas (Soni and Ou, 2010). About 11.7 % of irrigated rice area is in the central plain, while 6.4 %, 5 % and 1.4 % in the northern, northeast and southern regions, respectively.

Rice is an important crop for Thailand. **Table 4** presents area, production and yield of rice during 2005-2014. The major rice planted area in year 2014-15 decreased from previous years due to the change of government policy, declining price, and farmers' decision to switch to plant sugarcane which provided higher returns and market certainty. However, the yield slightly increased because the adequate rainfall. The second rice planted area also decreased from previous years due to lower water levels in major dams being not enough to cultivate, and declining price. The yield also slightly decreased because of insufficient rainfall (Soni *et al*., 2013; OAE, 2015).

Agricultural sector contributes to 10.5 % of Thai GDP (FAO, 2015), which is relatively smaller contribution since few years. However, the overall trend seems to be increas-

Table 2 Land utilization of Thailand, 2010-2013

	Total land (million ha)	Forest land (million ha)	Agricultural land (million ha)	Farm size (ha/HH)	Number of farms (million)
2010	51.3	17.2	23.9	4.07	5.88
2011	51.3	17.2	23.9	4.07	5.87
2012	51.3	17.2	23.9	4.04	5.91
2013	51.3	16.3	23.9	4.04	5.90

Source: OAE (2015).

Table 4 Rice (Major and second rice): Area, production, yield 2005-2014

Year	Planted area (1000 ha)	Harvested area (1000 ha)	Production (1000 t)	Yield (kg/ha)
2005	10,828	10,225	30,648	3.00
2006	10,819	10,165	29,990	2.95
2007	11,230	10,669	32,477	3.04
2008	11,172	10,684	32,023	3.00
2009	11,635	11,140	32,398	2.91
2010	12,908	12,120	36,004	2.97
2011	13,345	11,957	38,102	3.19
2012	12,966	11,957	38,000	3.18
2013	12,363	11,706	36,839	3.15
2014	11,592	11,130	33,808	3.04

Source: OAE (2015).

Table 3 Agricultural Landuse of Thailand, 2010-2013

	Total agricultural land (million ha)	Agricultural land use (million ha)				
		Paddy	Upland field crop	Orchard and perennial crop	Vegetable and ornamental plant	Other agricultural landuse
2010	23.91	11.24	5.01	5.55	0.22	1.88
2011	23.88	11.20	4.98	5.59	0.22	1.89
2012	23.88	11.19	4.98	5.59	0.22	1.89
2013	23.88	11.19	4.98	5.59	0.22	1.89

Source: OAE (2015).

ing (**Fig. 1**). The average farm size slightly declined from 4.07 in 2010 to 4.04 ha/HH (2013) (OAE, 2015). **Table 5** presents the average farm size in Thailand. Similarly, the agricultural land per capita of agricultural EAP shows declining trend over past three decades (FAOSTAT, 2013) (**Fig. 2**). The farmers in the Central plain region had the largest farms, followed by farmers in the Northern, Southern and the North-eastern regions (Chalachai *et al.*, 2013).

Table 5 Average farm size in Thailand

Year	Average farm size (ha/HH)
1995	4.20
1996	4.00
1997	3.96
1998	3.91
1999	3.71
2008	4.15
2009	4.08
2010	4.07
2011	4.07
2012	4.04
2013	4.04

Source: OAE (2015).

Amidst the impressive economic growth, like in many other Asian emerging market economies, Thailand is also facing rapid industrialization-led-urbanization. Traditionally an agricultural country, Thailand is on the ramp of transforming to middle income market economy. Out of its 67.2 million population, currently 43.5 million people live in rural settings, which is nearly 66.7 %; which was 70.5 % in 1990, and 68.9 % in 2000 (FAO, 2015). It is now increasingly realized that this urban-rural divide leaves peasants behind and causes an agricultural problem in this high performing Asian economy (Hayami, 2007). Moreover, agriculture is no longer the major share of household income in Thailand; farming contributed only around 28 % of Thai households' income (NSO, 2013).

These might necessitates appropriate structural change towards professional farming and creation of sufficient farm size and organization (Leturque and Wiggins, 2011). The need for modernization of agricultural through mechanization of

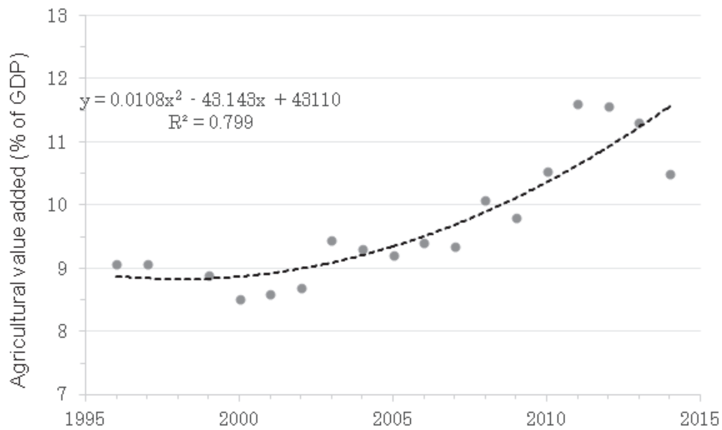


Fig. 1 Agricultural value added in Thailand, expressed as proportion of GDP (Source: World Bank, 2015)

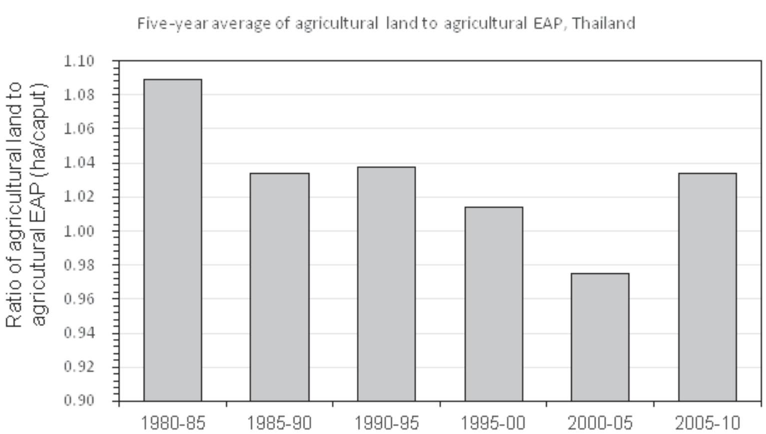


Fig. 2 Five-year average of agricultural land to agricultural economically active population in Thailand (Source: Data compiled from FAOSTAT, 2013)

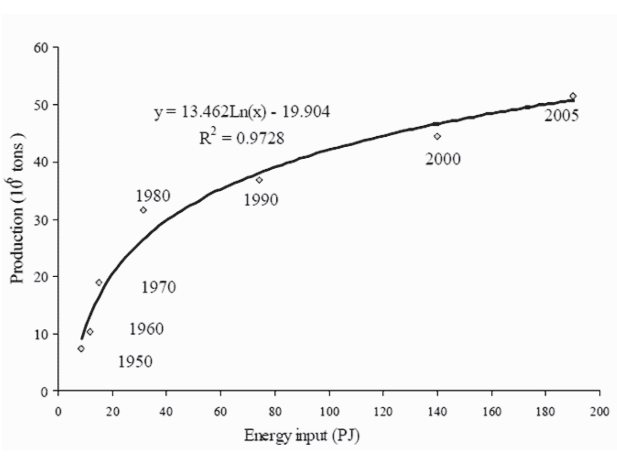
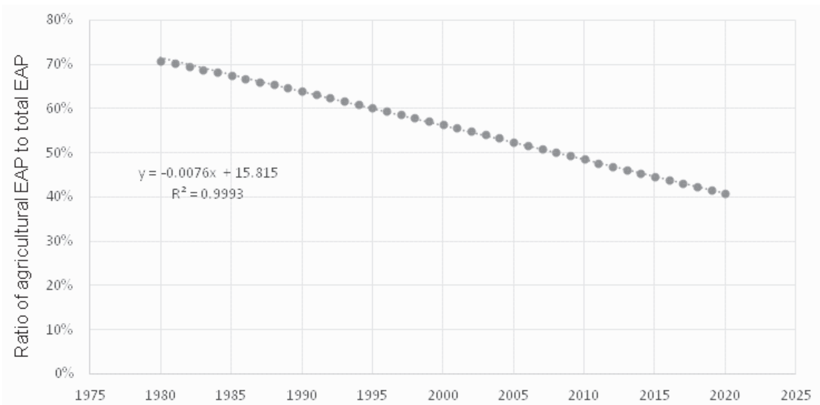


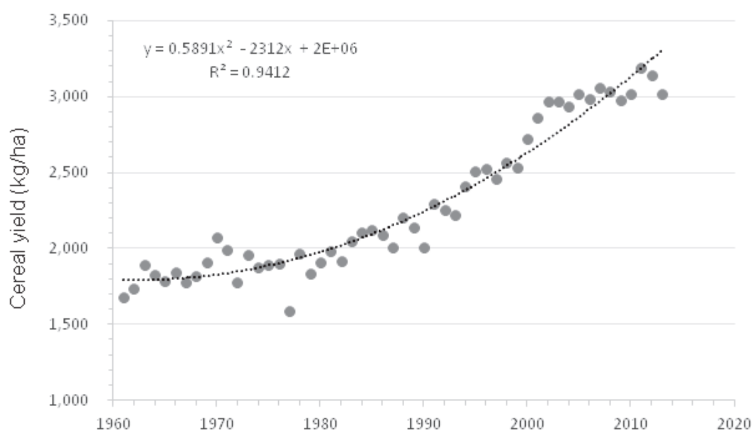
Fig. 3 Relationship between energy input and crop production in Thailand

its operation, is therefore inevitable. The agricultural value added per worker in constant US$ has increased from $645 in 1990 to $803 in 2000, to currently $1,195 (FAO, 2015). In a survey on investment behavior of rural households in Northeast Thailand, Hohfeld *et al.* (2012) found that only about one-third of the households in the region invest in agriculture; most investments are made in mechanization.



(Calculated from FAOSTAT, 2015)

Fig. 4 Ratio of economically active populations: Agriculture to total in Thailand



Source: World Bank (2015)

Fig. 5 Cereal yield in Thailand

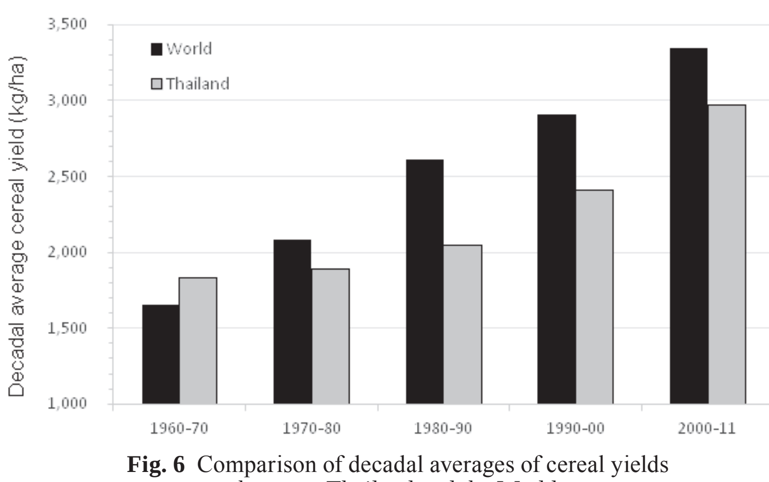


Fig. 6 Comparison of decadal averages of cereal yields between Thailand and the World

Growth in Agriculture

Growth in agriculture in Thailand can be understood as three distinct stages: a) Rice monoculture / natural resource-based agriculture (prior to 1955), b) Land-based resource / labor-intensive agriculture (1955-1985), and c) Structural shift in agricultural production (post 1985). Performance of agricultural production in Thailand was analyzed by Chamsing (2007) in terms of relationship between crop production output and energy input (**Fig. 3**). By 2005, the total energy input had increased by about 22 times compared to 1950, while the crop production had increased by about six times only. Most of this increase in energy input is caused by increased contributions from chemical fertilizers, pesticides and mechanical energy inputs.

Over the past five decades, Thai agriculture has grown at rates of 4.1 % p.a. initially (during 1962-1983), later slowing to 2.2 % p.a. (during 1983-2007) –while being more urbanized and industrialized (Leturque and Wiggins, 2011). Thai agriculture has been successfully managing the transition from expansion: a situation when it was possible to accelerate agriculture by utilizing abandoned factors of production to work without much improvement in productivity, to a later situation intensification: where land and labor become increasingly scarce and growth could only be realized through improved returns to these factors. Thai agriculture has done equally well in ensuring food security to its growing population. Growth in agriculture has overall contributed to reduction in rural poverty and increasing nutrition and food security. Dietary energy supply in kcal/per-capita/per-day has increased from 2,237 in 1990 to 2,580 in 2000 to currently 2,847 (FAO, 2015).

During 1960s to early 1980s, expansion of agricultural land was possible through squatting of forest fronts. This expansion could absorb excessive labor force resulted from the population expansion. During that period, agriculture was the key driver of the country's economy where about 70 % of the economically active population was employed in this sector. Later on, agriculture experienced the transition; the country witnessed rapid economic growth led by industrialization and manufacturing. Migration of rural laborers to seek non-farm jobs in urban setting became common (**Fig. 4**). Contemporary to that, it was no longer possible to expand new land for agriculture. Eventually the agricultural growth slowed down considerably. However, due to increased mechanization, capital intensiveness and availability of rural credit, productivities of labor and land increased significantly. Introduction of high yielding varieties and increased application of inputs resulted in increasing yields (**Figs. 5-6**). However, still there is room for further improvement, as the country still falls behind the world average of cereal yields.

Table 6 Chronological review of evolution in Thai agricultural mechanization

Indicative year	Key milestone in Thai agricultural mechanization
1891	Steam powered tractor and rotary hoes imported by Govt. [Unsuitable for paddy fields; Expensive]
1920	Some Ag machines imported for trial at Rangsit Rice Station (Central region) [Lack of trained local personnel; Onset of WW-2]
1947	Single axle 4.4 kW gasoline engine tractor with rotary hoes imported [Unsuitable for swampy fields due to low chassis]
1950	4-Wheeled tractors introduced by Rice Experiment Station on contracting basis [Project remained unsuccessful]
1955	262 tractors imported from various countries [Most successful remained Japanese power tillers]
1956-57	Local workshop started simplifying designs of imported tractors [Lowered cost; Suitable for local conditions]
1957	Axial flow pump design released by Agricultural Engineering Division of MoAC [Commercially popular and widely adopted]
1958	Design of a 25 hp 4-Wheeled tractor (Iron-buffalo) released by Agricultural Engineering Division to two private firms [Could not compete with imported tractors due to high cost; Firms stopped producing] First prototype of rice combine harvester designed (attached with 25 hp tractor PTO) for non-commercial production
1960	Ford established assembly line for 4-Wheeled tractors
1964	Massey Ferguson established assembly line for 4-Wheeled tractors
1964-65	Design modifications on imported power tillers by local workshops [Successfully simplified gearbox]
1966	Power tillers manufactured by few local firms [Lower price; Suitable to local conditions; Widely popular]
1967-69	Simple 4-Wheeled tractor (15 hp single piston diesel engine) developed by a local power tiller manufacturer (modifying power tiller gearbox and adding 2 more wheels and a seat)
1975	Prototype of axial flow rice thresher designed by Agricultural Engineering Division (blueprint from IRRI) [10 units sold immediately]
1976	Thai Society of Agricultural Engineers (TSAE) established
1977	Blueprint of portable rice thresher received from IRRI [Not widely used due to low capacity]
1978	Rice transplanter (12 rows, powered) imported from China [Not widely used]
1978-91	Basic national policy for agricultural mechanization outlined under 6th National Economic Development Plan (NEDP)
1979	Establishment of National Agricultural Machinery Center (NAMC) to test agricultural machinery
1981-82	1,000 units of Chinese reapers imported [Unsuitable for long stem rice variety; Finally abandoned]
1985-87	Thai-made rice combine harvesters manufactured by local firms
1990	Thai-made rice combine harvesters popularly adopted
1992-96	Specific objectives on R&D in agricultural machines added in 7th NEDP
1997	About 2,000 units of Thai-made RCH sold in Central region
1997-2006	Increasing agricultural production by promoting replacement of human labor by agricultural machinery was stressed in 8th and 9th NEDP
2001	Thai Machinery Association (TMA) established
2007-11	The 10th NEDP focused 'human' as center of development; Sufficiency economy; Sustainable development; Change management
2012-now	The 11th NEDP focuses on strengthening agricultural sector, and security of food and energy

Table 7 Operation-wise indicative level of mechanization in Thai agriculture

	Human labor	Engine (Gasolene/ Diesel)	Electric motor	Power tiller	4-Wheeled tractor	Self-propelled machine
Land preparation (Wet)				80 %	20 %	
Land preparation (Dry)				10 %	90 %	
Crop establishment	10 %			20 %	70 %	
Weeding	80 %			10 %	10 %	
Rice transplanting	20 %			50 %	30 %	
Broadcasting	80%	20%				
Spraying	30 %	40 %		20 %	10 %	
Crop care	50 %	20 %		10 %	20 %	
Fertilizing	50 %				50 %	
Irrigation		40 %	10 %	50 %		
Threshing		60 %	10 %		30 %	
Combine harvesting (rice)						90 %
Combine harvesting (corn)						10 %
Combine harvesting (sugarcane)						30 %
Processing (milling)		5 %	95 %			

Source: CSAM Country Report (2014). Note: Animal power is rarely used.

Evolution of Thai Agricultural Mechanization

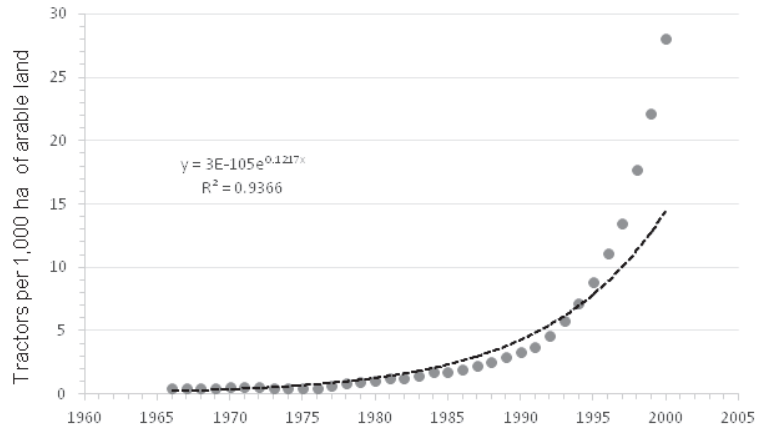
Thai farmers traditionally used simple tools, animal drawn implements and water wheels. Agricultural mechanization started in 1891with the import of steam powered tractor and rotary hoes by the government. Since then the country has witnessed several milestones in the course of mechanization development. **Table 6** presents a chronological review of such an evolution.

Status of Agricultural Mechanization in Thailand

As can be seen from **Fig. 7**, the number of agricultural tractors per 1,000 ha of arable land in Thailand has exponentially increased since 1960s (World Bank, 2015). Decadal average of tractor use is calculated from FAOSTAT (2013) (**Fig. 8**); in the recent decade, on an average there are above 50 tractors per 1,000 ha of arable land in Thailand.

Table 7 summarizes operation-wise indicative level of mechanization in Thai agriculture.

There exists considerable variation across the regions in Thailand in terms of agricultural machinery utilization. For different agricultural



(Source: World Bank, 2015)

Fig. 7 Number of tractors in use per 1,000 ha of arable land

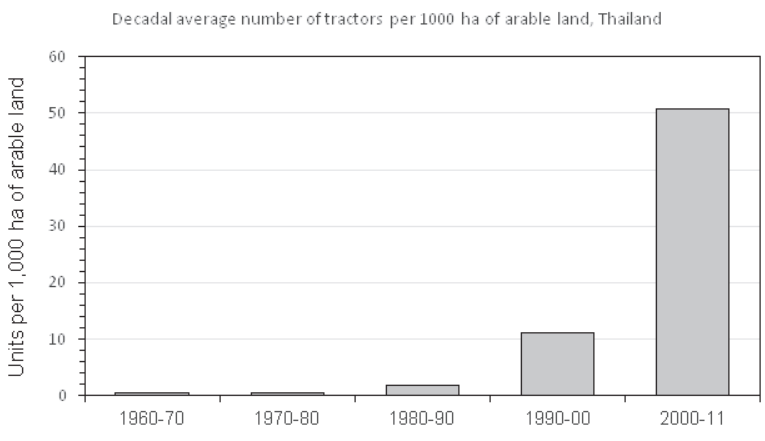


Fig. 8 Decadal average number of tractors per 1,000 ha of arable land

Table 8 Regional distribution of agricultural machinery in Thailand, in 2001

Agricultural machinery	Regional distribution								Whole country Unit (‘000)
	Northern		North-Eastern		Central		Southern		
	Unit (‘000)	%	Unit (‘000)	%	Unit (‘000)	%	Unit (‘000)	%	
Power tiller (2-Wheeled walking tractor)	818	47	243	14	414	24	278	16	1,753
4-Wheeled tractor	47	26	20	11	111	61	5	3	184
Irrigation pump	566	24	356	15	1,282	55	114	5	2,317
Sprayer (engine powered)	65	15	25	6	333	77	9	2	433
Sprayer (hand operated)	4,520	36	3,331	27	2,794	23	1,756	14	12,400
Thresher	7	9	26	34	40	53	3	4	76

Source: Thepent (2014); CSAM (2014)

Table 9 Agricultural machinery used in Thai rice production, in 2008

Agricultural machinery	Units (‘000)	Average price (THB/unit)
4-Wheeled tractor	287	303,000
Power tiller (2-Wheeled walking tractor)	2,645	30,500
Irrigation pump	1,431	4,500
Combine harvester	41	1,412,000

Source: Thepent (2014)

Table 10 Local manufacturers of agricultural machinery in Thailand, in 2009

Agricultural machinery	Local manufacturers (numbers)
Power tiller (2-Wheel walking tractor)	275
Tillage implements (small and large)	329
Planter	16
Sprayer	447
Harvester	386
Other	164
Repair & maintenance workshops	1,192
TOTAL	2,809

Source: Thepent (2014)

Table 11 Production capacity of major local manufacturers in Thailand

Agricultural machinery	Annual production capacity (units/annum)	Remarks
Power tiller (2-Wheel walking tractor)	80,000	1/
Tillage implements (large)	3,000	1/
Tillage implements (small)	90,000	1/
Thresher	2,000	1/
Combine harvester	600	1/
Sprayer (hand operated)	60,000	1/
Irrigation pump	55,000	1/
4-Wheeled tractor	40,000	2/
Rice combine harvester	3,000	2/

1/: From a survey of 70 agricultural machinery factories in Thailand (2001)
2/: An estimate from 2012
Source: Thepent (2014)

machinery regional distribution is summarized in **Table 8**. Agricultural mechanization for rice production has been the most impressive when compared to other crops in Thailand. Central plain of the country is the highest and nearly full mechanized region (Thepent, 2014; Nalavade *et al*., 2013). For land preparation, power tillers, tractors and rotavators are commonly used. For crop care, knapsack sprayers, power sprayers, and high pressure pumps with hose are popularly used. For harvesting paddy, Thai-made combine harvesters are mostly used in irrigated areas; whereas in rainfed areas manual harvesting by sickle is still used. In case of manual harvesting, rice threshers are employed. **Table 9** presents agricultural machinery used specific to rice production in Thailand, along with the average market prices.

Currently there are two modes of utilizing agricultural machinery: as an owner and/or through custom hiring service. The ratio of machine owners to the machine hiring service depends on the machine size, type and its price. Small and inexpensive machines are usually owned by farmers, such as power tillers, water pumps, sprayers, etc. In case of 4-wheeled tractors and power-operated threshers, only 6.4 % and 6 % of the total equipment are currently owned by Thai farmers, the majority is acquired through custom hiring services. Moreover, in Thailand there are still considerable number of small/marginalized farmers, having very small land holding and/or located in remote/unreachable rural areas, who cannot call for the custom hiring services.

Future Outlook for Agricultural Mechanization in Thailand

Labor shortage and necessity to lower production cost in agriculture make mechanization an inevitable solution in the present agricultural landscape in Thailand. It is expected that the demand for agricultural machinery will continue to increase in coming decade. However, different regions require different mechanization solutions. In the Central plains of Thailand, where farmers are more progressive and farm size is large, sophisticated and control-intensive machines such as harvesters, transplanters, planters and powered sprayers would be needed. However, still much effort is required to appropriately modify/adjust those sophisticated/imported machinery to adapt to local conditions (Thepent, 2014). On the contrary, in the North and Northeastern regions, farmers are relatively resource-poor and their farms are small. Farmers in these regions would require labor-intensive machines such as power tillers, water pumps and manually operated sprayers.

There seem to be a growing market for 4-wheeled tractors under 30 kW, along with matching rotary implements (Thepent, 2014). These tractors would be replacing the existing power tillers in rice production systems of Central plain region and the lower part of the Northern region.

Similarly, farmers are looking forward to appropriate and efficient harvesters for rice and sugarcane, as acute shortage of labor during peak harvesting season causes notable losses both in terms of timeliness and in terms of total cost of harvesting.

Status of Agricultural Machinery Industry in Thailand

Currently, Thailand is capable of producing most of the machinery needed for its agricultural operations. Most of the farmers use locally produced machinery, such as 4-wheeled tractors, power tillers, plough, harrow, pumps for irrigation, sprayers, threshers, reapers, combine harvesters, cleaning equipment, dryers, rice milling machines, processing equipment, etc. However, the machines locally produced by small or medium manufacturers lack standardization in quality, durability and performance. Some specific/sophisticated machines are imported by Thai companies from overseas.

As per 2009 estimate by the Department of Industrial Work, there were 2,809 local manufacturers of agricultural machinery registered in Thailand (CSAM, 2014; Thepent, 2014). Number of such manufacturers are summarized in **Table 10**. Production capacities of major local manufacturers in Thailand is presented in Table 11. Some proprietors import new and used machinery from China, Japan, Korea and Europe.

Conclusions

1. Over the past five decades, Thailand has been largely successful in managing its transition from an agrarian economy, to an economy based greatly on manufacturing and services, where agriculture assumes rather an agribusiness setting. Thus agriculture is left for elderly and unskilled people to manage, either as a part time activity or to rent their land out for unplanned agricultural activities.
2. Many households have diversified their income sources, with greater participation in non-farm activities. At the same time, there has been some specialization of agriculture for higher-value produce.
3. Agricultural mechanization is an inevitable solution to provide conditions that allow rural population to manage their farmlands with limited and expensive labor, within a short span of time, while permitting specialized farmers/entrepreneurs to invest and innovate.
4. Mechanization will continue to play an increasing important role in coming decades. It is expected that the demand for agricultural machinery will steeply grow in the coming decade.
5. Local firms are expected to venture in manufacturing locally-adaptable agricultural machinery, based on R&D –as the current business environment for agricultural machinery is healthy and conducive.

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VIET NAM

Viet Nam Agricultural Machinery Industry




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Introduction

Generally, in developing countries and particularly, in Vietnam, agricultural mechanization has allowed an increase to the plant area, and contributed towards enhance yields and quality of farming products. Planting, caring, tending and harvesting a crop requires not only significant amount of power but also needs a suitable range of tools, equipment and farm machines. Therefore, agricultural machinery manufacturing industry plays an important role in Viet Nam agricultural mechanization. This paper presents the status of Viet Nam agricultural machinery industry over last 10 years.

Table 1 Number of major machinery using on agricultural production in 2013

Number of major machines by units					Unit: Piece
Major machines	Total	By type of unit			
		Enterprise	Cooperative	Household	
				Total	Of which: Farm
Heavy tractors (> 35 HP)	17,206	375	114	16,717	1,362
Middle-weight tractors (from 12 CV to 35 HP)	221,445	76	76	221,293	2,755
Small tractors (12 HP and less)	294,618	19	30	294,569	598
Vehicles (Total)	248,767	2,282	99	246,386	3,280
Of which: Cargo and passenger vehicles	162,518	1,075	82	161,361	1,555
Electrical engines	262,393	544	1,145	260,704	2,269
Diesel/ petrol engines	319,975	597	822	318,556	5,552
Electric generator	211,975	1,151	232	210,592	6,364
Rice mowing machine with engine	266,371	29	364	265,978	462
Dryers, ovens	64,726	966	121	63,639	629
Milling machine	249,058	264	48	248,746	486
Motorized Insecticide sprayers	582,116	818	730	580,568	8,694
Mechanized water pumps	2,187,197	7,918	9,411	2,169,868	28,527
Animal food processing machine	72,288	160	141	71,987	1,464
Aquaculture food processing machines	6,700	73	47	6,580	472
Sowing machine	27,104	37	1,297	25,770	513
Rice Combine Harvesters	14,701	21	150	14,530	610
Other harvesters	66,658	11	52	66,595	142

Number of Major Machinery Using on Agriculture

The latest farm mechanization figure in 2013 covered by National census on agriculture, forestry and fishery is presented in **Tables 1-3**. Comparing to 2001, total capacity of tractors of all kinds (9 milion HP) was three-fold increasing with availability of 600.000 tractors in 2013, indicating a significant investment into farm mechanization.However, this capacity of tractors is still behind other Asian neighbours (equal to 1/3 Thailand, 1/4 Korea, and 1/6 China).

In Vietnam, the farm mechanization level is 1.86 hp/ha of cultivated land. This national average of farm mechanization level is lower than Japan (7 hp/ha, China, 4.10 hp/ha, South Koread 4.11 hp/ha) and higher than that of Philipines (1.23 hp/ha), Pakistan (1.02 hp/ha), and India (1.0 hp/ha).

Number of Manufactured and Imported Agricultural Machines by Kinds of Machines

At present, there are total about 600,000 tractors and power tiller of kinds, with the existing capacities of 3,472,868 HP in which 250,000 units under 12 HP, about 900,000 agricultural machines of all kinds (ploughs, rotative hoe, cultivator, cage wheels…, harvesters more than 19,000 units, threshers: 600,000 units with existing capacities of 471,661 ton/hour, water pumping machines: 1,340,080 units with existing capacities 57,094,439 m^3/h. In average, the power input per cultivated hectare reached up to 1,67 HP.

Dynamic engines occupation of household (piece):

- Electric: 178,362
- Electric motor: 160,437
- Diesel-petrol, diesel engine: 370,105

Main machines of household (piece)

- Disc plow: 60,000
- Tiller: 16,800
- Harrow: 42,000
- Sowing machine: 350,000
- Harvester: 19,221
- Threshing machines: 600,000

(The Mekong river delta: 12.455 harvester including of 8,919 combine harvester, 3,536 reaper).

- Dryer: 25,042
- Mill machine: 244,229
- Pump engine use for agriculture and forestry: 1,340,080
- Pump engine use for culturing fishery: 92,005
- Food processing machine for livestock: 13,278
- Food processing machine for aquaculture: 4,367
- Other food processing machine for

Table 3 Average rate of mechanization in agricultural production (adapted from [2])

Agricultural production activities	Mechanization rate, %
Soil preparation (rice cultivation)	72
Soil preparation upland crops	65
Active irrigation for rice	85
Transport in agriculture and rural	66
Rice drying in summer-auttumn season in Mekong River Delta (MRD)	38.7
Rice harvester in MRD	15
Rice thresher	84
Rice milling	95

[2] Nguyen Quoc Viet. Current status of Agricultural Mechanization in Vietnam (www.unapcaem.org)

Table 2 Number of major machines occupied by agricultural, forestry and fishery units per 100 units[1]

Machinery	Total	By type of unit: Enterprise	Cooperative	Household: Total	Household: Of which, farm:
Heavy tractors (more than 35 HP)	0.2	14.8	1.8	0.1	6.8
Middle-weight tractors (12-35 HP)	2.0	3.0	1.2	2.0	13.8
Small tractors (12 HP and less)	2.7	0.8	0.5	2.7	3.0
Electrical engines	1.7	21.5	18.2	1.7	11.3
Diesel/petrol, diesel engines	2.7	23.5	13.0	2.7	27.7
Electrical generator	1.2	45.4	3.7	1.2	31.8
Rice mowing machine with engine	2.2	1.1	5.8	2.2	2.3
Agriculture, forestry, fishery product dryers, ovens	0.6	38.1	1.9	0.6	3.1
Milling machine	2.0	10.4	0.8	2.0	2.4
Animal food processing machine	0.6	6.3	2.2	0.6	7.3
Mechanized water pumps for agriculture, forestry, fishery production	18.6	312.2	149.3	18.5	142.4
Aquaculture food processing machines	0.1	2.9	0.8	0.1	2.4
Sowing machine	0.3	1.5	20.6	0.2	2.6
Harvesters combine rice mowing machine	0.1	0.8	2.4	0.1	3.0
Other harvesters (reapers etc.)	0.6	0.4	0.8	0.6	0.7

[1]GSO (General Statistics Office) (2013). Result of the 2012 Rural, Agriculture, and Fishery Census. Statistical Publishing House.

agriculture, forestry and fishery: 48,157

Main machines per 100 households (piece/100 households):

• Large tractor (over 12 CV): 0.42
• Small tractor (12 CV and under): 1.4
• Electric generator: 1.28
• Electric motor: 1.15
• Diesel, petrol diesel engine: 2.66
• Harvester machine: 0.02
• Threshing machine: 4.31
• Drying room, dryer machine: 0.04
• Mill machine: 1.76
• Pump engine (include for daily life): 28.14
• Food processing machine for livestock: 0.10
• Food processing machine for aquaculture: 0.03

Main machines per 100 farms:

• Large tractor, plough (over 12 CV): 7.78
• Small tractor (12 CV and under): 10.8
• Electric motor: 1.57
• Diesel, petrol, motor: 20.5
• Electric generator: 8.59
• Threshing machine: 7.17
• Drying room, dryer machine: 1.14
• Mill machine: 3.46
• Pump engine (include for daily life): 102.15
• Food processing machine for livestock: 0.73
• Food processing machine for aquaculture: 3.04

Despite a remarkable increase in types and numbers of machinery/equipment, domestic agricultural machinery/equipment accounts for only 15-20 % in the agricultural machinery market. Majority of agricultural machineries are imported from Korean, Japan, and China (60 %). The local manufacturers are almost small mechanical workshops and have not equipped with knowledge and skills of technical designs and manufacturing technolgies. Therefore, component parts or accessories are far below quality standards. There is also no "supporting industries", which provides component parts or material for asssembly, for agricultural machinery manufacturing.

Table 4 Financial status of major enterprises in agricultural machinery sector

Unit: billion VND

Enterprises	Total asset	Capital	Net revenue	Net profit	ROE (%)
Long An Machinery Ltd.	207	94	NA	53	56.6
An Giang Machinery Ltd.	120	44	142	9	20.5
Fodd engineering joint-stock company	186	54	687	15	27.8
Hai Duong pump manufacturing joint-stock company	125	53	151	8	15.1
Mechanization electrification spare-parts joint-stock company	87	45	209	7	15.6

ROE: Return on Equity.

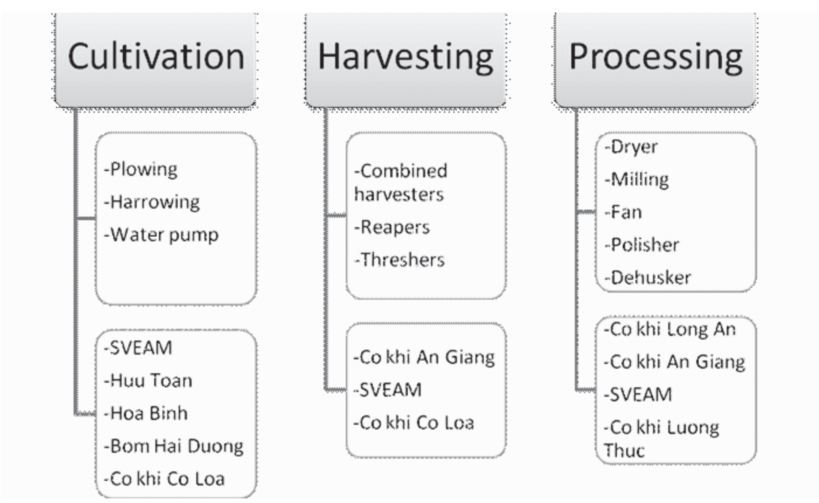

Fig. 1 Types of machines utilized in agricultural production and corresponding representative local manufacturers.

Current Status of Local Manufacturers in Agricultural Machinery Sector

As stated above, agricultural machinery industry is one of important sectors in providing materials for agricultural production. The increasing trend of farm mechanization replaces manual labor for enhancing production yield, reduce post-harvest losses is a driving force to develop the agricultural machinery industry. However, it has been shown that market share of local manufacturers (15-20 %) is quite small compared to foreign trademarks (60-80 %). The market survey also reported that domestic agricultural machineries are more expensive than the imported counterparts about 15-20 %. Small and slow growth of market share implies weak competitiveness of domestic agricultural machinery production.

Fig. 1 illustrates the three important processing operations in rice production and the corresponding machinery used and representative local manufacturers. The capital of some of typical local manufacturers is also listed in **Table 4**.

Among the local manufacturers, VEAM (Vietnam Engine and Agricultural Machinery Cooperation) is the leading manufacturer in Vietnam with 7,000 employees and 22 subsidiaries. As illustrated in **Fig. 2**, competitive advantages of VEAM in the market include wide product lines encompassing all operations in value chain of agricultural production and long-established enterprise. From a technical capability point of view, VEAM is also a leading enterprise with establishment of 2 research institutions, i.e. RITM and RIAM. The VEAM has 22 subsidiaries, of which competitive subsidiaries are An Giang Machinery (harvester, milling); SVEAM (milling, tractor), Co Loa Machinery (combined harvester, tractor), Tractor and Agricultural Machinery Enterprise (tractor) etc.

To compete with foreign manufacturers, domestic manufacturer pursuit the same business strategy, that is low cost product. This strategy is also employed by Chinese counterparts. Japanese agricultural machinery manufacturers follow business strategy of differentiation as shown in **Fig. 3**. Many attempts have been made by the domestic manufacturers to diversify product lines.

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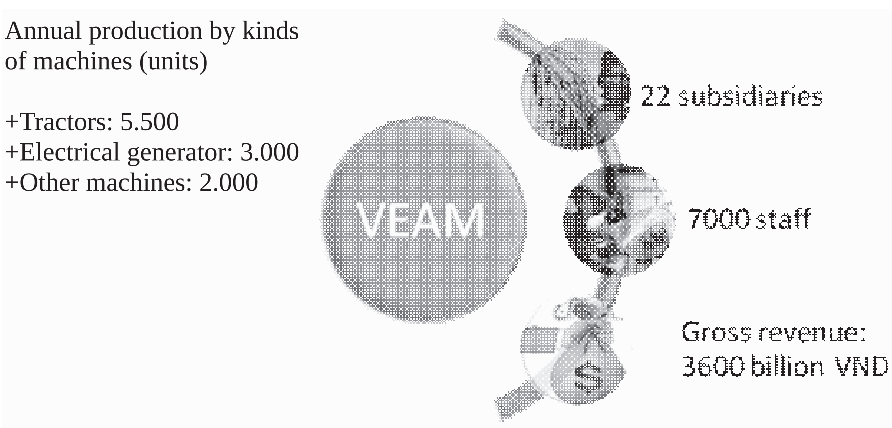

Fig. 2 Information of annual production of the major manufacturer in agricultural machinery in Vietnam: VEAM (Vietnam Engine and Agricultural Machinery Corporation)

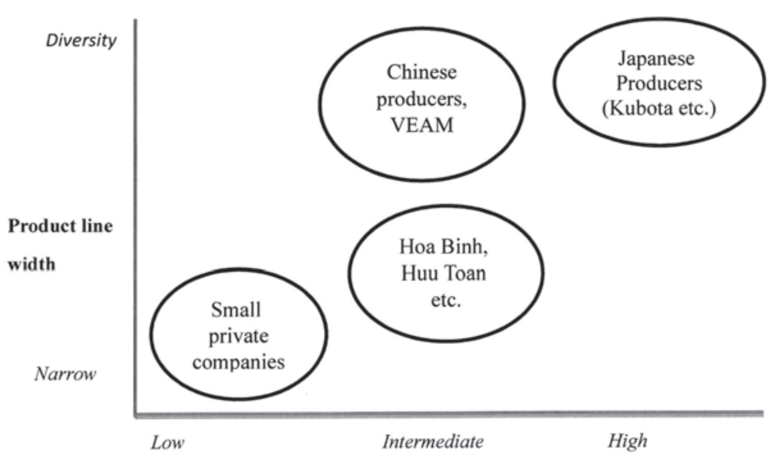

Fig. 3 Strategic groups in agricultural machinery sector.

INDONESIA

Present Status and Future Prospects of Agricultural Machinery Industry in Indonesia

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Introduction

This year Indonesia's rice production has increased by 6.64% or 75.55 million tons, the highest in the last 10 years (Central Bureau of Statistics, 2015). Such increase in production was due to the application of agricultural machinery through out the country from four-wheeled tractors, two-wheeled tractors, water pump, including post harvest machineries. **Table 1** shows the number of agricurtutal machinery used for agricultural production while **Table 2** shows the application of custom hiring for farm production in Indonesia especially for rice, maize and soybeans. The machinery used was a combination of domestic products and import machineries, where import machinery were still the dominant. **Table 1** indicate that thresher were used the most in agricultural production particularly for rice, followed by 2- wheeled tractor, water pump and RMU (Rice Milling Unit). Part of these machineries are now capable to be manufactured in Indonesia. Recently agricultural mechanization use in Indonesia began to adopt machine custom hiring system for agricultural production. This trend is surely will increse the use of agricultural machinery, since many Indonesian farmers are lack in skill to operate agricultural machinery. It is highly expected that the applications of custom hiring will eventually will help in increasing the use of agricultural machinery in Indonesia.

Custom Hiring

Now Custom hiring is beginning to take place in Indonesia. It trends to increase over the years and has contributed to the increase in agricultural production in Indonesia.

Table 2 shows the trend in custom hiring of agricultural machinery in Indonesia. It shows that significant increse was achieved in rice production while for maize and soybean, the impact on production increase are not very clear.

In **Table 3** we can see the change in custom hiring users based on the farmers skill. It shows the total increase in the number of custom hiring each year during 2006 to 2012. **Table 3** also shows that all type of costumer increase in the number each year for costum hiring. **Table 4** shows the availability

Table 1 Number of agricultural machinery used in Indonesia between 2009-2013. (Astu, 2014)

Year	2 WD Tractor	4.WD Tractor	Water pump	Transplanter	Thresher	Combined harvester	RMU	Dryer
2009	126,453	2,969	87,324	-	151,284	-	97,779	2,021
2010	126,016	2,969	87,801	-	201,241	-	97,881	2,436
2011	115,834	2,945	97,253	204	395,005	21	98,255	2,560
2012	121,397	3,153	107,876	360	397,255	221	98,219	3,311
2013	192,905	3,338	140,233	636	401,132	754	98,223	2,943

of agricultural machinery for pre-harvets activities. It indicates that two-wheeled tractors were the most available followed by water pump. The use of four- wheeled tractors were beginning to take place.

Table 5 show the availability of agricultural machinery used for post harvest activities. It shows that pedal thresher was mostly available followed by power thresher and small rice milling unit. **Table 6** shows the use of agriculttural machineries for maize prduction. From these Tables one can see that the use of agricultural machinery in Indonesia has incresaed yearly due to to the introduction of custom hiring system. This trend is also shown by **Table 7** where the mechanization index has increased annually. This is also probably due to the increase in capability of the domestic manufacturer to produce such machineries.

Agricultural Machinery Industry

As recent data shows that the domestic manyfacturer are now capabale to export their products to overseas such as to Nigeria, Sudan, South Africa, Philippines, Sri Lanka, Japan, Malaysia, and Timor (Leste, 2010). During the first quarter of 2010, exports reached US$ 7,584 million. Throughout 2009, exports reached US$ 24,245 million. As for imports, in 2009 it had

Table 2 Impact of costum hiring on food production (Astu, 2014)

	2008	2009	2010	2011	2012	2013
A. Paddy						
Total land (mil. Ha)	12,299	12,669	12,870	13,204	13,446	13,569
Production (miil. Ton dried)	60,326	64,399	65,150	65,757	69,056	71,291
B. Maize						
Total land (mill.Ha)	4,002	4,161	4,134	3,865	3,958	3,786
Production (mill.ton dried)	16,317	17,630	17,845	17,643	19,387	18,506
C. Soybeans						
Total land (mill.Ha)	0.591	0.723	0.672	0.622	0.568	0.601
Production (mill.ton dried)	0.776	0.975	0.905	0.851	0.843	0.780

Table 3 Change in number of costum hiring during 2006-2012 (Astu, 2014)

Year	Number of costum hiring			Total
	Beginner	Developing	Professional	
2006	7,390	141	39	7,570
2007	7,543	409	65	8,017
2008	8,571	851	100	9,522
2009	8,145	1,783	318	11,103
2010	8,887	2250	219	11,356
2011	8,801	2,693	453	11,947
2012	9,485	2,136	423	12,044

Table 7 Agricultural machinery utilization index for rice production in Indonesia, %.

Activity	Year			
	2004	2009	2010	2011
Land preparation	48	55	60	65
Seeding	0	1	2	4
Planting	4	5	6	7
Weeding	2	5	8	12
Pest control	100	100	100	100
Harvesting	5	10	18	26
Threshing	45	55	60	65
Drying	25	30	34	38
Milling	100	100	100	100

Source: IAARD Ministry of Agriculture, (2013)

Table 4 Availability of pre-harvest agricultural machineries for agricultural production in 2013

Type of agricultural machineries	Quantity (unit)
Two-wheeld tractor	189,760
Four wheeled tractor	2,992
Water pump	140,099
Cultivator	174
Rice trasnplanter	85

Source: Directorate General of Agricultural Infrastructure and Facilities (2014)

Table 5 Availability of post-harvest agricultural machineries in 2013

Type of agricultural machineries	Quantity (unit)
Combined harvester	400
Reaper	644
Paddy mower	3,416
Pedal Thresher	135,450
Power thresher	48,064
Vertical/continuous dryer	2,888
Flat bed dryer	1,069
Small Rice Milling Unit (RMU)	24,987
Medium RMU	8,177
Large RMU	10,263

Source: Directorate General of Agricultural Infrastructure and Facilities (2013)

Table 6 Availability of agricultural machineries for maize production in 2013

Name of agricultural machineries	Quantity (unit)
Corn sheller	7,038
Multipurpose power thresher	1,425
Flat bed dryer	240
Moisture tester	454

Source: Directorate General of Agricultural Infrastructure and Facilities increased from 2008, from US$ 314 million to US$ 376.8 million. Imports in the first quarter of 2010 reached US$ 96.1 million. (Ministry of Industry, October 2010). Farmers now tend to prefer to use domestically produced agricultural mahineries since these machines have after sales services and the spare parts are also avaliable. According to the Indonesian Center for Agricultural Engineering Research and Development, Ministry of Agriculture (2014), some names of manufacturers of major agricultural machinery in Indonesia are given in **Table 8**. As for 2014, in Indonesia there were 107 manufacturing and supplier of agricultural machineries (CBS 2015).

There are three kinds of manufacturer according to level of technology used, namely, advanced, medium and simple. This is explained in **Table 9** showing the number of units of agricultural machinery produced by each type of industry. It shows that the big manufacurers are beginning to produce a large number of agricultural machinery. **Fig. 1** shows an example of manufacturing industry in Indonesia. As the capability of domestic manufacurer will increase each year it can be expected that import will decrease accordingly. The supply chain of agricultural machinery in Indoneia follows the following methods:

Agricultural machinery supply system
- Employment contract (consignment)
- Cooperation credit/ capital from the supplier / manufacturer
- Grants through the revolving fund
- Loans from regional banks or financial institutions

Distribution system by the company
- Direct sales
- Lease-purchase
- Business management units
- Field operations by the company / manufacturer

Factors inhibiting the development of agricultural mechnization in Indonesia

There are some factors which become the main barrier for agricultural mechanization development in Indonesia. They are among others:

The availability of capital.

Generally, farmers have small land (0.5 hectares / person) and therefore they do not have enough capital to buy agricultural machinery which cost relatively expensive.

Soil Conditions

Topography of agricultural land in Indonesia are mostly undulating and mountainous which make operation with farm machinery.difficult

Labor

Due to the availability of abundant labor, the use of agricultural machinery will increase unemployment

Experts

Experts or competent persons in the development of agricultural machinery (mechanization of agriculture) are still inadequate.

Skill of farmers

Indonesian farmers are lack in skill to operate agricultural machinery, therefore, in order to increase the use of agricultural machinery, proper training of farmers and the

Table 8 Some major agricultural machinery manufacturers in Indonesia (Ministry of Agriculture 2014).

Name of company	Producst
PT Yamindo	Four-wheeled tractors, power tiller, mini tiller, rice milling equipment, and others
PT Kubota Indonesia	Disel engine (single cylinder),generator,power tiller, riding tiller, waterpump, RMU adand others
PT Agricndo	Four-wheeled tractor, power reaper, RMU, dryer, grain separator, rice huller,rice polisher,paddy cleaner, disel engine, elcetric motor,electric generator, power tiller, water pump, etc.
CV Karya Hidup Sentosa	Single cylinder diesel engine, two-wheeled tractor, a variety of tillage implements,power thresher, RMU, rice polisher,harvesting equipment, water pumps, etc.
PT Bura Barutama	Dryer,burner,RMU,corn sheller, paddy cleaner, power thresher,granulator,compost sieving machine.
PT Tractor Nusantara	This company is assembling and marketting, four -wheeled tractor from Massey-Ferguson brand
PT Altrak 1978	Distributor of four- wheeled tractor from New Holland brand and Kubota
PT Bina Pertiwi	Distributor of four-wheeled tractor of Kubota from Japan.
PT Satrindo MitraUtama	Distributor of John Deer's four-wheeled tractor

Table 9 Agricultural Machinery Industries in Indonesia in 2010 (MoA, 2013)

Industrial Scale	Unit	Production Capacity (Units / year)	Level of Technology
Industrial large-scale	3	955,550	High
Medium-scale industries	30	125,000	Medium
Small scale industries	1,063	15,000	Simple

Fig. 1

use of custom hiring may be recommended.

The Need for Testing and Evaluation of Agricultural Machinery

In order to promote the production of reliable agricultural machinery, the Minstry of Agriculture has established in 1975 a Sub-Directorate of Agricultural Mechanization: Training, Extension and Testing of agricultural machinery. Now the institution has changed its name to Center for Agricultural Engineering Research and Development. The purpose of such establishment was:

- To protect the consumers need (farmers and other users) through quality control for standardization, which refers to the Indonesian National Standard of the testing procedures, test methods and minimum technical requirements for certification
- Guarantee quality of agricultural machinery used by the farmers/ other users to meet the requirement of global trade
- Strengthen research and development of agricultural machinery more systematic and leads to the national needs
- Strengthen the growth of local agricultural machinery industry through developing and adopting National Standard of Agricultural Machinery(SNI).

Up to now, there were a total of 275 agricultutal machinery have been tested at the Center from preharvest to post-harvest machineries during 2010 to 2014.

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INDONESIA

Present Status and Future Prospects of Agricultural Machinery Research Activities in Indonesia

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Introduction

Population of Indonesia has reached 248,818,100 with annual population growth rate is 1.42 % (Statistical Year Book, 2014). According to BPS (2015), the demand of rice was about 33.34 mil ton. While the demand of corn and soybean is 22 mil ton and 2.25 mil ton respectively (Kementan, 2015).

Strategic plan of Ministry of Agriculture for 2015-2019 was set based on Mid-term Development Plan (RPJMN) 2015-2019 as a part of Long-term Development Plan 2005-2025, in which agriculture sector is still considered as important sector in economic development of the country. In the 2rd stage of RPJMN (2010-2015), efforts to achieve the target of agricultural development are, among others :1) increase sustainable self sufficiency of rice and corn; and 2) achieve self sufficiency of soybean. Ministry of Agriculture has launched an approach for agricultural development in more specific term "sustainable bio-industry agricultural system" (Kementan, 2014). It includes increase in agricultural production through intensification by adopting innovative technology in on-farm production system and extensification by increasing land area through revitalization of potential land area for agriculture. According to Pusdatin (2014), total utilized land area for agriculture is 39,475,694 ha, consisted of wetland (8,112,103 ha), upland (17,149,776 ha), and temporarily unused land (14,213,815 ha). This figure shows that there is about 14 mil ha land area which is temporarily unused and may be revitalized to be productive land by extensification program.

Government policy on food is to make food surplus within 3 years mainly for rice, corn and soybean (called PAJALE) and sugar as well as meat. In fact, the three commodities are still imported. Strategy to achieve food surplus includes: (1) increase planting area by 1 million ha through intensification and increase in cropping index; (2) improve and revitalize irrigation facilities; (3) provide good quality HYV seed at proper quantity, variety and time; and (4) increase the number of agricultural machinery.

Statistical Year Book, 2014 shows the harvested area, production and productivity for the 3 major cropsare as follows.

As reported by Ministry of Agriculture that between 2010-2014, there was an increase in rice, corn and soybean production as much as 1.63 %, 1.11 % and 1.93 % per year respectively. To meet the demand, production as well as productivity should be increased. Extensification of land area in outer Java may be a proper alternative for upland crops such as corn and soybean. During the year 2010-2014, the government

Table 1 Harvested area, production and productivity of major food crops [K1]

Items	Rice	Maize	Soybean
Harvested area (000 ha)	13,837.2	3,820.2	550.8
Production (000 ton)	71,291.5	18,506.3	780.2
Productivity (ton/ha)	5.152	4.644	1. 416

[K1] Perluditabahkandaya demand konsumsi dalam negeri agar diketahui berapaynagharusdi import.

has successfully opened new farmland area up to 347,984 ha, however the trend of land conversion reached up to 100,000 ha per year, meaning that the situation is just balance but at least no reduction in farm land area.

Present Status of Agricultural Machinery Research in Indonesia

Increase Productivity Through Intensification

As mentioned previously that one of the strategies to achieve food surplus is innovative technology adoption and increase the number of agricultural machinery. The fact that only about 11 % of farm labor is still in productive age, however 75 % of them only have basic education. It means that need strong effort to attract more young people with adequate level of education to participate in agriculture work both on-farm and off-farm production activities. Introducing mechanization (i.e. agricultural machinery) is in a definite need and considered as one of alternatives to increase quality of agriculture production system.

The overall goals of mechanization in Indonesia is to increase productivity by intensification, reduce post-harvest losses, increase added value and maintain the quality of farm product, that finally increases the welfare of farm households and creates employment opportunities in the rural areas. The most concern in introducing mechanization to the farmer is how to change their mindset and culture (tradition) so that the farmer may consider agriculture not just a farming but as a business.

Mechanization is expected to have contribution on production and productivity but it needs support from other aspects such as infrastructure (field condition, irrigation facilities, etc), good seed quality, fertilizer, pesticides and other inputs that farmer have good access on it.

Current Research and Development Agricultural Machinery in Indonesia

Considering the situation of Indonesian agriculture such as land holding that is only 0.25 ha per farmer, undulated topography, uncertain depth of hardpan, heavy soil texture (clayly, silty and volcanic ashy soil), availability of farm labor (varied and fluctuated), etc. From the beginning, Indonesia introduced "selective mechanization" involving technology which is considered appropriate in terms of technical, social and economical aspects. After several decades since the first time introducing mechanization in Indonesia in early 1960, there is still misperception of mechanization. As it is always associated with utilization of agricultural machinery, the mechanization is narrowly perceived as follows.

- replace human labor (as the machine has big working capacity)
- high cost (the price of machine is considered expensive)
- need repair and maintenance (complicated and costly)
- only suitable for flat land (limited maneuverability in certain condition)
- cause soil degradation (soil compaction especially in root zone area, soil hardness)
- raise environmental problem (air pollution during machine operation)

The situation now is much different especially in the area with lack of farm labor, no other choices for the farmer except using machinery for the selected on-farm operations. However, government, researcher, academician, industry and practitioner still need to work together to convince people that mechanization (agricultural machinery) will be beneficial to increase land productivity, labor productivity and decrease production cost.

In Indonesia, the institutions that are given mandates to do research and development of agricultural machinery include mainly research institutes under the Ministry of Agriculture and university (department and research center related to agricultural engineering). Industry i.e. agricultural machinery industries are also doing research as a part of their business development.

Indonesian Center for Agricultural Engineering Research and Development (ICAERD) established in 1987 was one of the research institutes under the Ministry of Agriculture that intensively develop appropriate agricultural machinery. Products of agricultural mechanization research and development (Astu Unadi, 2014) among others include:

- Various prototypes of agricultural machineries
- Patents
- Model development of agricultural mechanization in various region
- Integration model of crops, livestock and agricultural machinery to increase farmer income
- A number of policy recommendations for the development of mechanization
- Various national standards for agricultural machinery (test codes, procedure and methods, standard technical performance for agricultural machinery)

Current research is focused on machinery to support major crops production that are rice, corn and soybean. Several machines are under development (BPP Mektan, 2015):

- Rice combine harvester: improvement on track layer to reduce ground pressure so that the machine can be operated in swamp area.
- Corn sheller
- Large scale corn and soybean planter and fertilizer applicator

In the university, researcher should do research according to their competency and the topic chosen should be included in university research agenda (umbrella research). Most of research are competitive based and need to involve student. Research and development of agricultural machinery may be categorized as basic (fundamental) research, applied research and research with focus on strengthening mandate of division. Scope of research includes:

- Innovation on production machinery (on-farm and off-farm)
- Modification to improve the performance of the machinery
- Field performance test (including ergonomic aspect)
- Assessment on technical, social, economic and environmental aspect of technology adoption
- Identification and providing basic information to support machinery design (human factor in machinery design, working environment and condition of the machinery)

Current university research on agricultural machinery for food and estate crops are listed bellow (selected).

Tractor and engine:

1. Development of automation system of tractor - SMART Tractor
2. Design and performance test of automatic controlled mechanism of brake and forward-backward transmission of four wheeled tractor
3. Development of obstacle detection method for unmanned tractor using CCD camera
4. Design of engine using biofuel (Coco diesel, Nyamplung, etc.)
5. Performance test of engine using biofuel

On-farm machinery for food crops:

1. Design improvement of corn planter and fertilizer applicator powered by hand tractor
2. Design and testing of metering device for variable rate granular fertilizer applicator
3. An end-effector design for a sweet pepper harvesting robot
4. Development of robotic principle for agriculture activities
5. Development of machinery for precision farming

IT application on agriculture:

1. Development of data acquisition system of soil nitrogen level using infra-red sensor
2. The application of image processing and artificial neural network for the[K2] prediction of soil organic matter content
3. Tropical fruit maturity identification based on electronic nose system using array semiconductor gas sensors with neural network method
4. Development of remote control system on land use identification
5. Effect of noise on various crop growth
6. Development of automatic control system of green house

On-farm machinery for estate crops:

1. Conceptual design of oil palm fresh bunches catchment and its potential energy utilization
2. Design of compost applicator for dry land sugarcane
3. Development of oil palm fresh bunch transporter

Standard research and development process on agricultural machinery will start with problem and demand (need) identification and most of researcher will follow that mechanism. Recently some studies have indentified problem related to agricultural machinery utilization and need of appropriate agricultural machinery in Indonesia. Common problems are : 1) the number of machinery is relatively small compared to agricultural land area; 2) low affordability of the farmer to buy machinery; and 3) lack of knowledge to operate and manage agricultural machinery. It means that key growth drivers for agricultural machinery utilization are: 1) increase farming income (high support to commodities' prices); 2) support of credit system to the farmer; 3) government subsidies on farming equipment; and 4) support to farmers' institution.

Prospect of Agricultural Machinery Research in Indonesia

As described previously that government put priority on three major crops in order to meet the demand. Total area for rice, maize and soybean (PAJALE): 3.57, 3.78 and 0.61 mil ha respectively. Size of farmland: 0.3-1.0 ha per farmer while labor working in agriculture decreases from 31.17mil in 2003 to 26.13 mil people in 2013 (Astu Unadi, 2014).

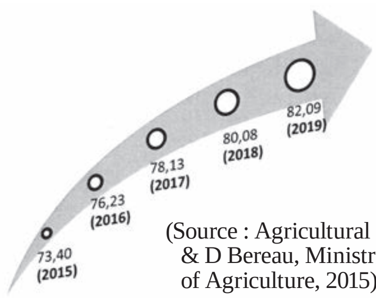
In case of rice, there are 10 provinces of Indonesia that were considered as rice production center area. However, as the land holding is limited to 0.25 ha per farmer, then it is difficult to increase the production with the traditional system. The main problems in rice production are as follows:

- Conversion and fragmentation of farm land
- Irrigation infrastructure not in function
- High labor cost (in most production area)
- Availability of agricultural machinery and spare parts (unsecure in the remote areas)
- Availability of extension service (not enough in number and capability)
- The farmer still use manual for most farm operation
- High percentage of losses (by manual operation)
- Availability of seed and fertilizer (unsecure in remote areas)
- Low productivity

• Price of commodities are fluctuated

Ministry of Agriculture has launched new policy related to production system of rice and one of the resolutions is to gradually introducing full mechanization system. Strategies to achieve the target are (Agricultural R & D Bereau, Ministry of Agriculture, 2015):

• Increase planting area of 1 million ha through intensification and increasing cropping index
• Improve and revitalize of irrigation facility
• Provide good quality of HYV seed at proper quantity, variety and time
• Increase the number of agricultural machinery, improve the capability of operator



(Source : Agricultural R & D Bereau, Ministry of Agriculture, 2015)

Fig. 1 Target of rice production 2015-2019 (mill. ton dried rough rice)

Fig. 1 shows the target of rice production for 2015-2019 with the increase in productivity from 6.015 kg to 8.050 kg harvested dried rough rice (GKP) per ha.

The first stage of implementation is for 100 ha by utilizing tillage machinery for land preparation, Indo Jarwo tranplanter for transplanting, weedingusing cultivator, and combine harvester.

To meet the target of implementing full mechanization for rice, the availability of appropriate machinery is a definite need. Most of the machinery has been developed, however, the condition of paddy field is varied from one area to another, yet the local tradition exists in the area. **Table 2** shows the need of various agricultural machinery in 2010, with an estimated need according to the targeted planting area in 2015.

Table 2 Number of various agricultural machinery in Indonesia 2010 (Astu Unadi, 2014)

Kinds of Machinery	Planting Area (ha)	Harvesting Area (ha)	Needs (unit)
Hand tractor	14,324,166	12,891,749	148,406
Irrigation pump	14,324,166	12,891,749	100,679
Harvesting	14,324,166	12,891,749	470,974
Power thresher	14,324,166	12,891,749	187,075
Dryer	14,324,166	12,891,749	58,760
RMU	14,324,166	12,891,749	13,127

The future research of agriculture machinery is still focused to find the appropriate machines that are suitable to the conditions of area in terms of design and scale as well. For rice mechanization, the research may focus on the adjustment of track or cage wheel as the most wetland rice field in Indonesia have no certain depth of hardpan, and so lower the ground pressure is suitable. For upland soybean and corn, the future research mainly would be on design and scale of machinery that will be suitable to the size of farm. In case of wet land soybean, future research is not targeted on the design of track or wheel with low ground pressure. **Table 3** shows the status of research and development of agricultural machinery for the three major food crops.

To foster the development of agricultural machinery in Indonesia, collaborative research between research institute, academician and industry is necessary. With the government support, the link of these institutions should be established to set the priority research.

Conclusions

To meet the target of implementing mechanization for rice, corn and soybean, the availability of appropriate machinery is a definite need both in design and scale. Most of

Table 3 The need of agricultural machinery research for major crops

<table>
<tr><th rowspan="2">Kind of machinery</th><th colspan="3">Research and development status</th></tr>
<tr><th>Rice</th><th>Corn</th><th>Soybean</th></tr>
<tr><td>Hand tractor
4-wheel tractor</td><td colspan="3">completed</td></tr>
<tr><td>Tillage machinery</td><td>Need further development for swamp and peat soil</td><td>completed</td><td>Need further development for swamp and peat soil</td></tr>
<tr><td>Planter
Fertilizer applicator
Sprayer</td><td>Need further development to operate in rice field with no or deep hard pan</td><td rowspan="2">Need further development of design and scale</td><td>Need further development of design and scale</td></tr>
<tr><td>Harvester</td><td>Need further development to operate in rice field with no or deep hard pan (reduce the ground pressure)</td><td>Need further development of design and scale especially for gambut soil (reduce ground pressure)</td></tr>
</table>

the machinery has been developed; however, it needs further research to achieve optimum performance with low cost of operation. The successful implementation of mechanization not only depend on the availability of machinery but also on the positive response and perception of farmer. For this, government role is important especially to facilitate extension, training and education to generate innovative farmers who would be adaptive to the agricultural technology development.

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PHILIPPINES

Agricultural Mechanization in the Philippines, Part I: Brief History

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Abstract

Several changes in the rice and other crop production landscape in the Philippines have occurred since an account of the status of agricultural mechanization was reported forty-five years ago in the first issue (Spring 1971) of Agricultural Mechanization in Southeast Asia, now AMA (Lantin, 1971). Part I of the two-part article on agricultural mechanization in the Philippines provides the brief background of its development. Part II will discuss the current status of agricultural mechanization and the formulation of strategies after having set out a firm policy as provided by the Agriculture and Fisheries Mechanization (AFMech) Law of 2013.

Historically, the following chronology of development events related to agriculture and agricultural mechanization that have been unfolding through the years and marked by milestones, have had significant impact on shaping the present status of agricultural mechanization in the Philippines:

Before 1521 (Pre-Spanish era)
- Blacksmithing and metalworking technologies, probably acquired from Chinese traders, are used for making weapons, household metal wares, hand tools and paraphernalia for fishing and rudimentary agriculture;
- Inhabitants thrive on hunting, fishing and little agriculture; natural resources are abundant and more than enough for a small population of tribes sparsely distributed throughout the archipelago;
- Ifugao rice terraces in the mountains of Luzon and cultivation techniques have already been well-developed and sustained through the culture of the Indigenous People since about 2,000 years ago.

1521-1898 (Spanish colonial regime)
- Spaniards introduce single animal-drawn wooden plow with cast-iron plowshare and moldboard, carabao (water buffalo)-drawn carts for agricultural produce transport and horse-drawn calesas (carriage) for personnel transport;
- Spaniards introduce processing technologies such as for making chocolate tablets from cacao, concrete and wood construction technologies for structures such as churches and public buildings and blacksmithing such as for horses a cart and carriage wheels, hand tools and plow accessories.

1902-1940 (American colonial regime)
- US military and investors first used three-wheel tractors in abaca (banana fiber crop) plantations in Mindanao to produce cordage for maritime usage and for export;
- US mechanization technologies transferred to Philippines such as the tractor-powered stationary rice thresher - the “McCormick” thresher or “trilladora”.

1941-1945 (Japanese occupation, World War II
- Japan introduces household gadgets such as lamps, cooking appliances
- No technology transfer on agricultural mechanization as Japan also uses draft animals in farm operations

1950-1970
- President Elpidio. Quirino (1948-1953) pursues industrialization making Philippine economy second only to Japan in Asia by early

1960s; unfortunately, this pursuit was not sustained by the succeeding administrations;
- Large grain silos for storage of paddy and corn are installed in Northern and Central Luzon but turned out to be "white elephants" and later dismantled;
- Human and animal farm power sources are predominant; agricultural mechanization and labor productivity levels are low;
- Small landholdings of up to 3 ha constitute 62.3 % of total farms in 1960;
- Four-wheel tractor sales are driven by credit programs and high sugar prices;
- IRRI is established in 1960 at the University of the Philippines College of Agriculture campus, now UP Los Baños (UPLB); the green revolution starts; IRRI develops IR8 or "miracle rice" in 1966;
- Hand tractors from Japan are introduced in early 1960s; Landmaster tractor from UK fits as workhorse for multiple cropping project by IRRI;
- President Ferdinand Marcos (1965-1986) builds infrastructures such as roads, ports, dams for irrigation and power generation as foundation for industrialization originally envisioned by President Quirino to support agriculture.

1971-1980
- Agricultural Mechanization in Southeast Asia (now AMA) launches its maiden issue -Spring 1971;
- IRRI Agricultural Engineering Department undertakes the Small Farm Machinery Development Program under USAID grant; the axial-flow thresher makes obsolete the traditional pedal drum and manual threshing methods;
- President Marcos declares martial law; Masagana-99 rice program enables export of rice; GO 47 strategy for corporate rice production fails; the barangay as basic political unit is organized;
- Institution-building and strengthening start: AMTEC in 1977; PhilRice in 1985; Philippines hosts the Regional Network for Agricultural Machinery (RNAM) at UPLB with the Agricultural Mechanization Development Program (AMDP) as country counterpart, which advocates agricultural mechanization policy;
- First fuel crisis occurs in 1973 and a second one in 1979.

1981-1990
- IRRI-AED releases more designs of small farm machines and devices;
- UPLB-based RNAM actively conducts regional activities on agricultural machinery and mechanization;
- SV Agro-industries in Iloilo develops floating power tiller; IRRI-AED modifies it into hydrotiller; both designs are adopted by farmers;
- Delta Motor Corporation with technology backstopping of Toyota Motor Corporation of Japan landmark manufactures 1,000 units of 10-hp diesel engine, the first in Southeast Asia;
- People's Power Revolution in 1986 causes political turmoil and economic downturn; cuts short the Marcos strategy of infrastructure development to support industrialization which in turn was aimed at supporting agriculture.

1991-2000
- IRRI-AED releases design of the rice stripper-gatherer SG800 based on stripper rotor technology developed by the UK Silsoe Research Institute;
- IRRI phases out design and development of rice production machinery and focuses instead on postharvest technologies starting in late 1990s;
- PhilRice-Rice Engineering and Mechanization Division (REMD) and the Bureau of Postharvest Research and Development (BPRE) sustain research, development and extension (RDE) activities of rice production and postharvest machinery;
- Functions of the Department of Agriculture and other government agencies are devolved to local government units (LGUs)

2001-2016
- The Agriculture and Fisheries Mechanization (AFMech) Law is passed in 2013; this landmark legislation now firms up the policy of modernizing Philippine agriculture through agricultural mechanization;
- The Philippines starts deliberate shifting from labor-intensive and low labor-productive farm operation methods to mechanized farming;
- PHilMech implements the Department of Agriculture's Rice Mechanization and Postharvest Program (RMPP) for 2011-2016; promotes production and postharvest machinery among Farmers' Associations on favourable procurement terms;
- The Philippines imports some 200,000 single-cylinder gasoline and diesel engines in 2013 alone (AMMDA, 2014) mostly from US, China, Thailand, Indonesia and Vietnam;
- A new National Agro-fishery Mechanization Program (NAFMP) is being formulated by the Bureau of Agricultural and Fisheries Mechanization Engineering (BAFE);
- Level of mechanization is still low with work animals still the predominant power source for small landholdings, which have presently increased in number, further reduced in size and been widely scattered because of partitioning

among heirs, inter-regional marriages, land reform and sale/conversion for non-agricultural uses.
• Small landholdings of up to 3 ha constitute 88.4% of total farms in 2012
• Power tillers are gradually replacing the carabao through increasing availability of custom hire services, but not as rapidly as desired because of high prices of imported engines
• Imported four-wheel tractors, rice transplanters and combines start getting popular
• Foreign exchange remittances by overseas Filipino workers and professionals slowing down due to Middle East crisis, low fossil fuel prices and economic growth rate slowdown – may affect importation of agricultural power and machinery
• Killer typhoon Haiyan or Yolanda devastates Leyte, Samar and other Northern Visayan provinces killing some 10,000 people (unofficial estimate) in 2013

Beyond 2016

The following are some issues to consider in the formulation of agricultural mechanization policies and strategies:
• Deliberate pursuit of national industrialization to support agriculture;
• National Agro-fisheries Mechanization Program (NAFMP) to continue distributing power and machinery which are "Made not in the Philippines?"
• Local manufacture of engines; development of renewable and environment friendly farming technologies;
• RDE on technologies for land levelling and precision agriculture, automation and robotics but not to neglect the classic designs for transition from traditional to high-tech agricultural mechanization;
• Overhaul of polices and laws for farmland inheritance, land forming and terracing for soil and water conservation as well as for agricultural mechanization;
• Building of infrastructures for irrigation and drainage, transport (roads, railways, cableways and ports) for efficient agricultural mechanization; and
• Other issues that may crop up.

Introduction

In the Spring 1971 maiden issue of AMA, then called Agricultural Mechanization in Southeast Asia, the article entitled "The Present Problems and Future of Agricultural Mechanization in the Philippines," related that agricultural mechanization then was just developing and that it would have a bright future if the problems identified were properly addressed. It was indeed a struggle promoting agricultural mechanization during the last 45 years in an environment where social concerns on rural poverty, small-sized landholdings and increasing population have been overriding considerations and stumbling blocks because of the misconception that agricultural mechanization wants only displacing farm labor.

Large-scale farm mechanization as in North America, Australia and some countries in Europe have been pre-conceived as not applicable for small-sized farms, especially the wetland rice fields in Southeast Asia. Adaptations of the technologies however, from here and there as well as from the AMA world and those of small farms in Europe, may be adapted through agricultural engineering and innovations.

The Spring 2016 issue aptly commemorates the 45th Anniversary of that first issue of AMA and the achievements made by its publisher, Farm Machinery Industrial Research Corporation, in cooperation with The Shin-Norinsha Co., Ltd. and the International Farm Mechanization Service in Tokyo, Japan.

The efforts of its Chief Editor, Mr. Yoshisuke Kishida and the Contributing Editors from around the world as well as the staff for AMA's sustainability and for the ever-improving quality towards excellence, have immensely contributed to its success during the past 45 years. Congratulations for the job well done with the hope for the continuing stream flow of information and the unfolding of agricultural mechanization technologies and strategies across the continents for the benefit of humankind, that indeed is the noble purpose of AMA.

Through 45 years, the progressive development of agricultural mechanization in the Philippines unfolded through government efforts in the formulation of policies and implementation of strategies, building of new institutional infrastructures and strengthening of the existing ones for conducting research, development and extension of agricultural machinery as well as for upgrading of human resources and participation in a regional network for exchange with other Asian countries of information in agricultural machinery and experiences in agricultural mechanization. The government also built new physical infrastructures and upgraded the existing ones, which not only supported agricultural development but also paved the way for the farmers adoption of new agricultural mechanization technologies.

The private sector also played a significant role in the supply of appropriate agricultural machinery to the farmers through commercial channels. Small-scale fabrication shops for agricultural machinery contributed to industrial growth in the countryside. Although importation of appropriate machinery enabled some farmers to avail of modern efficient machines thereby modernizing their agricultural operations, the real industrial progress and inclusive growth could have been achieved if the local manufacture of agricultural machinery were the path pursued by the private sector players in agricultural mechanization.

Brief History of Agricultural Mechanization

During the pre-Hispanic era (before 1521), there was already metalworking technology such as blacksmithing since metals were already used in weapons such as spears, arrows and knives as well as hand tools. Perhaps the metalworking technologies were acquired through trading with China.

As the Spaniards established colonial settlements (1521-1898), they introduced animal-drawn carts, sleds and horse-drawn carriages (calesas and caruajes) for transportation and cast-iron moldboard plows (arado), harrows and hand tools for growing rice and corn as well as export plantation crops (sugarcane, tobacco, coffee, pineapple and coconut) along with technologies for making them such as blacksmithing, foundry, masonry and carpentry. Skilled craftsmen made sturdy wooden plows and harrows as well as fine furniture. They also introduced from Europe technologies for processing cacao which they introduced from South America into chocolate drinks from tablets (tableas).

During the American colonial regime (1901-1940 and 1945-1946), three-wheel tractors were used in abaca (a banana species fiber crop) in plantations in Davao province in Mindanao. Abaca production and processing into cordage were for strategic maritime usage and for export. The large stationary rice thresher-the “McCormick” thresher or trilladora powered from the power-take-off of a three-wheel tractor was a common sight in Central Luzon, which was known as the rice granary of the Philippines. Under the Parity Agreement, American investors established industries in the Philippines.

During World War II Japanese occupation (1941-1945), the Imperial Army introduced small household gadgets but no technology transfer on agricultural machinery was carried out as Japan had the same level of agricultural mechanization as the Philippines, that is, use of animal-draft technology. They however, introduced the yu-yu eel in the rice terraces in Ifugao province and its culture is being currently revived through a small project funded by the Japan International Cooperation Agency (JICA).

The rehabilitation period after WWII (1946-1950) was marked by activities of rebuilding the infrastructures destroyed during the war but was complicated by the Huk Rebellion by farmers clamoring for social justice.

During the period 1950-1970, work animals were used as power sources for doing farm operations in the predominantly small landholdings of up to 3 ha/farming family – carabaos or water buffaloes for land preparation for wetland rice, cattle for the production of upland crops and horses for transportation in mountainous areas. Manual harvesting using sickle and manual threshing by hitting the rice panicles against a hard object or by foot trampling were the common methods. The hold-on pedal thresher with wire-loop rotating drum were popular in some provinces but did not spread to other places because of preferences. Agricultural mechanization level then was much lower; so was the land and labor productivity, than at present.

Large grain silos for storage of paddy and corn were installed in Northern and Central Luzon under the auspices of the US Economic Cooperation Agency with the National Economic Council (ECA-NEC), now US Agency for International Development-National Economic and Development Agency (USAID-NEDA). These silos however, had not been utilized because of technical problems such as moisture condensation due to improper drying (there was lack of mechanical drying facilities), high atmospheric humidity and poor grain aeration. Moreover, grain production volume was not sufficient. The silos that dotted the countryside were later dismantled.

During the early 1950s, four-wheel tractors were introduced for land preparation – plowing and rotary tilling in wetland rice lands and land preparation and furrowing for planting in sugarcane plantations. Four-wheel tractors being used in soft flooded fields for wetland rice had their rubber tires fitted with cage-wheel or steel-lug extensions to increase traction and floatation because carabao mud wallows posed bogging down problems. Further destruction of the soil hard pan worsened the problems and forced owners to shift the use of large tractors to custom hire services in dry land operations for corn, coconut and other upland crops production. Interestingly, the hard pan has been observed to become shallower through increased use of power tillers since its introduction from Japan and UK during the early 1960s and by IRRI starting in the late 1960s.

The Landmaster hand tractor from UK gets popular among farmers because of its simplicity during the late 1960s. It was the workhorse for IRRI’s multiple cropping project because of its lightweight, ease of operation and versatility in terms of variety of implement attachments for growing wetland rice and different upland crops. Although multiple cropping required intensive cultivation activities, the technology was demonstrated as feasible if power-intensive operations were mechanized using the hand tractor. Yet farmers could increase their income by intensification and diversification. Unfortunately, for some reason, the supply of Landmaster tractors was discontinued and the manufacturing technology was never transferred to the Philippines.

In some large rice, sugarcane and corn farms, four-wheel tractors procured through the Central Bank: International Bank for Rural Reconstruction loan program (1966 to 1980) and driven by the above-world market prices of sugar through the US Sugar Quota program became popular for custom hire services. Mismanagement of the enterprise however, led to loan repayment defaults and repossession of large tractors by the banks. The problem stemmed from the fact that some unscrupulous clients who promised to pay the custom hire service provider during harvest, some months after the services were rendered, “pole vaulted” on their promise, that is, sold their harvest to the highest bidder and made all sorts of excuses and a new promise to postpone payment till the next harvest. In the meantime, the service provider, lacking income defaulted on his amortization payments to the bank.

Cage wheels and lug extension attachments in rubber tires improve traction and minimize bogging down in deep mud;

The following is a chronology of agricultural mechanization developments during the last 45 years:

1971-1980. This period marked the establishment and strengthening of most institutional and physical infrastructures for agricultural mechanization. The UPLB College of Engineering and Agro-industrial Technology Agricultural Mechanization Development Program (UPLB/CEAT-AMDP) led the agricultural machinery and mechanization research, development and extension and participates as Philippine counterpart in the UN ESCAP Regional Network for Agricultural Machinery (RNAM) which the Philippines hosted at UPLB. The other agricultural mechanization-related institutions were established during were the National Postharvest Institute for Research and Extension, now Center for Postharvest Development and Mechanization (PHilMech) and the Agricultural Machinery Testing and Evaluation Center (AMTEC).

UPLB/CEAT-AMDP had been advocating the formulation of agricultural mechanization policies and strategies but was frustrated by government’s neutral attitude (not opposing but not pushing) of letting agricultural mechanization run its course naturally and implementing mechanization-related activities based on ad-hoc strategies. The government has been wary of social and economic consequences because of displacement of labor. The program released designs of small farm machines adapted from RNAM-participating countries. It also organized training, industrial extension and demonstrations of new machines.

The International Rice Research Institute-Agricultural Engineering Department (IRRI-AED) undertook the Small Farm Machinery Development Program (SFMDP) supported by the USAID grant. In 1972, it released the design of the power weeder but was not promoted because of labor displacement implications. A Japanese company adapted the IRRI-designed power weeder IRRI and commercially manufactured it in Japan. Ironically, the spraying of environment-harmful and labor-displacing herbicides started getting popular for weed control. Spot hand-weeding however, continued to be practiced to supplement the use of herbicides in wetland rice culture.

The power tiller (PT) and the axial-flow thresher (AFT), which were introduced during the mid-1970s, were readily accepted by farmers because they were suited for easing the power-intensive operations. The large demand prompted the establishment of small-scale agricultural machinery fabrication enterprises to supply such machinery.

IRRI-AED earlier abandoned the design project on stripper harvester because of problems in grain losses and increasingly complicated design solutions. The designs of the table and long-drum panicle-feed threshers were also abandoned because of non-acceptability by farmers. Pedal threshers were popularly used in some provinces but were rejected by farmers when introduced in other provinces where the manual beating of the rice panicles was the traditional method.

Institutions for research and extension for rice, sugarcane, tobacco, coconut as well as for irrigation services, agricultural machinery testing and evaluation, agricultural credit, farmers’ cooperatives and irrigator’s associations and agricultural machinery manufacturers’ associations were established and strengthened. The Philippine Council for Agricultural Research and Development was organized.

In the area of human resources development through education and training of engineers, technicians and farmers, several public and private colleges offered agricultural engineering courses; however, the quality of engineering education has perceived to diminish.

Credit institutions and programs were also established to promote agricultural mechanization through purchase of tractors and agricultural machinery. The CB:IBRD credit program (1965-1980) was a major driver of purchase tractors and other agricultural machinery but had led to bankruptcy and repossession of tractors by the bank because of mismanagement of custom hire service enterprises as there was no training and previous experience in the business. Defaults in payment by the client-farmers who promised to pay at harvest were high and collection activities were not pursued in earnest. One of the common causes of non-payment was the "pole vaulting" scheme where the farmer secretly sold his harvest to the highest bidder and then fabricated alibis of losses due to typhoons and misfortunes. The incidence of foot-and-mouth disease of carabaos in 1975 resulted also in large purchases of power tillers and four-wheel tractors (Reyes and Agabin, 1985).

The agricultural machinery designs released by IRRI and government institutions catalyzed the formation of industry groups such as the Agricultural Machinery Manufacturers and Distributors Association (AMMDA), the Laguna Machinery Manufacturers Association (LAMMA) and other regional and provincial groups for manufacturing, importing and trading activities for supply of agricultural power and machinery. A few inventors succeeded in commercializing their creative ideas such as the "Turtle Power Tiller" and modified designs of the PT, AFT, flat-bed grain dryer. Many of their products are still popular at present.

In 1979, the headquarters of the Regional Network for Agricultural Machinery (RNAM), a UNDP-assisted project of initially eight Asian countries, namely India, Indonesia, Islamic Republic of Iran, Pakistan, the Philippines, Republic of Korea, Sri Lanka and Thailand, with supplementary funding from Australia and Japan and which was executed by the UN Economic and Social Commission for Asia and the Pacific (ESCAP) with technical collaboration of FAO and UNIDO, was established at the UPLB Campus. Its Regional Office coordinated the set programs and activities related to information dissemination and strengthening of the National Institutes in the participating countries whose number increased to 11 by 1991 with the joining of Bangladesh, Nepal and China. In 1991, the headquarters was temporarily transferred to ESCAP in Bangkok, Thailand until it had a permanent one in Beijing, China. RNAM is now called the Center for Sustainable Agricultural Mechanization or CSAM.

1981-1990. During this period, IRRI-AED released the designs of agricultural machinery for industrial extension and demonstration to farmers and conducted training in the manufacture of manual rice transplanter, hydro-tiller, micro-tiller, axial-flow pump, reaper and small-scale renewable energy resources applications like those for water lifting (ram pump and tapak-tapak pump, Savonious windmill), pest control (rat trap system, plastic fence, snail egg clapper) and heating and cooking devices (rice hull stove, rice hull furnace, rice hull char for charcoal briquette making); conducts industrial extension and demonstration to farmers.

Many local fabricators benefitted from such releases because they made prototypes of the small machines for export to institution partners of IRRI in other countries. They in turn extended them to local fabricators who modified them to suit local conditions and demonstrated them to farmers in collaboration with the national institutions.

In 1985, the Philippine Rice Research Institute (PhilRice) was established. Subsequently, laboratory buildings, research facilities and technical assistance from JICA boosted its institutional strengthening. Its Rice Engineering and Mechanization Division (REMD) designed, fabricated, field tested, demonstrated to farmers and extended the rice machinery technologies to local manufacturers for commercial manufacture.

RNAM conducted regional training workshops on policies and strategies, coordinated sub-network activities on rice tranplanters, weeders, cereal harvesters and manufacturing technologies for seed-fertilizer drills, grain threshers and other developed machinery prototypes, catalyzed exchanges of prototypes of machines and produced technical publications on agricultural mechanization.

Advocacy for increasing agricultural mechanization was hampered by concerns of labor displacement and economics of applications in small farms. The government has stayed neutral by neither rejecting nor pushing initiatives for agricultural mechanization. Untimely introduction of new mechanization technologies have self-correcting mechanisms. An example is the case of sabotaging the performance of a rice reaper by planting wires in the field to damage the cutter blades in some places but no such incidents happened in other places. Another case is that of the farmer who initially accepted the manual rice transplanter but later voluntarily rejected it because he saw that some of his workers in the transplanting crew would be deprived of income.

The Delta Motor Corporation, a distributor of Toyota car models, pioneered in Southeast Asia in the local manufacture of 10-hp diesel engines. It initially produced 1,000 units of prototype engine upon encouragement by President Marcos who intended it to be the workhorse by farmers (to replace the carabao) and fishers as well as by the small-scale industries to generate jobs as industrialization increased. The company had the technology backstopping of the Toyota Motor Corporation of Japan.

The People's Power Revolution in 1986 caused political turmoil and economic downturn and unfortunately, cut short the Marcos strategy of infrastructure development to support industrialization, which in turn, was aimed at supporting agriculture initially by generating jobs and increasing the buying power of consumers for farmers' produce.

The Presidential Commission on Good Government (PCGG) sequestered the factory facilities in 1986 on charges of financing anomalies and resulted in idle assets and forgone opportunities because the case has not yet been resolved after 30 years. In the meantime, Thailand, Indonesia and Vietnam have overtaken the Philippines in engine manufacture through joint ventures with foreign companies.

1991-2000. President Fidel Ramos (1992-1998) pursued strategies towards making the Philippines a Newly Industrializing Country by establishing industrial estates to attract foreign investors to establish industries. The Cavite-Laguna-Batangas-Rizal-Quezon (CALABARZON) industrial zone caused the massive conversion of agricultural lands into industrial estates. Unfortunately, the Asian Financial Crisis of 1997 wreaked havoc on the industrialization plans and more so was not pursued by the succeeding administrations.

During this period, IRRI-AED released the design of the rice stripper-gatherer SG800 during the mid-1990s. Unlike that pursued during the early 1970s, the new stripper-gatherer design adapted the keyhole rubber stripper-rotor technology developed by the UK Silsoe Research Institute. In spite of its technical success however, the stripper-gatherer was not adopted by the local manufacturers because of the perceived high harvesting losses, inability to strip harvest a lodged crop, the cumbersome switching of the filled grain box with an empty one and the re-threshing/cleaning with a mini-axial-flow thresher. Its promotion was also set back by the displacement of harvesting labor.

By the late 1990s, IRRI phased out the design and development of rice production machinery and focused instead on postharvest technologies to solve the second-generation problems brought about by increased rice yields. The capacities of the National Agricultural Research institutions in the rice-producing countries had already been strengthened to design and develop agricultural production machinery.

The PhilRice-Rice Engineering and Mechanization Division and PHilMech sustains RDE activities of rice production and postharvest machinery.

2001-2010. The Department of Agriculture, through PHilMech and PhilRice introduced the Ginintuang Masagang Ani (GMA) program to boost rice production. The Philippine Government started encouraging agricultural mechanization to boost crop production and enhance land and labor productivity.

Inter-island transport of people and commodities was boosted by building the maritime transportation through development of port facilities and promotion of investments in roll-on-roll-off shipping lines.

2011-2016. ***The Present Status of Agricultural Mechanization***. This will be discussed in Part II of the article.

■■

PHILIPPINES

Agricultural Mechanization in the Philippines, Part II : Current Status

by
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Abstract

Part I of the two-part article on agricultural mechanization in the Philippines provides the brief historical background of its development. The past colonial governments of Spain (1521 to 1898), which had focused on plantation crop production for supply of raw materials to the mother country and made the local inhabitants "hewers of wood and drawers of water," and the US (1901 to 1946), which focused mostly on basic and soft profession education (teaching, law and medicine) and little in hard profession and technology education (agriculture, engineering and industry) had not transferred agricultural mechanization technologies early on and more importantly, had not established a culture base of entrepreneurship and manufacturing of power and machinery such as blacksmithing and foundry to support agriculture.

Such historical developments have shaped the less risky and easier importation culture than local manufacture of the agricultural machinery at the expense of exports of raw agricultural and natural resource products. The foreign exchange revenues could have financed infrastructures and manufacturing equipment. The vision of President Quirino (1948-1953) to strengthen industrialization by initially protecting the fledgling industries that he encouraged to be established during his term was met with strong opposition lobby among the import-oriented business sector of the time and led to his failure to get re-elected for a second term. What started out as an economic tiger in Asia, second only to Japan, resulted in the Philippines being a laggard among the newly industrializing countries because the succeeding administrations ignored his vision of an industrialized Philippines although President Marcos (1965-1986) and President Ramos (1992-1998) revived it, albeit partially during their terms.

Part II discusses the current status of agricultural mechanization, which may lead to the formulation of strategies as provided by the Agriculture and Fisheries Mechanization (AFMech) Law of 2013, a landmark legislation that firms up the policy of modernizing Philippine agriculture through agricultural mechanization supported by the installation of institutional and physical infrastructures starting in the early 1970s.

Industrialization for economic development is recommended as strategy to support agricultural development.

Introduction

Currently, the level of mechanization is still low with humans and work animals being the predominant power sources for small landholdings, which have presently increased in number, further reduced in size because of partitioning among heirs, land reform and sale/conversion for non-agricultural uses. The farm holdings are widely scattered because of inter-regional marriages and therefore, difficult to manage closely. Power tillers (PTs) are gradually replacing the carabao through the increasing availability of custom hire services.

The carabao or water buffalo; however, is not intended to be fully phased out because of the continuing upgrading program by the Philippine Carabao Center (PCC) (established in 1992) for fresh milk as well as for meat production and food processing. There is a need to develop the local dairy industry as powdered milk has been a traditional import supplying more than 90 % of the milk needs. Thus, the current milk industry is characterized by importation, reconstitution and repackaging of powdered milk even as the National Dairy Authority (established in 1995) pursues its mandate of developing the dairy industry. Yet for small farms, which has increased in number, the carabao can be an old reliable work animal in some places. The PCC includes in its program upgrading the carabao also as work animal.

Imported power and machinery consisting of single-cylinder engines, four-wheel tractors, combines, rice transplanters and precision planters, dryers and rice mills are now increasing in number essentially because of the current RMPP. A sustainable agricultural mechanization will depend upon the strategies, support and implementation of the NAFMP in the coming years.

Table 1 gives a bird's-eye view of Philippine agriculture, the development of which, among other factors, depends upon and is influenced by agricultural mechanization.

Table 1 Some current statistics on Philippine agriculture.

Item	Quantity/Value	Remarks
Number of people employed in the agricultural sector	12 million	Represents 33 % of total labor force
Number of coconut farmers	3.3 million	One of the poorest groups in the agriculture sector
Number of rice farmers	3 million	Rice farmers are seasonally and continually mired in debt from paddy traders to sustain themselves between harvests
Total agricultural land	11.14 million ha	0.93 ha per farmer
Total arable land	5.4 million ha	
Area planted to coconut in 2011	3.4 million ha	0.45 ha arable land per farmer
Harvested area for rice	4.4 million ha	Twice a year in irrigated areas (about 1 million hectares); once annually in rainfed and upland areas
Income of rice farmers per hectare from 2010 to 2013	pesos15,830 to 21,910	Increase of 38.41 %, from US$ 338.80 to US$ 466.17 @ 47.00/US$
Rice farmers' income per year per hectare	Pesos 45,000	Best estimate; US$ 957.45
Coconut farmers' income per year per hectare	Pesos 20,000	Best estimate; US 425.53 Inter- and multiple-cropping may increase income
Poverty threshold income for a family of five	Pesos 8,022 per month.	US$ 170.68 per month; Poverty threshold refers to the minimum income a family or individual must earn in order to be considered "not poor".
Annual importation of rice, 2000 to 2015	0.6 million ton to 2 million tons	Importation on the upward trajectory
Record production of rice/year	18 million tons in 2015	Production still unable to catch up with population increase
Average number of typhoons per year	20 2-3 typhoons are devastating to people and agriculture	The strongest recorded typhoon, Haiyan or Yolanda hit Leyte and the Northern Visayas in November 2013 with more than 200 km/h winds and produced a storm surge that killed about 10,000 people, left families homeless and devastated local
Coconut exports in 2011	Pesos 1.4 billion	US$ 29.79 million
Contribution of the agricultural sector to the gross domestic product or GDP (**Fig. 1**).	Pesos 14. 7 billion	US$ 312.76 million or 11 %, a decline from 11.2 % in 2013 and lower than the industry sector. Services sector has the largest share; industry sector must be promoted to support agriculture as in other countries

Source: CAMP —Coalition for Agricultural Modernization in the Philippines - an advocacy group based in Los Baños, Philippines and with members composed mostly of retired scientists, academicians and professionals, 2015

Table 2 Number of farms/holdings and average area per farm/holding in 1980 and 2012.

Year	Number of Farms/Holdings	Average Area per Farm/Holding
1980	3,420,323	2.84
2012	5,562,577	1.29

Source: Philippine Statistics Authority, Censuses of Agriculture and Fisheries, 1980 and 2012.

Number and Area of Farms/Holdings Reported in 2012

There were 5.56 million farms/holdings covering 7.19 million hectares or an average area of 1.29 hectares per farm/holding (**Table 2**). The number of farms/holdings increased from 1980 to 2012 by 62.6 percent as the average area of farms/holdings decreased from 2.84 hectares per farm/holding in 1980 to 1.29 hectare per farm/holding in 2012. This size reduction could be accounted to the partitioning of farms/holdings by inheritance, parcel sales of land and land reform.

About 98 percent of the total farms/holdings in the country in 2012 had size of 7 hectares and below. Of these, three in every five farms/holdings were below 1 hectare with an average area of 0.28 hectare per farm/holding. About 32 percent or 1.78 million farms/holdings belonged to farm/holding size group of 1.00 hectare to 2.99 hectares. The area of these farms/holdings totalled to 2.59 million hectares with an average of 1.46 hectare per farm/holding. One out of ten farms/holdings belonging to 3.0-7.0 hectares had an average area of 4 hectares per farm.

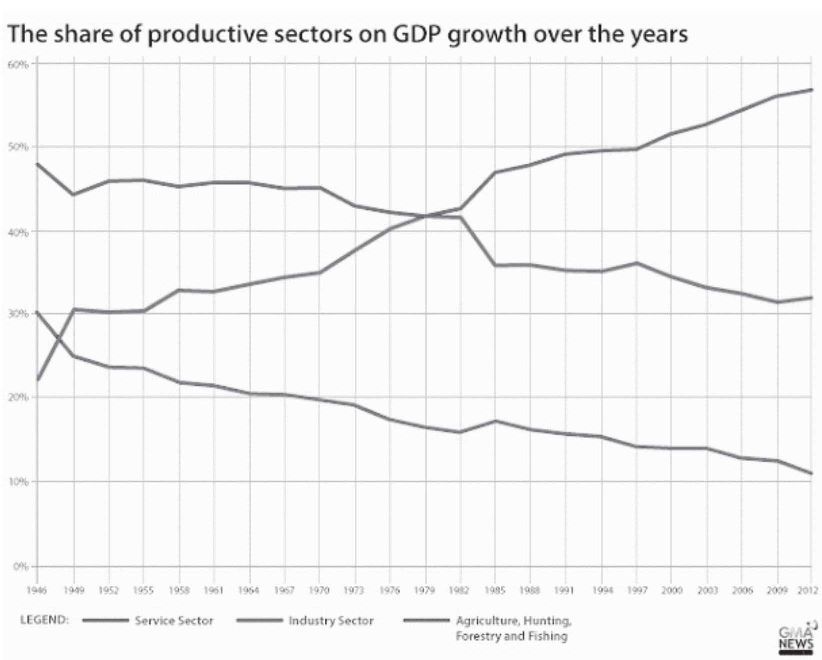
Table 3 shows that small landholdings accounted for 62.30 % of total farms in 1960 and 88.37 % in 2012.

2 percent of the remaining number of farms/holdings had size of more than 7 hectares, which were categorized as large farms/holdings. These measured to 1.6 million hectares.

Table 3 Number of farms/holdings by size of farm/holding: 1960 and 2012.

1960			2012		
Size of farm, ha	Number	%	Size of farm, ha	Number	%
Below 0.2	201,019	0.9	Under 0.500	2,159,963	38.30
0.2 to 0.5	69,074	3.2			
0.5 to 1.0	160,680	7.4	0.500 to 0.999	1,004,633	18.06
1.0 to 2.0	642.060	29.6			
2.0 to 3.0	458,914	21.2	1.00 to 2.999	1,780,702	32.01
Sub-total	1,330,129	62.3	Sub-total	4,945,298	88.37
3.0 to 4.0	253,087	11.7			
4.0 to 5.0	152,398	7.0	3.00 to 7.000	518,046	9.31
5.0 to 10.0	289,730	13.4			
10.0 to 15.0	86,164	4.0	7.001 to 9.999	44,102	0.79
15.0 to 20.0	13,667	0.6			
20.0 to 25.0	9,788	0.5	10.000 to 24.999	49,657	0.89
25.0 to 30.0	7,378	0.3			
50.0 to 100.0	2,466	0.1	25,000 to 49.999	3,877	0.07
100.0 to 200.0	1,777	0.05			
Above 200	1,042	0.05	50.000 and over	1,597	0.03
Total	2,167,644	100.00	Total	5,562,577	100.00

Sources: Philippine Statistics Authority, Census of Agriculture and Fisheries, 2012 and Agricultural Census of the Philippines, 1960 as cited by Lantin, 1971.



Source: CAMP

Fig. 1 Downward trend of the contribution of agriculture to gross domestic product (GDP), a common phenomenon among advanced and newly industrializing countires.

Share of Agriculture, Industry and Service Sectors to Gross Domestic Product

Fig. 1 shows the downward trend of the contribution of agriculture to GDP similar to developed countries and the advanced developing countries. This trend in the Philippines means that the service and industry sectors comprised the bulk of contribution to GDP. The industry sector; however, was on the downward trend starting in 1982, a reflection of the political turmoil during the last few years of Martial Law that ended with the so-called People Power Revolution in 1986.

The contribution of the industry sector particularly manufacturing, which would have employed the unskilled and semi-skilled labor from the farms, had remained stagnant. The shortfall in its growth has been compensated by the upward trend in the service sector, which comprised the employment of some 3 million skilled and semi-skilled workers and professionals abroad (overseas Filipino workers or OFWs) and of the highly skilled and educated professionals in the domestic business process outsourcing (BPO) services.

The service and industry sectors are the primary contributors to GDP and therefore, must be promoted to support agriculture even as agriculture should all the more be developed to maintain its share ratio. The absolute value of contributions of both sectors should; however, be high and the poor should not be left out as beneficiaries.

The rural employment profile is characterized by the poor landless farm workers being seasonally employed by similarly poor farmers with small landholdings. These poor "employers" not only have to borrow money (or get advance payment with interest for harvest) to defray input and operational expenses but also have to absorb all the production risks brought about by typhoons and calamities. They have no recourse but to get loans from their ***suki****[*]* paddy traders using their harvest as collateral. In many cases, rice traders exploit them by buying high-moisture paddy at low price and collecting high interest rates for their loans, which are paid in kind.

Table 4 Installed power per hectare in Asian countries.

Country	Installed Power, hp/hectare
Japan	7.00
Republic of Korea	4.11
People's Republic of China	3.88
Pakistan	1.02
India	1.00
Thailand	0.79
Islamic Republic of Iran	0.70
Philippines	0.52
Indonesia	0.41
Bangladesh	0.40
Nepal	0.31

Source: PHilMech

Present Status of Agricultural Mechanization

By simplified definition, agricultural mechanization embraces the use of human, animal and mechanical power for farm operations and processing. The degree of mechanization can be gleaned from the mix of the sources of power.

The commonly used measure of the level of mechanization is the installed power per hectare or hp/ha. **Table 4** shows that the level of mechanization in the Philippines of 0.52 hp/ha is low compared to other Asian countries. The Department of Agriculture has planned to increase this value to 4 hp/ha at least in the short term through its Rice and Mechanization and Postharvest Program (RMPP).

Levels of Mechanization

The levels of mechanization as defined in the Philippines by kind of power source and by degree of control by human intervention are as follows (UPLB-BAR, 2011 as cited by Amongo *et al*., 2011):

Low level: the operation is carried out by non-mechanical power sources, human and animal and controlled by human, e.g. manual harvesting rice using the sickle; plowing using carabao or water buffalo and moldboard plow.

Intermediate level: the operation is carried out by a mechanical power source in combination with a non-mechanical source and controlled by human, e.g. threshing using stationary axial-flow thresher (AFT) where feeding of straw-and-grain materials, supplementary cleaning and bagging are performed by human power.

High level: the operation is carried out by a mechanical power source and controlled by human,

* ***Suki*** is a Filipino word adopted as an English word that means an arrangement between the seller and buyer for regular patronage in exchange for favourable treatment.

Table 5 Levels of mechanization in the production and processing of selected crops (PCAARD, 2009 as cited by Amongo *et al*., 2011).

Operation	Rice & Corn	Vegetables, Legumes and Root Crops	Coconut	Sugarcane	Fruit Crops	Fiber Crops
Land preparation	Intermediate to High	Low	Low	Intermediate to High	Low	Low
Planting/ Transplanting	Low	Low	Low	Low to Intermediate	Low	Low
Crop care/ Cultivation	Low	Low	Low	Low to High	Low	Low
Harvesting	Low	Low	Low	Low		Low
Threshing/ Shelling/ Hulling	Intermediate to High	Low	Low			
Cleaning		Low	Low		Low	
Drying	Low	Low	Low			Low
Milling/ Village-level processing	High	Low	Low		Low	Low

e.g. rice combine.

Full mechanization: a high-level mechanization where control by human is reduced or substituted by electronic control gadgets, e.g. application of remote-control, computer-program automation and robotics.

By the above definition, the levels of mechanization for the production and processing of major crops in the Philippines are shown in **Table 5**. The predominantly low level of mechanization reflects the low productivity of labor employed in the operations. Thus, design (preferably adaptive for fast tracking), development and industrial extension of machines for commercialization to get them into the hands of farmers and custom service providers are needed to achieve high labor productivity and product competitiveness in the ASEAN Economic Integration.

Work animals have been the traditional sources of power for farm operations and rural transport of goods. The carabao or water buffalo has been mainly used for land preparation in wetland rice cultivation; cattle for dry land crop cultivation; and horse for transport in mountainous areas. They have been the mainstay as source of farm power by Filipino farmers with small landholdings, which range from 1 to 3 ha/farm comprising 62.3 % of all farms in 1960. As of 2012, this value increased to 88.37 %.

Gavino *et al*. (2006) found that Regions I, II and III (Northern and Central Luzon) had the same levels of rice mechanization of various farm operations. These levels were high in land preparation using hand tractor (95 %); low in crop establishment (100 %) of which direct-seeding was performed using drum seeder (0.3 %); low in crop care (100 %) where spraying with chemicals for pest control was performed with manual sprayer (100 %) and irrigation was performed by gravity system (85.5 %); low in harvesting manually using sickle (92.6 %); intermediate in threshing which was performed with mechanical thresher (93.9 %); and low in transporting inputs and harvests by walking on bunds or dikes (35 %), using animal-cart (40.6 %) and using jeep and truck (23.4 %); low (manual) in drying performed by using solar energy or sun drying (96.7 %); and high (mechanical) in milling (100 %).

Most of the Indigenous Peoples in the mountainous Cordilleras; however, are still using the mortar and pestle in threshing and hulling sun- and stove- dried rice panicles. Rice mills being introduced will change their traditional diet consisting basically of brown rice or unpolished to polished rice, which might make them vulnerable to malnutrition as what has happened to the poor in the lowlands when such mills were introduced during the late 1940s.

Table 6 shows the level of adoption of agricultural machinery.

The Rice Mechanization and Postharvest Program

The Center of Postharvest Development and Mechanization (PHilMech) under DA is mandated to implement the provisions of the Agricultural and Fisheries Mechanization Law that includes the Rice Mechanization and Postharvest Program (RMPP) for 2011-2016 (Bingabing *et al*., 2015). A new National Agro-fishery Mechanization Program (NAFMP) is being formulated by the Bureau of Agricultural and Fisheries Mechanization Engineering (BAFE) in coordination with the key players in mechanization consisting of government institutions and agencies, Department of Agriculture (DA) bureaus in collaboration with the local government units (LGUs) and NGOs.

Agricultural production and processing machinery were to be distributed to Farmers' Associations under the 85 : 15 scheme that is, 85 % of the machinery cost by the Government and 15 % of the cost by the association. The machines distributed in 2011 were rice combines, hand tractors, four-wheel tractors and threshers and those in 2012 were shallow tubewells, drum seeders, combine harvesters, mini-combines, reapers and seed cleaners.

The production machinery component of the program consists of primary machinery - hand tractor, 4-wheel tractor (depending upon location and need) and thresher - and secondary machinery - seed cleaner, reaper, drum seeder, mini-combine harvester and combine harvester.

The postharvest equipment component consists of: multi-purpose drying pavement (MPDP), biomass-fed flatbed dryer, multi-pass mill systems, recirculating dryer and biomass fuel furnace.

The qualified beneficiaries of the program are the following:

1. Farmers' Associations (FAs), Irrigators' Associations (IAs) and Farmers' Cooperatives (FCs) which are recognized by the Securities and Exchange Commission (SEC), Department of Labor and Employment (DOLE) or the Cooperative Development Authority (CDA) and
2. Private individuals who wish to engage in rice milling business.

Bingabing et al. (2015) described the level of agricultural mechanization for each major field rice production and postharvest operation in each of the 13 regions in the Philippines. He pointed out the following:

1. The mechanization of planting, weeding, spraying and harvesting in some regions were done mostly manually or with the aid of manually operated implements or gadgets such as knapsack sprayer and sickle. As such the level of mechanization is negligible.
2. The plowing, harvesting and threshing operations employed

Table 6 Machines and equipment used for specific rice operations and their level of adoption in the Philippines (Adapted, - italics show changes - from Bautista, 2003 as cited by Elepaño, 2015).

Operation	Machine/ Locally Adopted Equipment	Level of R&D/ Adoption/Prospects
Land preparation	Traditional tillage by using carabao or cattle	Still being used in rice, corn and sugarcane areas by small landholders.
	Power tiller + attachments	Has replaced work animals in most irrigated rice areas
	Four-wheel tractor + rotary tiller (rotavator)	Used in landholdings of more than 5 ha; in maize and sugarcane; excess capacity is utilized for custom hire services. Reconditioned compact tractors are becoming popular in Luzon for custom land preparation.
Transplant-ing	None; mostly done manually by contracted transplanting crews	The IRRI-developed 6-row manual transplanter during the early 1980s was initially accepted but later abandoned because of labor displacement; the machine may now be appropriate because of labor shortage during peak transplanting periods.
Direct seeding	None; mostly done by broadcasting	Manually-drawn and power-tiller-mounted 6 to 12-row drum rice seeders have been developed by PhiRice and molded plastic versions are being commercialized by some manufacturers; high-capacity (up to 3 ha/d) Korean tractor-mounted planter has been tried by a Philippine-Korean Project; precision rice planter is being developed by PhilRice, UPLB and private innovators for wetland and upland rice production to replace transplanting because of high labor cost.
Crop protection	Lever-operated knapsack sprayer	Popularly adopted sprayers are imported from China and Taiwan
	Manual push-pull type rotary weeder	Traditional design; the cono weeder developed by IRRI was found best but needs popularization
Irrigation	National Irrigation Administration (NIA) and local Irrigators' Association facilities	Common where available; some farmers have back-up shallow tube well (STW) for cases of water shortage
	Centrifugal pump	Highly adopted for STW
	Axial-flow pump	Not common in farms but adopted in fishponds
Harvesting	Mostly manual using sickle by contracted team paid 10 % of the harvested and threshed paddy;	IRRI-developed reaper-windrower from China design (mid-80s), paddy stripper (early 1990s) and PhilRice cutter harvester (2010) need promotional activities for adoption by farmers; rice and corn combine use is getting popular and patronized through custom-services.
	Manual harvesting of sugarcane by migrant workers using knife usually imported from Brazil	Sugarcane harvester has been introduced in large plantations
Threshing	Axial-flow thresher Manual whacking of panicles, foot-threshing and pedal threshers	Widely used; developed by IRRI during late 1970s; designs were quickly adapted and commercialized by small-scale agricultural machinery fabricators; threshing still labor-intensive; 8-10 contracted laborers operate with custom service provider and paid 9 % share of harvest.
Drying	Sun drying of paddy on road and other pavements; problems encountered during the rainy season; flat-bed dryer with rice husk furnace common	Imported batch recirculating dryers of 6 to 10-ton capacity are used the National Food Authority; custom service providers in rice mills offer drying services.
Milling	Rubber-roll type huller, cono (abrasive stone) and steel polisher;	Highly mechanized except in remote upland areas where mortar and pestle system is still used; imported rice mills are preferred for quality and efficient performance.
Storage	Traditional in sacks; rare as bulk	NFA and the rice millers store dried paddy in their warehouses; farmers store paddy only enough for home consumption and food security
Transport	Power tiller + trailer	Highly adopted in Central Luzon rice areas
	"Three-wheels" –locally designed self-propelled wagon using engine	Common in Laguna Low-hanging cableway for transport of bananas from field to processing plant has been adopted by some corporations in Davao; Sugarcane transport from field to milling central is mostly done by trucks; old rail transport system is getting obsolete; harvesting, in-field transport and loading of cane into trucks is done manually by contract labor, called "sacadas" who are migrants from other islands in the Visayas;

mechanical power from engines.

3. Rice seedlings are generally planted manually by a contracted transplanting crew.
4. Unlike before, farmers have become familiar with and no longer have fear of engine-powered machines.
5. Most of the palay or paddy is sun dried because of free solar energy and high cost of mechanical dryers. However, there are disadvantages of grain losses and non-uniform drying especially during the rainy season.
6. As of 2013, the level of agricultural mechanization expressed as the sum of all power sources, human, animal and mechanical for operations on a unit area is 2.31 hp/ha showing an increase from 0.52 hp/ha estimated in 1990 (RNAM, 1990).

Status of Harvest and Postharvest Operations for Rice

Except for the emerging mechanization of harvesting and threshing of rice by combines through custom hiring, rice is essentially harvested manually in the traditionally way using sickle for cutting the stalks and stacking the harvested straw with the grain-on-panicle. Threshing must be carried out immediately or the next day, especially if the rice has been harvested wet to avoid grain fermentation that reduces grain quality. The farmer is charged a selling price deduction by the bulk buyer based on the latter's perceived poor quality and high moisture content of the grain. The farmer cannot wait for another buyer for two reasons –first, the buyer is his money lender and secondly, the grain deteriorates with time so it cannot be withheld without incurring yet additional risks. Thus, poor as he already is, he is caught in a bind.

The Indigenous Peoples in the Cordilleras harvest their heirloom rice grown in terraces by cutting the panicles with a knife and tying them into about two-kg bunches, which they initially dry under the sun when feasible and then store them on a platform over the wood stove to complete the drying and also to ward off insects. The panicles are threshed and husked by pounding in mortar and pestle, which is laborious and time-consuming.

Since the late 1970s, threshing has been being carried out using the IRRI-developed axial-flow thresher which is manually transported by at least four persons and set beside the stack of harvested paddy. Historically, the system is essentially the same as that before WWII. A huge stationary thresher, popularly called "Mc Cormick," that was made by the International Harvester Company of the US, was set in place using a three-wheeled tractor, which powered the thresher through a belt-and-pulley drive. A threshing crew of about 20 men and women work around the thresher performing specified tasks for gathering the cut harvest from the field, feeding the harvest to the thresher and bagging the cleaned paddy output.

In the modern version of the threshing system, some 8 to 10 men and women workers perform the threshing operation using the IRRI-developed axial-flow thresher. The payment is based on the cleaned paddy output percentage which is shared among the owner of the thresher and the workers on prorated basis. The threshing team may or may not be also the harvesting team but the harvesting and the threshing teams are paid 10 % and 9 % of the net harvest, respectively or a total of 19 % of the net blower-

Table 7 Percentage of the area cultivated that used mechanized operations in 2013 (Bingabing, *et al*. 2015).

Region	Plowing	Harrowing	Planting	Weeding	Spraying	Harvesting	Threshing
CAR	46.98	39.96	*	*	*	2.7	50.22
1	49.14	49.68	*	*	*	9.18	53.46
2	51.3	49.68	*	*	*	9.18	48.06
3	52.3	52.92	*	*	*	0.54	51.84
4	31.86	29.7	*	*	*	8.64	45.36
5	38.34	30.78	*	*	*	*	48.06
6	47.52	48.06	*	*	*	*	48.06
7	18.36	39.96	*	*	*	*	42.12
8	18.36	47.52	*	*	*	*	51.84
9	ND	ND	ND	ND	ND	ND	ND
10	35.1	19.44	*	*	*	*	48.6
11	30.24	39.96	*	*	*	*	53.46
12	43.2	43.74	*	*	*	*	51.84
13	27.54	29.7	*	*	*	*	50.22
ALL	37.8	39.96	*	*	*	2.16	49.68

* Negligible, ND: No data

cleaned paddy. These percentages may vary depending upon the location. In contrast, a farmer contracting the custom hire services using rice combine may pay as low as 10 % of the harvest thus, increasing his income.

In the current system, the farmer shoulders the risks and the field losses of about 4.5 % of the total harvest and therefore, could incur total cost of 23.5 % of the harvest. Thus, the farmer may end up poorer than the workers. Whatever is left of the harvest may just be enough to pay back his debts usually to the buyer or trader of the paddy. The farmer always sells the harvest as sacked wet paddy because of lack of drying and storage facilities. The buying price for it is based on the prevailing one with deductions for adjustments in weight if the paddy has high moisture content such as during the wet season and for poor quality such as plenty of partially filled grains and immature grains. These quality indicators are at the whim of the trader and are usually exaggerated to his favor.

The advent of custom hiring of combines, which cost the farmer much less in terms of fees paid to the service provider and reduced grain losses with a bonus of quick harvest and disposal in case of an impending inclement weather, gives the farmer a break. The weather forecasting agency or PAGASA now gives about 5 days lead time before a typhoon strikes an area.

The farmer gambles it when the maturity date of the rice crop falls earlier than the estimated latest day of landfall of the typhoon minus one day for safety factor because the lead end of the typhoon is already felt before the actual landfall which is reckoned from the position of its eye or center. Either the farmer decides to harvest partially immature grains or wait it out and risk either a partial loss of harvest due to lodging caused by strong winds or a complete loss due to flooding of the field as what had happened during the typhoon Nona in late 2015. It may also happen that the typhoon would suddenly change course avoiding his locality, in which case, there will be opportunities foregone because of harvesting several days before maturity date.

The farmer's decision is also influenced by the availability of the combine since competition for the combining services could be fierce. Here, the Government can play a significant role by assisting in the hauling in of privately owned combines stationed in far-away areas forecast as not to be affected by the typhoon. Owners may opt to register their combine as deposit in a machinery bank or operate an "Uber-like" combine business, a move that is also advantageous to them.

In preparing for an impending calamity, DA, in collaboration with the National Disaster Risk Reduction Management Council or NDRRMC,

Table 8 Harvest and postharvest losses of rice (Adapted from Bingabing *et al*., 2015).

Operation –Description of method	Average Loss, %	Share, %
Harvesting –manually cutting using sickle and windrowing	2.3	12
Stacking –manually collecting the windrows; in-field transporting and piling into a large heap or stack	0.08	0.5
Threshing –manually throw-feeding into an axial-flow thresher; separating grain from chaff using plastic net tray and blower; and bagging the cleaned grain; 8-9 persons in the threshing crew	2.13	13
Sundrying –spreading the grain on a fine net or directly on the road pavement	5.86	36
Milling –using small single-pass and large rice mills	5.52	34
Storage –using sacks instead of bulk storage	0.8	5
Total	16.47	100

Table 9 Farm machinery targeted for distribution to major rice-producing areas, units, 2012-2016. (Bingabing, *et al*., 2015).

Farm Machinery	2011	2012	2013	2014	2015	2016	Total
A. Primary							
Hand tractor	3,096	8,989	8,830	3,263	3,361	3,462	31,000
4-wheel tractor	163	100	75	75	50	37	500
Thresher	1,031	2,996	2,944	1,088	1,120	1,154	10,333
Shallow tube well (STW)		10,875	14,865	8,585	7,675	7,000	49,000
B. Secondary							
Drum seeder		1,145	1,275	510	525	545	4,000
Combine harvester		16	16	16	16	16	80
Mini combine		16	16	16	16	16	80
Reaper		945	990	345	355	365	3,000
Seed cleaner		360	360	360	360	360	1,800
Total	4,290	25,442	29,371	14,258	13,478	12,954	99,793

may deploy the combines-for-hire deposited in the virtual machinery bank in the anticipated emergency areas. NDRRMC normally caters to saving lives in times of impending disasters but this new role caters to food security.

Table 8 shows the average losses incurred in harvest and postharvest operations and the contribution of the field operations in the loss.

The target units of machinery for distribution to farmers from 2012 to 2016 are shown in **Tables 9** and **10**.

Present Status and Future Prospects of Agricultural Machinery Research Activities

Historical background

The establishment of institutional infrastructures for the conduct of research activities and the development of human resources in agricultural machinery and mechanization date back to 1909 when the University of the Philippines College of Agriculture (UPCA) was founded in Los Baños. The department of agricultural engineering pioneered in educating students in research and engineering fundamentals. By 1911, it had published the Philippine Agriculturist, which in 1999, became The Philippine Agricultural Scientist published by the College of Agriculture and in 2001, became accredited as an international science information journal. The department of agricultural engineering has evolved into the College of Engineering and Agro-industrial Technology (CEAT) of the University of the Philippines Los Baños, which has the Agricultural Mechanization Development Program (AMDP) that collaborates with other institutions in the implementation of the Agriculture and Fisheries Mechanization Law of 2013.

The other pioneer institution is the Bureau of Plant Industry through its Agricultural Engineering Division, which initially designed and developed improved hand tools and animal-drawn implements. During the mid-1950s, the Division engineers designed steel lug extensions for rubber tires of four-wheel tractors to increase traction in soft soils of paddy fields.

The International Rice Research Institute (IRRI) was established at the UPCA Campus in 1960. IRRI's Agricultural Engineering Department (AED) carried out design and development of small-scale machinery starting in 1967, when it developed the power weeder but was not accepted by the farmers who preferred the cheaper spot- weeding method or the manually operated rotary weeder. Besides it was perceived at the time to displace labor for weeding. It was developed ahead of its time. The farmers abandoned the use of the push-pull rotary weeder when herbicides were introduced even if there are suspected harmful health consequences due to contamination of the groundwater supply.

The IRRI power weeder design; however, was adapted by the Otake Agricultural Machinery Company, Limited of Japan. It became popular among the Japanese farmers because of its labor-saving feature*. The power weeder design may later be adopted in the Philippines in view, not only of rising labor costs in weeding and of the trend in organic farming like in the System of Rice Intensification (SRI), a labor-intensive but claimed as a yield-increasing method of rice production. As an organic farming method, SRI requires the use of hand-pushed rotary weeder for soil aeration instead of herbicide spraying and farmers may yet adopt the power weeder because it will now be appropriate once they adopt the SRI method or go for organic farming.

By 1970 USAID gave IRRI a long-term research grant for the Small Farm Machinery Development (SFMD) program. One of the initial projects under the SFMD program was the design and development of a simplified power tiller (PT) from Japan.

The PT was readily accepted by the Filipino farmers not only because it was low-cost, simple and perceived as an appropriate substitute for the carabao but was also locally fabricated, except for its engine power unit. The simplified version of the Japanese power tiller was also deemed suited to the cut-and-weld fabrication technique and modest facilities and equipment in small workshops in the towns nearby IRRI. This initial success inspired Dr. Amir U. Khan who headed the AED. Small-scale workshop owners not only in the Philippines but also in other rice-growing developing

Table 10 Rice postharvest facilities targeted for distribution to major rice-producing areas, 2012-2016, units (Bingabing, *et al*., 2015).

Postharvest Facility	2011	2012	2013	2014	2015	2016	Total
A. Drying Program							
Mechanical dryer	391	896	891	348	358	369	3,253
Multi-purpose drying pavement	871	787	844	348	358	369	3,576
B. Rice Milling Program							
Rice mill for farmers	16	100	107	33	36	37	329
Rice mill for private millers	40	40	15	15	15	125	

Source: Personal communication with Dr. Makoto Hoki, Emeritus Professor, Mie University who worked with Dr. Amir U. Khan on the power weeder from 1967 to 1969 at the IRRI AED.

countries had made their own versions of the IRRI-designed PT.

By mid-1970s, IRRI AED released the design of the axial-flow thresher (AFT) after unsuccessful earlier design concepts for thresher and harvester consisting of the rotary table thresher and the long-drum thresher, which are head-feed or hold-on type and used wire-loops in the threshing drum. The design of the rice stripper-harvester was complicated, encountered fabrication problems and resulted in high grain losses in the field. The rice stripping concept was revived in 1990 using the design adapted from the Silsoe Research Institute in UK. By 1995, the stripper gatherer model SG800 was being manufactured by small workshops in the Philippines, Thailand and Indonesia but only one in Indonesia had sustained production as of 2013 (Gummert, *et al*., 2015).

The throw-in type concept using the peg-tooth type threshing drum has a high-capacity threshing and partially solves the problem of threshing and cleaning harvested wet paddy. Several derivatives of the AFT evolved as it became adapted by small-scale machinery workshops. The Kaset Phattana Group in Thailand, whose Thai engineer-owner graduated from the University of the Philippines, successfully adapted the axial-flow thresher for its rice combine. The combine has become popular in Thailand for providing custom-hire services.

The AFT was an instant success when it was first demonstrated to the machinery fabricators and farmers. Soon after, the AED was swamped with requests for drawings for fabrication. AED conducted training of manufacturers and after successful fabrication and field trials, released the drawings to the National Agricultural Research System (NARS) in the rice-producing countries then conducted training of small-scale manufacturers from those countries. The local manufacturers, now members of the Laguna Machinery Manufacturers Association (LAMMA), served as resource persons and welcomed the international trainees to tour their small shops, which were typical of their own shops. The LAMMA members were swamped with orders from the countries for AFT prototypes to serve as models for their own fabrication. No other IRRI-developed machine had met such scale of success. It won an international award for IRRI as having most impact in rice postharvest processing around the world.

The next technology was the 6-row manual rice transplanter developed and demonstrated by IRRI during the early 1980s in Libmanan, Camarines Sur. The farmer collaborator readily adopted the technically “perfected” machine was but abandoned its use shortly thereafter because, according to him, he could not bear displacing his loyal women workers for hand transplanting of rice seedlings.

Nevertheless, situations may be different in other places. The Regional Network for Agricultural Machinery (RNAM) adapted for its Sub-network Activity, the IRRI rice transplanter as the machine for study, adaptation and promotion to manufacturers in the member countries. The Sri Lanka RNAM National Institute (NI) was the most enthusiastic among the member NIs and had a GTZ-funded project that worked on its improvement along with another new IRRI-designed machine –the vertical rice conveyor reaper-windrower– an adaptation from a Chinese design.

AED developed more than 100 other technologies that were not adopted by the intended users to the same extent as the AFT. If these technologies were reviewed or improved and efforts were made in demonstrating them to the users, these could still be adopted by users as their time has probably come. There may not be any need to reinvent the wheel and if necessary, the designs are useful for making innovations. Working drawings of the machines are available at IRRI.

Research, Development and Extension of Agricultural Machinery

Institutional development for research, development and extension to address specific commodities or crops has been a major undertaking of the Philippine Government since 1971. Imbedded in the programs of such institutions are projects related to agricultural mechanization of crop production and postharvest processing activities primarily to increase production, enhance productivity and uplift the lives of the farmers as well as the entrepreneurs in small-scale agro-industrial enterprises. The institutions are also specialized by region to address the major crops grown in such regions like legumes, root crops, fiber crops, tobacco, sugarcane, mango, aquaculture, etc.

Table 11 shows some of the tech-

Fig. 2 The “Laboy” tiller developed by PhilRice and solves the problem of bogging down of tractors in deep mud;

Table 11 Technologies developed for rice mechanization (Adapted from Amongo *et al*., 2015).

Operation	Developed Technology	Institution/ Company
Land preparation in wetland rice fields – at least 2 cm deep water is required for efficient operation	* Laboy tiller for waterlogged fields with 1/2 to 1.5 m deep mud and peat-like soils (**Fig. 2**)	PhilRice, 2007
	* Basic power tiller or rotary tiller modified (simplified) from Japanese models	IRRI, 1970
	* Ride-on attachment for hand tractor	PhilRice, 2003
	* Floating rotary tiller called “Turtle Power Tiller,” consisting of a turtle back-like pontoon that forms a deep single rut per swath and a front-end mounted rotary V-blades on a pair of cage wheels; 1.5-2 ha/day capacity with 2 persons working alternately	SV Agro-industries, Inc., Iloilo City, Central Philippines, 1976
	* Hydrotiller - modified “Turtle Power Tiller,” with twin pontoons like in a catamaran to reduce the deep rut and to improve maneuverability	IRRI, 1984
	* Portable floating microtiller for the Ifugao rice terraces; light and portable	IRRI, 1986
	* UPLB hand tractor of rugged and heavy construction consisting of a transmission system adapted from junked vehicle differential assemblies; suitable for upland cultivation	AMDP-UPLB
	* Carabao or water buffalo and plow, harrow and cart for wetland plowing, harrowing, puddling, levelling and dryland transport	Traditional;still used in small landholdings in remote areas; also for meat/milk
Reduced tillage finished in 15-19 days; with	Method: Flash-flooding for 2-6 days interval, spraying with post-emergence herbicide, scattering the straw, flooding, first pass of leveller using riding hand tractor to press the stubbles into the soil and second pass to level the soil; then field is ready for transplanting or direct seeding	
	Completed in 15-19 days; unit production cost reduction of 6-20 % without reduction in yield	PhilRice, 2010
Planting	* Drum seeder, manual and tractor-drawn	IRRI, 1985; AMDP-UPLB,
	* Korean 8-row rice seeder, capacity, 4 ha/day	PhilRice- Korea Project on International Agriculture, 2012
	* Manual 6-row rice transplanter	IRRI, 1980
	* Riding-type 6-row transplanter	PHilMech and PhilRice, 2015
Weeding	* Wetland rice manual weeder	AMDP-UPLB,1979
	* Power weeder; commercialized only in Japan	IRRI, 1969
Harvesting	* Mini-combine harvester	PhilRice IRRI, 1985;
	* Reaper harvester	PhilRice IRRI, 1993;
	* Stripper harvester	PhilRice
	* Rice cutter harvester	PhilRice, 2010
Threshing	* Axial-flow thresher	IRRI, 1973
Drying	* Flatbed dryer	UPLB, 1968
	* Maligaya flatbed dryer	PhilRice
	* Reversible airflow flatbed dryer	PhilRice
	* Biomass-fed furnace/heater system	IRRI, 1980
	* Modified flatbed dryer	PHilMech
	* Multi-fuel biomass furnace	IRRI, 1970;
	* Moisture meter	PHilMech
	* GrainPro Solar Bubble Dryer (SBD)	GrainPro, Inc.
	* GrainPro Collapsible Dryer Case II™	GrainPro, Inc.
Milling	* Brown rice huller	PhilRice 2010
	* Micromill	IRRI,1992/PhilRice
	* Centrifugal huller cum panicle thresher for the Cordillera rice terraces	IRRI, 1994
Storage	* Hermetic seed storage (SAKLOB)	PhilRice, 2010
	* Hermetic storage	PHilMech, 2010

Operation	Developed Technology	Institution/ Company
Cleaning	* Seed cleaner	PhilRice
Sorting	* Computer vision system	PhilMech
Renewable energy applications	* Rice hull stove	IRRI, 1980;
	* Gasifier stove	PhilRice
	* Open-type rice hull carbonizer	PhilRice
	* Mobile gasifier engine system	PhilRice
	* Wind pump irrigation system	PhilRice
	* 1-kW propeller type micro-hydro turbine	PCARRD, 1999; PhilRice IAE-UPLB
	* Hydraulic ram or ram pump	AMDP-UPLB, Private manufacturer,1995; IRRI
	* Biomass (rice husk) furnace	IRRI, 1986;
	* Solar dryer; mechanized sun drying	PhilMech
	* Solar water pump	DOE
	* Micro-hydroelectric systems	DOE-AREC, CLSU, BSU; other universities

Table 12 Power requirement, fuel, electricity consumption and field/throughput capacity of commonly used rice machines (Belonio, *et al*., 2015).

Machine	Power Unit	Fuel/ Electricity Consumption	Field/ Throughput Capacity
Power tiller			
Plowing	7-hp diesel engine	0.87 liter/h	1 ha/day (8 h)
First harrowing	-do-	-do-	-do-
Second harrowing	-do-	-do-	-do-
Levelling	-do-	-do-	-do-
Irrigation pump	8-hp diesel engine	0.8-1.0 liter/h	10 liters/s; 24 h/ha
Combine harvester	60-hp diesel engine	15 liters/ha	2.5 ha/day
Axial-flow rice thresher	16 hp gasoline engine	2 liters/h	1 ha harvested/6 h
Flatbed dryer	12-hp diesel engine; 90,000 kcal/h heat input biomass furnace	1.2 liters/h; 30 kg rice husk/h	6 t/10h
Recirculating dryer	10-kW electric motor; 15,000 kcal/h heat input from kerosene burner	11.6-15 kWh/t; 6 liters kerosene/h	6 t/7-9 h
Grain cleaner	3-hp, 220-Volt electric motor	0.39-0.58 kWh/sack	30-45 sacks/day
Multiple-pass rice mill	20-kW, 220-Volt electric motor	20 kWh/t	1 t paddy/h

nologies developed by the research institutions.

The Laboy tiller works effectively in clearing tall grasses. Its features are:

Portable. Lightweight and can be easily transported; Simple design. Utilizes parts that could be easily bought in local stores; Efficient. Works well even in fields with soft, deep, or very deep mud (“laboy” soil) and long stubbles; and Fast. With an average capacity of 1ha/day in deep muddy field

The requirements for operating various machines are shown in **Table 12**.

Table 12 shows the average values gathered during the 7-year period of the PhilRice-Agricultural Competitiveness Enhancement Fund (ACEF) Project.

Institutional Infrastructures

Although the institutional infrastructures were established primarily to develop human resources and to support/undertake agricultural and fisheries research they also indirectly support the agricultural mechanization RDE activities.

The following is a list of institutions that have been established since 1971 and have activities focused on the promotion of agricultural mechanization through RDE programs for which a roadmap has been prepared by DA.

The following agricultural research and development institutions also fund research proposals for agricultural mechanization:

1. Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD);
2. Philippine Council for Industry and Energy Research and Development (PCIERD);
3. Bureau of Agricultural Research
4. Agricultural Competitiveness Enhancement Fund (ACEF)

The following institutions have in-house RDE activities in agricultural mechanization:

1. Philippine Rice Research Institute (PhilRice) with its Rice Engineering and Mechanization Division (REMD);
2. Philippine Center for Postharvest and Mechanization Development (PHilMech);
3. Agricultural Training Institute (ATI);
4. The Agricultural Mechanization Development Program AMDP); it has been the Philippines counterpart program for the Regional Network for Agricultural Machinery (RNAM), now the Center for Sustainable Agricultural Mechanization (CSAM) based in Beijing.
5. The Agricultural Machinery Testing and Evaluation Center (AMTEC)
6. State universities and colleges (SUCs).

The following international institutions/projects based in the Philippines have played an important role in the design and development of agricultural machinery and mechanization of small-sized farms as well as in the extension of modern mechanical technologies in the rural areas.

1. The International Rice Research Institute (IRRI);

2. The Philippine-Sino Center for Agricultural Technology (PhilSCAT);

3. The Regional Network for Agricultural Machinery (RNAM, now CSAM) -a UNDP- assisted project originally of eight Asian countries (India, Indonesia, Islamic Republic of Iran, Pakistan, Philippines, Republic of Korea, Sri Lanka and Thailand) with support from the Governments of Japan and Australia and contributions from the Participating Countries. RNAM was executed by the Economic Commission for Asia and the Pacific (ESCAP). Bangladesh and Nepal joined RNAM in 1987 while the People's Republic of China joined in 1990. RNAM was based at UPLB from 1979 to 1991 and subsequently became the Center for Sustainable Agricultural Mechanization (CSAM) based in Beijing, China.

The RNAM Regional Office coordinated the network of National Institutes and catalyzed the close collaboration and exchange of information and experiences in the technological, sociological and economic aspects of agricultural machinery and mechanization through sub-network activities, in testing, evaluation and adaptation of rice transplanters, cereal harvesters and weeders as well as improvement of manufacturing technology of seed-fertilizer drills, grain threshers and other already developed and accepted improved agricultural equipment.

Other major activities consisted of exchanges of commercial prototypes; mechanization impact studies and capacity-building through regional training-workshops on policies and strategies, design and development, testing and evaluation, local manufacture, extension and popularization of developed machines and group study-tours. Technical publications consisted of the RNAM Newsletter published every four months, technical series and test codes and procedures for farm machinery.

The National Institute for the Philippines has been UPLB/CEAT with the Institute of Agricultural Engineering as the implementing unit through its Agricultural Mechanization Development Program and represents the Philippines in international forums organized by CSAM.

For sustainability of national efforts after RNAM, the institutional arrangement of forming and strengthening a National Network (NN) of institutions and organizations was recommended. At present, no formal NN has been formed but in effect UPLB CEAT, PhilRice, PHilMech and PhilSCAT each have their own NNs according to their resources, mandates and major activities Thus, UPLB/CEAT, an academic institution has links with its counterparts in SUCs, PCAARD, PCIERD, DOST institutions; PhilRice has its own regional branches and collaboration with IRRI; PHilMech collaborates with the DA-RFUs, LGUs and Farmers' Associations including Farmers' Cooperatives as well as perhaps with other specialized institutions and NGOs in its mechanization program; and PhilSCAT has its trilogy of technical development strategy for domestic adoption. Virtually, a NN may be considered as already formed and may need streamlining the coordination and synergy of the plans, strategies and activities.

The following NGOs also play the role of modernizing Philippine agriculture through professional practice of agricultural engineering, commercial distribution and adoption of agricultural machinery technologies, whether locally manufactured or imported.

1. The Philippine Society of Agricultural Engineers (PSAE);

2. The Agricultural Machinery Manufacturers and Distributors Association (AMMDA) –About 80 % of the sales of agricultural machinery are to the account AMMDA members (AMMDA, 2014).

3. Inventors' organizations - those with inventive aptitude, undertake private design and development of machinery to meet local demand. The "Turtle Power Tiller" is an example for solving the floatation problems of tilling deep mud. The invention gave rise to the development of IRRI's "Hydrotiller" and PhilRice's "Labor" tiller.

4. The Laguna Agricultural Ma-

chinery Manufacturers Association (LAMMA) –established during the mid-1970s when several small-scale metal fabrication shops in the vicinity of IRRI took advantage of the demand for IRRI-designed and developed power tiller (PT). Their local supply of power tillers eventually caused the gradual replacement of the carabao with mechanical power. Not long after, IRRI released the design of the axial-flow thresher (AFT) which also became popular because of the need for threshing the increased yields of rice and as soon as possible because inclement weather will cause deterioration of grain quality if not threshed on time.

The machinery fabricators in Laguna had the first crack of the local and export market for AFT. Rice research institutes in different countries ordered prototypes to be copied by their local manufacturers and in a way the Laguna fabricators played a role in disseminating the AFT to other countries. They formed the LAMMA and continued with the supply of new machines like the hydrotiller and the turtle power tiller which competed with the PT in terms of larger capacity and better mixing of the soil and trash during land preparation. The dissemination of the hydrotiller to other countries followed the same pattern as that of the AFT.

In 2015, through the Microenterprises and Small and Medium-scale Enterprise Development (MSMED) program of the Department of Trade and Industry, LAMMA was provided with some units of shop equipment under the Shared Service Facilities (SSF) public-private partnership project which aims to improve the competitiveness of MSMEs. LAMMA members are active in supplying turtle power tillers, PTs, AFTs, dryers and rice mills.

5. Other regional and provincial machinery fabricators associations.

The Philippine financial system consists of formal institutions such as banks and non-banks as well as the non-formal ones like relatives, friends, money lenders, etc. (**Fig. 3**). The smallholder farmers who are “non-bankable” because they have no collateral may still avail of the formal lenders like the micro-finance institutions patterned after the Grameen Bank in Bangladesh.

A possible scheme for the custom service provider entrepreneur to avoid defaults in payment by the farmer is for the farmer’s wife (Nanay) who is a client-member of the micro-finance to apply for a special loan for hiring the services of the mechanizing the operations. The micro-finance organization pays the provider directly and the “Nanay” takes responsibility for payment, possibly from the earnings of an enterprise she may be engaged in after due training in entrepreneurship. In this way, the harvest time of the crop need not be the payment time. The farmer is encouraged to have crop insurance. This scheme will make the custom hiring service provider viable and at the same time benefit the farmer through mechanization.

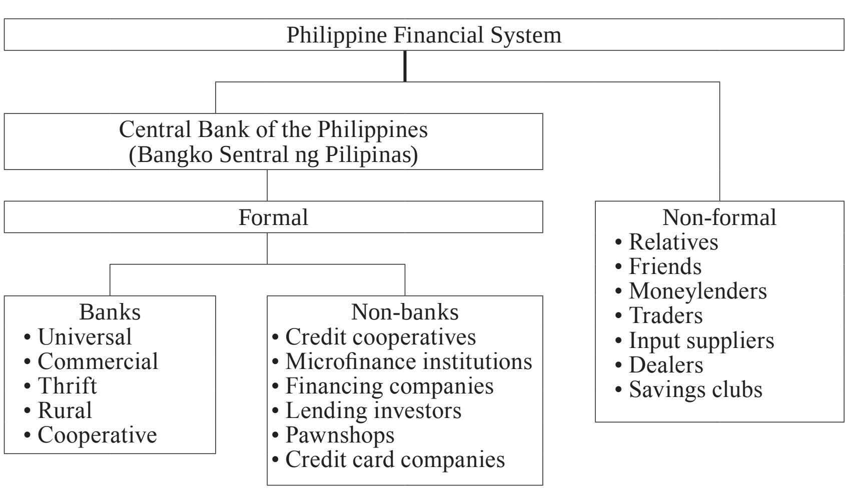


Fig. 3 The Philippine financial system (Source: Resurreccion, 2015).

The following are pertinent laws on agricultural machinery and mechanization:

1. The Agricultural and Fisheries Modernization Act or AFMA (Republic Act 8435) enacted in 1997 support mechanization programs of the Department of Agriculture;

2. The Agricultural and Fisheries Mechanization Law or AFMech (Republic Act 10601) enacted in 2013 to support the agricultural mechanization program.

3. The Agricultural Competitiveness Enhancement Fund or ACEF (Republic Act 8178) was established in 1996 to provide agricultural loan funds and to provide scholarships to agriculture-, fishery- and forestry-related degree courses, including agricultural engineering. The law expired in December 2015 and is likely to be extended.

4. Private lending institutions, organizations and individuals consisting of the formal-banks and non-banks, and the non-formal lending organizations.

Government Policy on Agricultural Mechanization

It is now clear that the Philippine Government is supporting agricultural mechanization which had been a contentious issue at least during the past 45 years. It passed the Agricultural and Fisheries Mechanization (AFMech) Law in 2013. Previous to this Act, the Government or at least the Department of Agriculture had neither supported nor opposed agricultural mechanization, preferring to let its development follow a natural course. As examples, DA has supported the establishment of the AMTEC and the participation of the Philippines in RNAM which it hosted at UPLB (1979 to 1991) and expressed desire for its continued hosting. RNAM was finally transferred to Beijing where RNAM has evolved into the ESCAP Center for Sustainable Agricultural Mechanization. (CSAM).

By the AFMech Law, funds have been allocated in the 2016 national budget, thereby assuring the implementation of planned activities for research, development and extension. The establishment of National Network for such activities has been an outstanding recommendation of RNAM since the 1980s but could not be implemented because of the lack of funds and the enabling law. Thus, significant activities and outputs of the members of the NN, which is called the Agricultural and Fisheries Mechanization RDE Network (AFMechRDEN), will be expected.

The following excerpt from the Republic Act No. 10601 or AFMech Law - An Act Promoting Agricultural and Fisheries Mechanization Development in the Country (Republic of the Philippines, Congress of the Philippines, 2013) - reflects the Government policy of agricultural mechanization. With the law in place, the promotion of agricultural mechanization can be expected to proceed with well-planned strategies involving the institutions.

SEC. 2. Declaration of Policy. — It shall be the policy of the State to:

a. Promote the development and adoption of modern, appropriate and cost-effective and environmentally-safe agricultural and fisheries machinery and equipment to enhance farm productivity and efficiency in order to achieve food security and safety and increase farmers' income;
b. Provide a conducive environment to the local assembling and manufacturing of engines, machinery and equipment for agricultural and fisheries production, processing and marketing;
c. Ensure the quality and safety of machineries and equipment locally manufactured or imported by strengthening regulation through the development and enforcement of machinery and machine performance standards, regular testing and evaluation, registration, and the accreditation and classification of suppliers, assemblers and manufacturers to ensure compliance to prescribed quality standards;
d. Strengthen support services such as credit faculties, research, training and extension programs, rural infrastructures, postharvest facilities and marketing services;
e. Unify, rationalize and strengthen the implementation, coordination of activities and mechanisms on agricultural and fisheries mechanization programs and projects; and
f. Deliver integrated support services to farmers, fisherfolk and other stakeholders, and assist them to be able to viably operate and manage their agricultural and fisheries mechanization projects.

With the firmed up policy provided by the enabling AFMech Law or 2013, DA-PHilMech has the mandate to implement the Philippine agricultural mechanization program that is, to "generate, extend and commercialize appropriate and problem-oriented agriculture and fishery postharvest and mechanization technologies.

PHilMech collaborates with the DA-Regional Field Units (RFUs), PhilRice, Local Government Units (LGUs) and other Government agencies and institutions like the UPLB which implements the AMDP and AMTEC. The private organizations consisting of AMMDA and LAMMA are also partners in the mechanization program.

Mechanization programs are also planned and implemented by DA agricultural research and development institutions specialized in rice, corn, sugarcane, tobacco and fish as well as in fiber and forestry products by the Department of Science and Technology with complementary activities such as in postharvest processing.

The RMPP aims at increasing the yield while reducing the cost of production using modern technologies. Its general objectives are:

1. Enhance knowledge of farmers on technologies for agricultural production as preparedness measure against climate change;
2. Achieve the increase in income of about 15 % using appropriate agricultural technologies.

Its specific objectives are:

1. Increase paddy production by 5 % using intensive agricultural mechanization technologies; and
2. Increase the supply of rice by 5 % utilizing modern postharvest technologies and practices.

Present Status and Future Prospects of Agricultural Machinery Industry in the Philippines

AMMDA, whose members' share of the market for agricultural machinery is about 80 percent, is the major player in the agricultural machinery industry in the Philippines. AMMDA has a strong lobby capacity like declaring that the association is the recognized voice of the agricultural machinery industry and therefore, has great influence in formulating agricultural mechanization policies and strategies.

Stumbling Blocks to Local Manufacture of Agricultural Machinery

While some manufacturers envision the Philippines to be industrialized, others are purely only profit-oriented. An example of a real industrialization champion is Domingo M. Guevara (DMG) who, in the 1960s dreamt of exporting Filipino-made cars, which he actually did with his own-developed vehicle, "Sakbayan" - Sasakyang Katutubong Bayan (literally, a native vehicle) with a Volkswagen engine as the only imported content. National Artist Nick Joaquin wrote: "He had brought this country's economy to a crucial threshold: the point of take-off for a NIC, a Newly Industrializing Country." Indeed, it was the time when the industrialization initiatives of President Quirino during the early 1950s had borne fruit because the Philippine economy was outstanding in Southeast Asia. The subsequent political power during martial law era (1972-1986) frustrated his dream and opted to depart for abroad as a security measure. Thus, a golden opportunity for reviving industrialization has been foregone.

Of course, in a profit-oriented organization, vested commercial interests and bias come into the picture. For example, the definition of local manufacturing as indicated in the Implementing Rules and Regulations (IRR) of the Agricultural and Fisheries Agricultural Mechanization (AFMech) Law of 2013 or Republic Act 10601, viz. "local manufacturing shall mean the production of machinery for agricultural and fisheries purposes by a company using both imported parts and components with a minimum of thirty percent (30 %) locally manufactured parts and components," reflects the status quo of the agricultural machinery supply industry and contradicts the declaration of local manufacturing, particularly of engines being promoted as stated in the IRR. Moreover, the proposed feasibility study for local engine manufacture, which is also provided in the IRR, is not to be carried out by an independent professional consultancy group but by those known to be biased for importation of agricultural engines and machinery or against local manufacture. Thus, local manufacture of engines will not likely prosper unless certain provisions of IRR of the AFMech Law are amended and political will is demonstrated.

The feasibility study for the manufacture of engines is; however, the responsibility of and is best done by the prospective investors themselves instead of the Government or of a group that it has commissioned. The investor's study group needs accurate benchmark information and data.

Attracting foreign investors, which is the current thrust of the Philippine Government to compete with ASEAN countries for foreign direct investments (FDIs), is best done by heeding the recommendations of their embassy commercial attachés and ambassadors on reducing to the minimum, the numerous steps and the onerous procedures and requirements for doing business that only invite corruption; improving or building more infrastructures and lowering power costs, among the few suggestions cited. Finding out what disastrous effects could possibly happen if the friendly procedures for doing business by the competitors in economic integration - Singapore, Thailand, Vietnam and Indonesia - were to be adopted or made friendlier. So far, as the laggard in attracting FDIs, the Philippine Government has apparently not addressed the issues.

The long-standing case with political underpinnings of the sequestered local manufacturing plant by a company, which has already successfully manufactured 1,000 units of the 10-hp diesel engine prototype by 1985, the first in Southeast Asia, has not yet been resolved after 30 years of litigation. The long delay has made a serious setback in whatever plans the Philippines had for the local manufacture of an engine needed as workhorse by the farmers, fishers, small-scale agro-industrial enterprises and construction contractors.

It has been a great opportunity loss in terms not only of job generation but also of an important step towards industrialization, which could support agriculture by increasing the buying power of consumers to pay for higher prices for produce of farmers. As pioneer in small-engine manufacture, the Philippine company, had it been released early on from sequestration, could have moved on quickly from the initial learning experience in manufacturing an engine model that would have served farmers and fishers for a long time before it became obsolete. An updated model would have easily been manufactured using more sophisticated and modern manufacturing technologies through the technological backstopping of its partner Japanese company which is a long-recognized leader in the automotive industry. Perhaps, the Government could consider withdrawing the case or grant amnesty for the common good. Then the company, if it is still interested, could move on or perhaps sell the facilities to a new investor.

Local machinery industry players had consistently harped since the 1960s that the Philippines could not compete with the high-technology manufacturing process in developed countries. The lack-of-market alibi has been adopted from the chicken-and-egg philosophy to escape risks of failure. The fact is that Thailand, Vietnam and Indonesia, which started their local engine manufacture much later than the Philippines, now manufacture and export engines to the Philippines, which as of 2013, had an actual market of about 167,000 single-cylinder engines (**Table 13**), which can go up to more than 200,000 units/year if other engine imports were included.

Local manufacturing of engines is related to food security. If the overseas jobs bubble engaged in by some 4 million overseas Filipino workers (OFWs) bursts, there will be a significant reduction in the availability of foreign exchange currency to finance importation, reminiscent of the situation during the 1970-1980 period. An outbreak of disease or war in the Middle East and the current low prices of crude oil may trigger the expensive hasty evacuation or repatriation of OFWs resulting not only lost income of foreign exchange but also its outflow to defray expenses. The shortage of engines, which is the workhorse of rice farmers, will affect Philippine rice production as the reliable carabao and the plow have mostly been replaced by engine-powered rotary tillers.

A case in point is the near-famine disaster that was averted in southern Bangladesh when the 1991 killer cyclone with 250 km/h winds killed about 138,000 people, devastated the rice production areas and decimated about 90 % of the work animals because of a storm surge (Wikipedia, 2010). Apart from the direct impact of the Category 5 hurricane, the spectre of famine loomed because of lack of work animals to perform land preparation for planting of rice.

With political will and against the recommendation of his technical advisers who opted for importing quality but more expensive engines, the President of Bangladesh decisively imported cheap but low-quality engines from China to stretch the budget to have several units of engines and power tillers that would at least outlast the impending crisis. The Chinese-made engines and power tillers were imported in large quantities and distributed to farmers. At last, the fields were planted and rice was eventually harvested. The country was saved from famine, but the epic did not end there.

True enough after one or two seasons' usage, as the technical advisers had predicted, most of the Chinese-made engines started to break down. Fortunately, a flourishing indigenous foundry industry in Bogra saved the situation. Spare parts for the Chinese engines were locally fabricated and suddenly there was a flurry of economic activities in foundry works, machining/finishing and sale of the engine spare parts, including pistons, piston rings, crankshafts, etc., which were found by farmers to be of better quality than the imported originals because of fierce competition among the local manufacturers. Farmers had learned to strip the engine and make repairs on site and after a little while, were back at work using the machine. They had also learned to replace the broken parts with the locally manufactured spare parts, which they readily purchased from downtown stores.

A far-reaching benefit was an estimated 100,000 jobs had been generated in many small-scale foundry and machining shops as well as in the trading of the spare parts.

As of March 2010, Bangladesh had exported 50,000 units of pump to India and the foundry industries have been aiming at supplying manhole covers, electric motor casings and other cast-iron products to the European Union where such products are in great demand (Anonymous, 2010). The lesson learned is that a viable manufacturing industry for agricultural machinery could mean food security, could save the country from famine and could alleviate poverty because of job creation.

The lesson from Bangladesh is the wake-up call for the policy and decision makers in Philippines to have a paradigm shift from the current culture of importation to that of local manufacture to create jobs in the rural areas. This indeed takes political will to do.

Characteristics of the Agricultural Machinery Industry

The Philippine agricultural machinery industry is characterized by the following:

Engines and sophisticated agricultural machinery supply is basically through importation; some machinery models locally assembled and have locally available materials content, which are also imported; thus, the local input is mostly labor;

Hesitation in local manufacture of engines and other agricultural machinery has been brought about by lack of competitive economic and technology advantage versus the high-technology production not only in advanced countries but also

Table 13 Estimates of sales volume of power and machinery sold in 2013 (Adapted from AMMDA, 2014).

Single-cylinder Engine Gasoline/ Diesel		Four-wheel Tractor			Rice Combine	Direct-coupled pump
		Mini- 4WD, < 50 hp		4WD 51-200 hp		
Brand New	Surplus (Second-hand)	Brand New	Surplus (Second-hand)			
160,000	7,000	500	400	600	1,500	8,000

in developing countries where joint ventures in manufacturing are in place. This situation; however, has been brought about by lack of or timid pioneering spirit among the industry players and previous lack of support from the Government even for existing small-scale fabrication shops. Ironically, the Government itself had been instrumental in blocking such initiatives by sequestering instead of encouraging fledgling but promising manufacturing industries. Examples are the integrated steel mill company and the manufacture of mechanic's tools, utility vehicle and 10-hp diesel engine; recently; however, the Department of Trade and Industry, in collaboration with the Department of Science and Technology, have been giving assistance to small-scale machinery fabricators' associations in establishing the Shared Services Facilities (SSF); It is a wonder why several million dollars' worth of new vehicle license plates have to be imported by the Government. This reflects the lack of local talent and interest in manufacturing even of a simple item that can provide needed jobs.

Small, simple and locally designed/developed agricultural and postharvest machinery are mostly locally fabricated by small-scale fabrication shops using cut-and-weld manufacturing technology with little quality control in terms of metallurgical content, standardization and using imported machine parts like bearings, sprockets and chains and fasteners;

The local content of the machines passed as locally manufactured is low; the AFMech Law of 2013 provides that a machine having at least 30 % local content is considered locally manufactured;

The value of the imported material content oftentimes constitutes more than half of the total machinery cost because there is no basic local steel industry.

Mechanized Production of Upland Rice –An Opportunity for Self-Sufficiency in Rice

Wetland rice fields are mostly small landholdings. Field working size and shape may be increased and modified physically by land forming and institutionally through land consolidation, land clustering, cooperatives, suitable farmland inheritance laws, regulations and other legal instruments for appropriate land use; such interventions open the field for efficient operations and increased productivity through agricultural mechanization.

Current machinery research and development is mostly focused on wetland rice, whether irrigated or rainfed, because the strategy for achieving rice self-sufficiency is through enhancement of land productivity or high yield per unit area. Irrigated wetland rice fields are seldom idle unlike the dry lands where there are opportunities for increasing rice production for rice self-sufficiency through expansion of cultivated areas for rice. The low land productivity of upland rice production is compensated by the high labor productivity or low cost of production, if mechanized. Mechanization of upland row crops, which is standard in developed countries, is easier and more straightforward than that for wetland rice.

The opportunities for reviving the production of upland rice, which has been traditionally for subsistence farming, may be exploited by the following:

Passing countervailing laws and legal instruments that assure or guarantee owners of idle lands of retaining their properties may encourage them to permit the temporary institutional use of their land properties by professional agriculturist and agricultural entrepreneur associations or farmers' cooperatives rather than by individual farmers who are instead hired as workers. The apprehension of non-farming landowners for losing their land to the individual tiller or leaseholder because of the current land reform laws prevents utilizing their idle lands such as those in housing subdivisions, industrial sites and farmlands of absentee owners who may be busy with non-agricultural business or are residing abroad. Some farmland owners have been reported to deliberately fallow or make their land properties idle for some time because it will pave the way for their allowable conversion into industrial or commercial usage to increase their market values.

The current low land productivity of upland rice production may be offset by planting high-value premium upland rice for brown rice, by the high labor productivity through agricultural mechanization and by application of modern technologies including sprinkler irrigation by tapping water resources using rainwater harvesting and storage technologies as well as by using water-lifting devices such as ram pump, sloping land agricultural technology, multiple cropping and bird and rodent control.

Demand for Agricultural Machinery

Although statistics show that farm labor is abundant, farmers find difficulty in getting farm workers or are constrained to get them under contract terms, which usually result in unsatisfactory quality of outputs. Farmers are realizing that availing themselves of mechanized farming custom hiring services result in higher productivity of labor, better quality of produce, lesser losses, faster work rate and reduced costs than hiring labor using manual methods.

Thus, a strong demand for modern machinery is indicated and the promising system is through custom hire services from providers. Just the same, such providers should render their services in a professional manner, which may be achieved by competition. The Government may wish to encourage investors in providing custom hire services which also means that quality machines should be made available in the market. Moreover, the after-sales services including repair and supply of spare parts should be in place. Farmers with landholding of at least five hectares for rice production would do well to invest in appropriate agricultural machinery. For economical usage such machines should have high utilization rate by engaging also in custom-hire service enterprise to utilize excess capacity.

SANRAM, a successful custom hire service provider in Los Banos, Laguna has institution clients, IRRI and UPLB and performs field operations in their experiment farms. Andales, *et al.* (2015) and Amongo, *et al.* (2014) reported that Cornworld is another successful custom service provider in Isabela province.

The unsuccessful ventures in custom service providing had been beset with (1) low repayment rate or defaults in by farmer clients resulting in bankruptcy and repossessed tractors in Tarlac province and (2) cut-throat competition because of the proliferation of custom service providers in a limited area such as in Nueva Ecija province. Just like what happened during the late 1970's when the US Sugar Quota ended, the recent custom service providers lacked management training to cope with the changing economic environments.

There is strong demand for the following agricultural machinery for the applications indicated (Suministrado, 2011):

1. Rice production and postharvest processing —transplanter, harvester (reaper or combine depending upon the budget) and drier;
2. Production and postharvest processing of corn, vegetables and upland crops, coconut and other fruit crops
3. Production of livestock, poultry and aquaculture.

Agricultural engineers may consider providing design and installation services for agricultural structures and controlled-environment agriculture, precision agriculture and smart farming, facilities for organic fertilizer production in support of commercial organic farming and renewable energy utilization for the future development of agricultural mechanization in Philippines.

Challenges

Strong political will by policy and decision makers is needed for an honest-to-goodness creation of a viable local manufacturing industry for agricultural power and machinery. With the increasing awareness for developing renewable energy resources to power farm machinery, the manufacture of direct-current electric motors for direct-coupled machinery applications, is a way forward and is pioneering in one way. Such DC motors can get power from batteries charged by solar panel or small wind turbines and other renewable energy sources. Except for the power-intensive land preparation, cultivation and harvesting operations, most other field operations need little forces but higher speeds to run machines like transplanting and planting by direct seeding as well as spraying, applying fertilizer and compost, seed cleaning and sorting, where DC motors can be the suitable power sources.

The AFMech Law of 2013 and its IRR practically spell out the roadmap for agricultural mechanization in the Philippines. The implementers headed by PHilMech must face the challenges, some of which include low farm gate prices, inaccessible or yet unknown alternative markets, dictated prices by middlemen, high cost of farm inputs, incidence of pests and diseases, environmental harm issues, lack of or inadequate support infrastructures such as road and irrigation systems, land forming and contiguous farming system for efficient machinery operation and lack of access to current farming technologies.

The policy recommendations for addressing these challenges include free-market pricing of commodities, improved and more friendly access to loans, establishment of trading centers or stations, organized machinery centers offering custom hiring and machinery repair and tune-up services, financial and institutional support to small-scale manufacturers and agricultural mechanization-related enterprises. Examples are professional fee collection system for custom hire services rendered, construction of institutional and physical support structures and an organic law discouraging land partitioning while encouraging alternative livelihood.

Elepaño *et al.* (2015) listed the problems of the agricultural machinery industry and the possible solutions as shown in **Table 14.**

The Future of Agricultural Mechanization in the Philippines

The following questions deal on some issues on policies and strategies which would bear on the future of agricultural mechanization in the Philippines:

Will distribution to farmers of imported tractors, engines and high-tech agricultural machinery be sustainable when foreign exchange revenues fall?

Will local manufacture of engines be ever started? The rationale for not doing so by Government planners influenced by industry players, who have been comfortable with importation since the 1960s –not economically viable because of lack of market volume and no competition with countries with advanced manufacturing technologies– has been out-dated by:

1. The Philippines had already surpassed the threshold demand of 100,000 units of engine for economic local manufacture (about 200,000 units were imported in 2013);
2. Thailand, Indonesia and Vietnam, which were in more challenging positions during the 1960s and during the 1990s have been manufacturing engines through joint ventures; ironically, the Philippines has been importing from those countries in large numbers thereby losing job generation opportunities for Filipinos.
3. President Marcos (1965-1986) initiated the manufacture of about 1,000 prototype units of a 10-hp diesel engine by 1985 but the company was sequestered by the succeeding administration; the case has not yet been resolved since 30 years ago and no solution such as amnesty rehabilitation of the manufacturing plant has yet been thought about.

Will agricultural machinery research and development thrust be towards high-technology applications for small-scale machines like those for precision land levelling and planting, precision agriculture, automation and robotics?

Will political will overhaul land forms for rice and upland crops (consolidation, agricultural land inheritance laws, terracing, soil and water conservation methods, etc.); build infrastructures for irrigation and drainage and roads (or low-hanging cableways and railways) for efficient transport in remote areas thereby supporting agricultural mechanization?

Will political will pursue industrialization like what Korea, Japan, Taiwan and China did to support agriculture in terms of creating highly remunerative jobs to landless farm workers (e.g. integrated mining and steel industries) and of increasing consumer buying power to afford high farm-gate prices of agricultural produce?

Will political will and courage overhaul labor laws and easing up business-setting processes like drastic reduction of red tape, requirements and procedures that turn off potential investors and make the Philippines non-competitive with the ASEAN countries with respect to attracting foreign direct investments in industries and preventing withdrawals by those that are in place? With ASEAN Economic Integration the Philippines must compete not only in products but also in how the products are produced with quality at low cost. The Philippines should do no less than what the other ASEAN countries are doing. Politicians and economic decision makers must take into account that transfer of technology through for-

Table 14 Agricultural machinery industry problems and possible solutions (PRPC 2000).

Problem	Solution
Technical	
High acquisition cost	Collective machinery ownership/ machinery pooling/custom hiring
Inappropriate technology for existing field conditions	Needs assessment for the suitability of agricultural machinery (AM)
Low RDE capability for appropriate farm machinery design and manufacture	Capacity/capability training for AM end-users
Socio-economic	
Low income/ lack of capital	Provide credit facilities; cluster farms into groups
Small and fragmented landholdings	Farm clustering and custom services
Unfavorable market price for the farmer	Floor price; train farmers to be entrepreneurs (processing and business)
Cheap and abundant labor (in some areas) and seasonal labor shortage	Absorb unemployed into other jobs; retool Encourage farm business enterprises Create new jobs in agricultural activities (waste handling, food processing, etc.)
Environmental/infrastructural	
Lack of infrastructures	Put in place irrigation, processing facilities, farm roads, access to market
Diversity in agroecosystem	Adjust AM to specific local conditions Select the most promising machines to produce locally
Weak agricultural manufacturing industry	Support local manufacturers through R&D, training and financial assistance Introduce the business service and maintenance of AM Promote joint ventures with foreign manufacturers
Environmental degradation	Control the utilization of chemicals Promote sustainable farming systems
Political/institutional	
Lack of/inconsistent political will to support AM	Educate political leaders on the importance of AM Put AM into long-term strategic programs Promote AM through international networking and cooperation

Source: PRPC 2000 as cited by Elepaño *et al.*, 2015 eign investments in industries is a key to competitiveness.

Will there be political will to assuage militant activities apparently aimed at closing down establishments through organizing debilitating strikes? Militants have track records of forcing numerous establishments to close down, downsize their personnel and operations or pull out and transfer them to other investment-friendly ASEAN countries. No wonder jobs had been lost and new jobs have never been created. Ironically, the Government has been blamed for not creating enough jobs for the jobless. The undesirable contract labor, which is inimical to both labor and investor, has been resorted to in preventing industry-debilitating strikes.

Recommendations

The key to increased agricultural production and enhanced productivity of agricultural land and labor as well as rural prosperity is ironically outside the agriculture sector itself. Rather, it is in the industry and the services sectors. The age-old paradigm, wherein agriculture is to remain as a major provider of jobs to the rural folks and landless farm workers, must shift from a situation where they are wittingly or unwittingly condemned to a life of poverty to one of prosperity. The present status is that the poor employee (landless worker) and equally poor employer (farmer) share to live on the low value and low volume of agricultural produce, precisely because of that thinking.

The classic argument of politicians and decision makers that the Philippines is basically an agricultural country, rich in natural resources and that agriculture employs a large portion of the unskilled rural labor has, since 45 years ago never improved the lot of the people in the rural areas where poverty is highest. The fact that daring rural folks migrate to the urban areas to seek better fortune but end up in squalor is a sign of despair that should wake up the powers that be.

Japan pioneered industrialization in Asia and prospered. The newly industrializing countries in Southeast Asia has long surpassed, in terms of economic progress, the once prosperous Philippines whose economy was second only to Japan in Asia because it once pursued industrialization during President Quirino's term (1948-1953) precisely because they embarked on industrialization.

Thus, it is recommended that the new administration focus the economic development on industrialization and develop further or strengthen the services sector where wealth is generated that will support agriculture. But of course, agriculture must continue to be developed, this time in a modern and productive way through agricultural mechanization and agricultural technologies to sustain food security and to achieve the prosperity of the farmers and rural folks.

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CHINA

The Current Situation and Future of Agricultural Machinery Industry in China

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Preface

China is a large agricultural country. Agriculture is the foundation of its national economy. Agricultural modernization is the foundation as well as a shortcoming of China's 'four modernizations' (industrialization, informatization, urbanization and agricultural modernization). The fundamental way out for agriculture is mechanization. Agricultural machinery is a vital support for agricultural modernization. Therefore, China's agricultural machinery industry keeps growing with the development of "four modernizations", agricultural modernization in particular. After witnessing a golden period of development for more than ten years in this century, China has become the world's leading manufacturer of agricultural machinery.

In the future, as a key industry in the plan of "Made in China 2025", China's agricultural machinery industry will face new opportunity with the speed-up of four modernizations as well as industrial and economic restructuring. Through adjustment and upgrade, China's agricultural machinery industry will surely enter a new development period and finally realize the transformation from a large producer into a powerful manufacturer.

The current situation of China's Agricultural Machinery Industry

Agricultural Machinery Industry in China is developing rapidly. China has become the world's leading manufacturer of agricultural machinery.

The product variety has been constantly expanded amid unremitting improvement of technology.

Over the last century, products of China's agricultural machinery industry were mainly served for individual farmers. Thus, the products were based on small to medium field machinery, with limited variety, low efficiency, lack of automatic operation and simple structure. In this century, with the development and structure adjustment of Chinese agriculture, the product variety of agricultural machinery is being expanded rapidly. China now is capable of producing 65 major categories, covering agriculture, forestry, animal husbandry, fishery and renewable energy. Among these products, planting machinery includes 14 major types and more than 3,500 items (**Table 1**).

Not only was increased the number of varieties, but also the tech-

Table 1 The classification of China agricultural machinery industry

Categories	Groups	Sub-groups	Types
Planting machinery	14	113	468
Animal husbandry machinery	7	45	164
Fishery machinery	5	20	103
Forestry machinery	14	34	104
Agro-products processing machinery	16	108	495
Agricultural transportation machinery	5	8	27
Renewable energy utilization machinery	4	9	13
In total	65	337	1,374

Data source: National Bureau of Statistics of the PRC nology was improved continually. In the last century, the tractors produced in China can only equipped with engines less than 100 horsepower. They adopted sliding-gear type gearing mechanism or meshing bushing shift structure which were underdeveloped gear technologies. Now the high-powered tractors of more than 100 horse-power and synchronizer are in mass production in China. The advanced 200 horsepower shift tractors at international level have also been launched. The 100 horse-power grain combine harvesters are the major products in the market. Self-propelled ensilage harvester, high-clearance applicator, matching implement of high-powered tractor and other state-of-art products in the world have come out consecutively in our country.

The quantity and scale of agricultural machinery enterprises are expanded constantly. The industry structure is optimized gradually.

Booming agricultural machinery market gave birth to an increasing number of varieties and agricultural machinery enterprises. Basic statistics show that the number of agricultural machinery enterprises with an annual sales income no less than RMB 5 million enlisted in National Statistics Bureau has increased according to the National Bureau of Statistics of the PR China from 1,658 in 2001 to 2,670 in 2010. In 2011, the bottom line of annual sales income for being an enterprise of designated size was lifted to 20 million yuan and the agricultural transportation industry was incorporated into automobile industry. Under such circumstance, the number of enterprises with designated size dropped to 1,832. However, this number has continuously increased in recent years, which stood at 2,207 in 2015 (**Fig. 1**).

The number of enterprises increases and the industry structure is optimized in the meantime. There are several large-scale enterprises with annual sales income over 10 billion yuan leading the whole industry, such as Foton Lovol International Heavy Industry Co., Ltd., YTO Group Corporation, Shifeng Group, Wuzheng Group. A batch of small scale enterprises featuring specialization, exquisiteness and uniqueness have become the main body of the industry.

The production and sales of agricultural machinery industry increase rapidly. Industrial benefit has been improved ceaselessly.

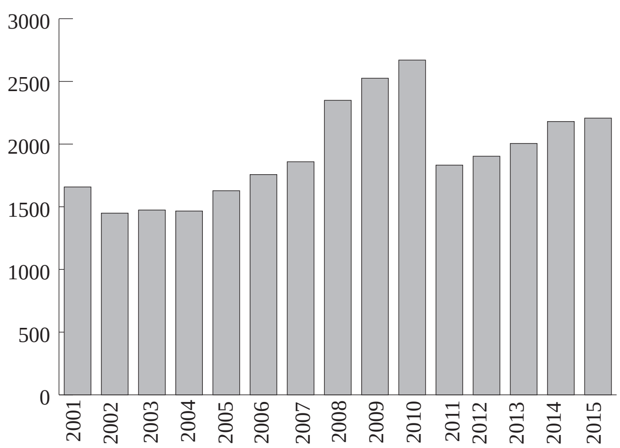
The gross annual sales income of agricultural machinery enterprises above designated size has grown to 260 billion RMB in 2010 from was 48.2 billion RMB in 2001, with an annual increase of 21 %. Growth rate reached nearly 20 % during 2011 to 2013. In 2014, the growth rate declined to less than 10 % (**Fig. 2**).

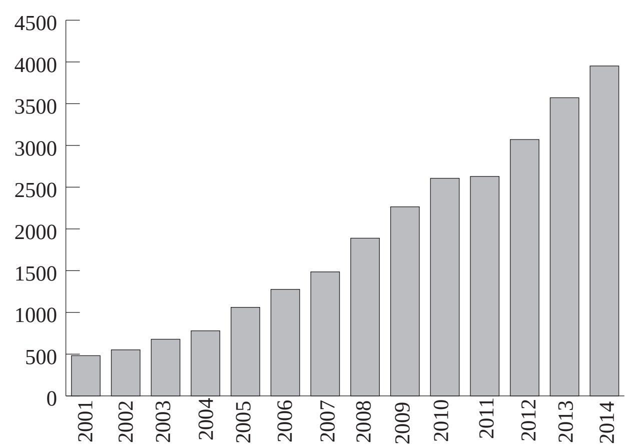
With the increase of sales income and the promotion of products, the benefit has been improved. The gross profit has grown rapidly from 644 million RMB in 2001 to 18.09 billion RMB in 2010 (**Fig. 3**). Profit rate was only 2 % at the beginning of this century, which has reached 6.2 % in 2005. The average rate of profit is about 6.5 % in recent years, approaching the average level of China's equipment manufacture industry.

Output of main agricultural machinery doubled

The output of high and medium power tractor (above 20 horsepower, four-wheel tractor) of enterprises above designated size in China increased by nine folds from 38,000 in 2001 to 341,000 in 2010. The output of key enterprises in tractor industry was more than 300,000 in 2011-2013 (**Tables 2a** and **2b**).

The output of combine harvester





Data source: National Bureau of Statistics of the PRC

Fig. 1 Number of enterprises with designated size in China

Fig. 2 The gross sales income of enterprises with designated size (Billion RMB Yuan) Data source: National Bureau of Statistics of the PRC

Table 2a The output of high and medium power tractor (unit: ten thousand)

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
3.8	4.5	4.8	9.8	16.2	19.9	20.3	21.7	31.2	34.1	37.43	34.5	37.5	29.7

The output from January to May in 2015 was 178,500 up by 5.61 % year on year.

Table 2b The output of combine harvester (unit: ten thousand)

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	2.5	4.3	4.6	7.1	11.4	5.8	8.4	14.6	15.8	14.5	16	17.3	14.3

The output from January to May in 2015 was 95,500, up by 36.55 % year on year.

Note: The data in 2001-2010 was the statistics from enterprises above designated size in China (Source: National Bureau of Statistics of China) , The data in 2011-2014 was the statistics from key enterprises. (Source: China Association of Agricultural Machinery Manufacturers).

of enterprises above designated size in China was 158,000 in 2010 (8 times as 2002). The output of combine harvester of key enterprises in China has been increasing due to the rapid growth of the corn picker since 2011.

The globalization and stable export growth of China's agricultural machinery industry

The globalization of China's agricultural machinery industry relies on the opening-up policy of Chinese Government. an increasing number of foreign agricultural machinery enterprises have entered Chinese market, including the famous international enterprises such as JOHN DEERE, CNH, AGCO, CLAAS, which have built their factories in China. More than 10 Japanese enterprises such as Kubota, Yanmar and Iseki are producing tractors, combine harvesters and other agricultural machineries in China and have achieved good benefit. The wholly owned or joint venture enterprises of foreign investor have become an important component of China's agricultural machinery industry. In 2014, the sales revenue of wholly owned or joint venture enterprises accounted for 8 % of the total sales.

According to the international market demand, the Chinese agricultural machinery enterprises have adjusted product structure to meet the demand from international market and maintained stable growth of export value (**Fig. 4**). The export value was more than 10 billion USD in 2014 (30 times as 2001). The export revenues accounted for 16.8 % of the total.

The rapid development of China's agricultural machinery industry promotes the significant increase of the standard of China's agricultural machinery.

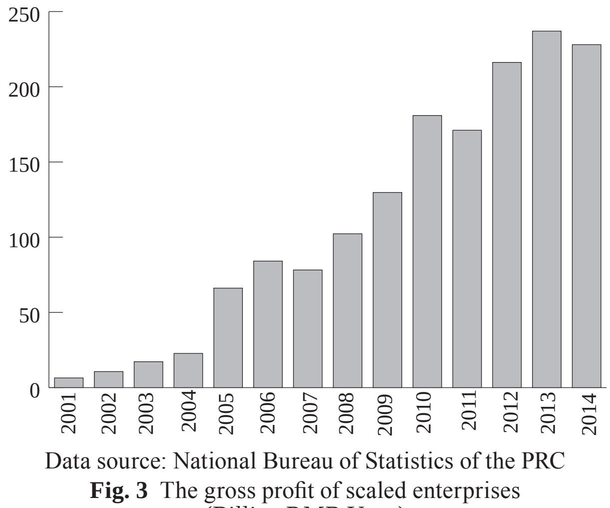
The rapid development of China's agricultural machinery industry offers a wide range of products suitable for Chinese agricultural production. The products meet the fundamental needs of domestic market and promotes the significant increase of China's agricultural machinery level. The sales value of imported agricultural machinery only accounted for 5 % of total sales value in China.

The total power of China agricultural machinery in 2014 was 1.081 billion kWh, which is 1.62 times as 2004 (**Fig. 5**).

The comprehensive mechanization level (plowing, planting and harvesting) of the main crops was 61.66 % in 2014. The figure was only 34.72 % in 2004 (**Fig. 6**).

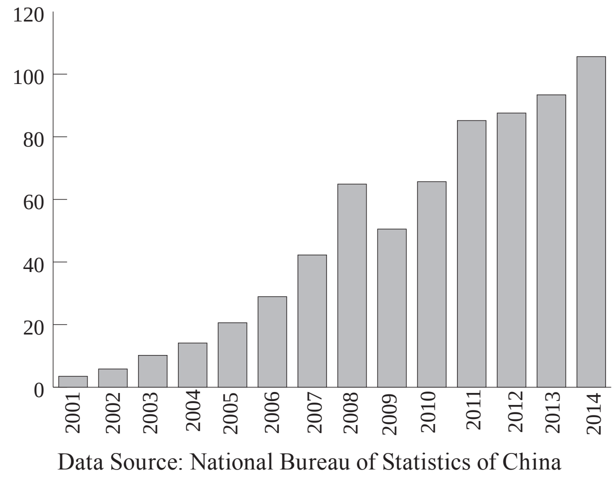
The total ownership of high and medium power tractor in China was 5,679,500, which is 5 times as 2004 (**Fig. 7**).

The total ownership of combine harvester in China was 1,584,600, which is 3.9 times as 2004 (**Fig. 8**).



Data source: National Bureau of Statistics of the PRC

Fig. 3 The gross profit of scaled enterprises (Billion RMB Yuan)



Data Source: National Bureau of Statistics of China

Fig. 4 Summary sheet of export value (Billion RMB)

The reasons for rapid development of China's agricultural machinery industry

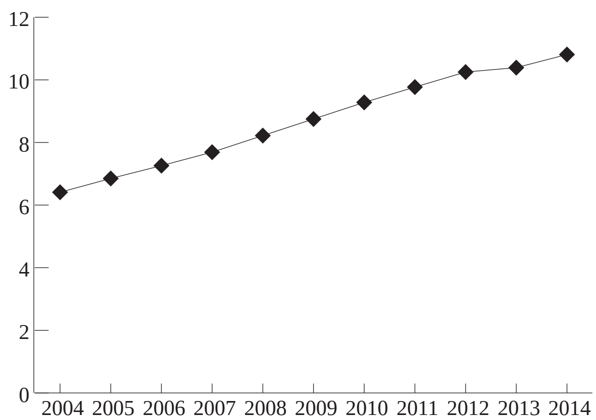
The main reason lies in the market need and government policy support.

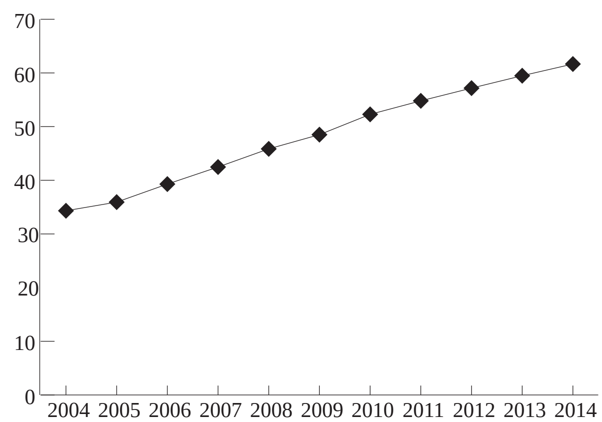
Transfer of rural labor and replacement of labors by machines become an inevitable tendency.

Since the 21st century, China has accelerated the construction of "four modernizations", a large numbers of rural labor force have moved into cities with increasingly intensified industrialization and urbanization. The percentage of employee in primary industry (agriculture) as to the total social employee decreased year by year. The percentage decreased from 50 % in 2000 to 29.5 % in 2014. There is structural shortage of labor in rural areas, whereas labor costs keep rising. Therefore, machines replacing human labor become an inevitable tendency, which inject vigor into agricultural machinery market in China. The fast development of agricultural machinery market over the last decade has transformed China from human labor-based agricultural production to machine-based agricultural production.

Reform of the rural economic system has promoted the upgrading of agricultural machinery.

In the 21st century, a new operation system for the combination of collectivization, professionalization, socialization and systematization has taken shape which replaces the household management-based system. The new operating entities (family farms, cooperatives and agricultural enterprises) have been gradually set up, which not only promotes the large-scale production, but also increase the demand of agricultural machinery. The adjustment of agricultural production structure has turned the single food

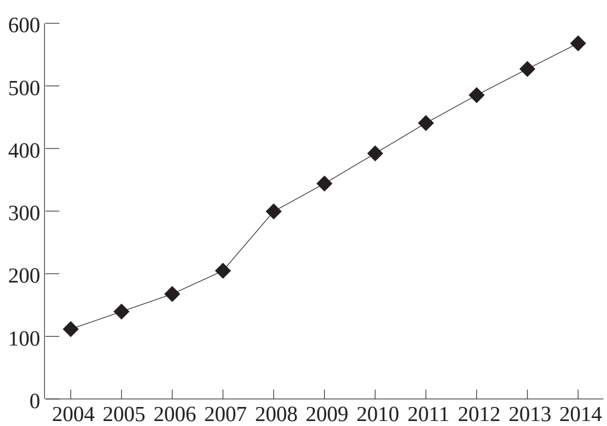


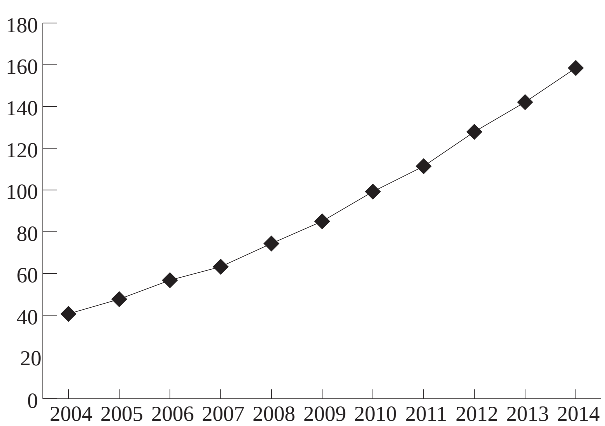


Data Source: Ministry of Agriculture, China

Fig. 5 The total power of China agricultural machinery (Billion kWh)

Fig. 6 The comprehensive mechanization level (plowing, planting and harvesting, %)





Data Source: Ministry of Agriculture, China

Fig. 7 The total ownership of high and medium power tractor in China (Ten thousand)

Fig. 8 The total ownership of Combine Harvester in China (Ten thousand) production in the past into the integrated development of agriculture, forestry, animal husbandry and fishery, which further expanded the varieties of agricultural machinery in China.

National policies on supporting and subsidizing farmers has boosted agricultural machinery market

In 2004, China enacted the ‘Agricultural Mechanization Promotion Law’ to enhance the support to agricultural mechanization. The central government applies several policies including ‘Subsidy for Grain Planting’, ‘Subsidy for Growing Superior Grain Cultivator’, and ‘Subsidy for Agricultural Machinery Purchase’. For instance, farmers will get 30 % subsidy from government when they purchase agricultural machinery products. The amount of subsidies provided by the central government increased year by year, from 70 million yuan in 2004 to 23.75 billion RMB Yuan in 2014 (**Fig. 9**). The policy of “Subsidy for Agricultural Machinery Purchase’ has greatly boosted the enthusiasm of farmers to purchase the machinery, which has stimulated the market.

The future of China’s agricultural machinery industry

New opportunities of China’s agricultural machinery industry

With rural reform further deepened, the supporting role of agricultural machinery will be more prominent

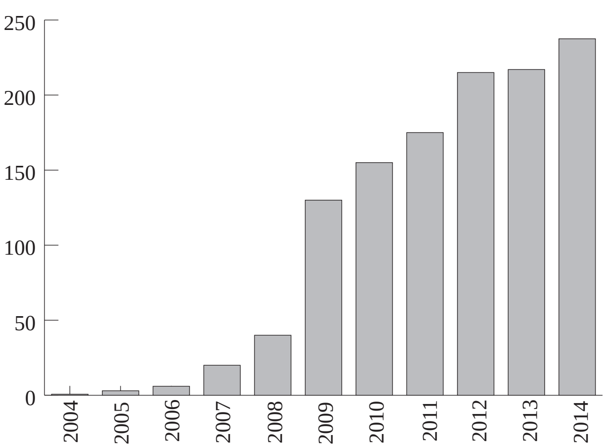
Food security is the top priority of China, so the reform of rural economy will be further deepened; and a new economic system further improved. Rural land contract management right is being transferred to the new entities faster and faster, large-scale production will be formed that demands a large number of agricultural machinery products.

China’s industrialization and urbanization are speeding up

Rural labor transfer will continue, and labor costs will increase, agricultural machinery will completely replace the manpower for agricultural production.

The agricultural development has entered a new phase.

After decades of development, China has achieved a high level of field work mechanization. The Chinese agricultural mechanization is currently transferring from field work to full process mechanization and comprehensive mechanization on agriculture, forestry, livestock and fishery, which creates a wider market for the agricultural machinery industry.



Data Source: Ministry of Agriculture, China

Fig. 9 Agricultural Machinery Purchase Subsidy (Billion RMB Yuan)

National policies on supporting and subsidizing the farmers will continue to be applied

Countryside, agriculture, and farmers are still the focus of Chinese government. They will continue to receive support from government organs. Policies to subsidize farm machinery purchase will be implemented continuously and further strengthened.

Agricultural machinery industry was included in the“ Made in China 2025” as one of the key development sectors.

Chinese government attaches great importance to the development of agricultural machinery industry. Agricultural machinery industry has been included in ‘Made in China 2025’ by the State Council as one of the key development sectors. China will enhance support for the development of key sectors. Agricultural machinery industry will accelerate intelligent manufacturing to upgrade the whole industry.

In summary, China’s agricultural machinery industry is facing new opportunities and a new market of medium and high end products that are efficient, various, energy saving and environmental friendly. Agricultural machinery industry will usher in sustained and steady development in the future.

Future targets

China’s agricultural machinery industry aims to meet market demands to the maximum and change from “Made in China” ‘to’. “Manufactured in China”.

Main tasks

Products structure will be adjusted, in which medium and high end products become the majority.

The current low level products cannot meet new demands of the market, therefore the products structure is in desperate need of readjustment. Middle and high level products, such as the new model power shift large horsepower tractors, intelligent grain combine harvesters, high-efficient forage harvesters, accurate sprayers, and protective integrated tillage machines, should embark on industrialization, The development of key technologies and supporting technologies such as hydraulic drive technologies and components, environment friendly engines, CVT technology for tractor, agricultural intelligent technologies and components needs to be strengthened.

Industrial structure needs to be adjusted

Keeping in line with market principles and the guidance of government policies, China's agricultural machinery industry should adjust its industrial structure and optimize industrial chain so as to as address the current situation where there are a great number of companies, yet their scales are not big enough and production forces, and finally achieve the optimized industrial structure with large enterprises as the core while small and medium enterprises that produce whole machine or accessories featuring specialization, exquisiteness and uniqueness as the body.

Manufacturing level needs to be improved

Advanced manufacturing technologies need to be adopted extensively to achieve the transformation from traditional manufacturing to digital manufacturing. Manufacturing quality needs to be improved to ensure the reliability of the machines.

Management level needs to be improved

The integration of industrialization and informatization should be strengthened, and site management experiences from advanced agricultural machinery enterprises abroad should be learned to achieve the information-based management in operation process.

Summary

Global development of agricultural machinery industry is conducive to the fast development of China's agricultural machinery industry. Chinese agricultural machinery enterprises will insist on Going-out strategy and contributing to the global agricultural mechanization. At the same time, Chinese agricultural machinery enterprises as well as the global enterprises are facing new opportunities. Chinese government will continue to insist on the Opening-up policy, and encourage global agricultural machinery enterprises to enter Chinese market and jointly develop the Chinese market in order to make contributions for Chinese modernization.

■■

CHINA

Status and Trends on Sci-Tech Development of Agricultural Machinery in China

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Abstract

Agricultural machinery, as the material basis for developing modern agriculture, is an indispensable means for improving agricultural production efficiency, transforming the agricultural development pattern, enhancing the comprehensive competitiveness of agriculture, and ensuring national food security and effective supply of agricultural products. In recent years, in the process of rapid socio-economic growth in rural China, with the effective implementation of agriculture and farmers-friendly policies, agricultural machinery has become a most dynamic industry in the whole machinery sector in the country with daily improved research capacities and industrial technologies, and greatly enlarged product varieties and industrial scale. Under the new circumstances in the country, with the urbanization being accelerated and the rural labor increasingly transferred, development of farm machines suitable for the national conditions in the process of agricultural mechanization shall be the fundamental approach to solve the problem of "Who farm and how to farm", in order to meet the requirements in building up the modern agriculture with a sound mode and in a vertical direction. In this review, the paper describes the achievements made in the agricultural machinery and agricultural mechanization, the implementation of the key Sci-Tech planning projects, the innovation of basic applied technologies and key common products, as well as the establishment of four-in-one industrial chain innovation system covering projects, bases, personnel and mechanism in China. It also summarizes the development of the major technologies and products from 7 perspectives such as precision farming and intelligent technologies, farm power and tractors, multifunctional working machines, harvesters, livestock machinery, agro-products and food processing equipment, and agro-forest biomass utilization equipment. In conclusion, the paper indicates the future trends and priorities in the sci-tech development of the agricultural machinery in China from the following four aspects: Strengthening basic research and advancing original innovative capabilities, developing key common technologies and equipment for sound supply of domestic agricultural machinery, upgrading the productivity and quality of high-end equipment, and accelerating going-global for agricultural engineering in the process of the internationalization.

Key words: Agricultural machinery; Development; Achievements; Technology; Intelligence.

Introduction

Food is the paramount necessity of the people, and agriculture is the first priority of a country. In China, which is a developing country with more than 1.3 billion population, agriculture has always been the primary industry with strategic importance in maintaining the national stabilization with the prolonged public support. The Central Committee of the Communist Party of China and the State Council have always attached great importance to the national agricultural development and food security issues. Especially in the 21st Century, the No.1 Documents published by the CCCPC have thrown its spotlight on the issues of agriculture, farmers and rural areas for 12 consecutive years, during which we realized increasingly improvement of grain production and farmer's income. China has made remarkable achievements to feed 23 % of the world's population on the 7 % of the world farmland Agricultural machinery and mechanization which has always played a decisive role in making such great achievements in this process, lays sound foundation for the development of modern agriculture and constitutes the essential approach in improving the agricultural productivity, transforming the growing pattern, upgrading the comprehensive competiveness and safeguarding the national grain security and effective food supply (Chen, 2008). In recent years, in the process of rapid socioeconomic growth in rural China, with the effective implementation of agriculture and farmers-friendly policies, agricultural machinery has become a most dynamic industry in the whole machinery sector in the country, with daily improved research capacities and industrial technologies, and greatly enlarged product varieties and industrial scale. Under the new circumstances in the country, with the urbanization being accelerated and the rural labor increasingly transferred, development of farm machines suitable for the national conditions in the process of agricultural mechanization shall be the fundamental approach to solve the problem of "Who farm and how to farm", in order to meet the requirements in building up the modern agriculture with a sound mode and in a vertical direction (Li, 2011).

In this review, the paper analyzes the sci-tech development of agricultural machinery, industrial upgrading and scientific innovation system in China, especially focusing on the research on the intelligence-based new technologies and products, and indicates the future trends and priorities in the sci-tech development of the agricultural machinery in the country.

Industrial Evolution and Sci-Tech Development

Achievements in Agricultural Machinery and Mechanization

China has established comparatively complete industrial system in agricultural mechanization, which serves as the backup for the agricultural modernization with Chinese characteristics. In 2014, the total output value of large-scaled agricultural machinery enterprises (those with over 10 million output value) exceeded 400 billion Yuan, with an annual average growth rate of over 20 % for ten successive years. Starting from scratch, China has made continuous breakthroughs in developing over 4000 types of key agricultural machinery products from single functions to multiple operations, as well from single segments to extended production chains. China has become the largest producer and user of farm machines and entered into a new era of mechanized agriculture. The market share of domestic-made agricultural equipment has been stable at about 90 % and the comprehensive mechanization level of major grain crops at 61 % in 2014. A service industry in agricultural machinery has been generated with 170,000 operation organizations absorbing nearly 50 million workers and creating revenue of 480 billion Yuan. Moreover, a group of highly qualified professional farmers skillful at mechanization, agronomy and management have been created for developing the brand and efficiency-oriented agriculture with a high level of specialization and standardization in a new era of agricultural Mechanization.

Achievements in Sci-Tech Research Activities

The country has organized and implemented a series of key Sci-Tech planning projects. During the Twelfth Five-Year Plan Period, the state "Twelfth Five-Year" Sci-Tech development plan listed "multi-functional agricultural equipment" as one of the seven key topics of modern agriculture. It has created a layout for key special research plan for technological development of agricultural equipment industry, initialized and implemented the National Sci-Tech Support Plan "Research of key technologies for modern multi-functional agricultural equipment production" and "Development and industrialized demonstration of modern energy saving and high efficiency facility horticulture", "Research and demonstration of modernized agricultural machinery equipment" and "Key technologies and equipment of commercial handling of agro-products producing area", and the key project of National High-Tech Research and Development Program of China (863 Plan) "Intelligent agricultural technology and equipment".

The industry has made breakthroughs in a group of basic applied and key common technologies through special projects, a series of major equipment such as high horsepower tractors, multi-functional operation, precision plan protection, harvesting, irrigation, agro-products processing and biomass with high efficiency, supported the technological innovation and industrial upgrading of the whole agricultural production chain "from field to table", and ensured food security and effective supply of agro-products in the country.

China has established and improved the Four-in-one industrial chain innovation system and enhanced our original innovative capabilities from the perspectives of improving innovation mechanism and extending industrial chain, namely the sci-tech research with the national key laboratories as the core, the industry-university-research cooperation linked by the strategic Technological Innovation Alliance, the utilization of research results with Chinese National Engineering Research Center as the backup, and the industrial service on the platform of innovative services.

The country has also implemented institutional innovation coordinating projects, bases, talents and mechanisms, improved the market-oriented and enterprise-driven sci-tech innovation system in the agricultural equipment industry with the Technological Innovation Alliance as the core, and combination of manufacturers, universities and research institutions. In this process, over 1,000 scientists and technicians have been educated, including many innovative teams in key technologies, forming a relatively high core competitiveness and innovation capacities among the leading enterprises.

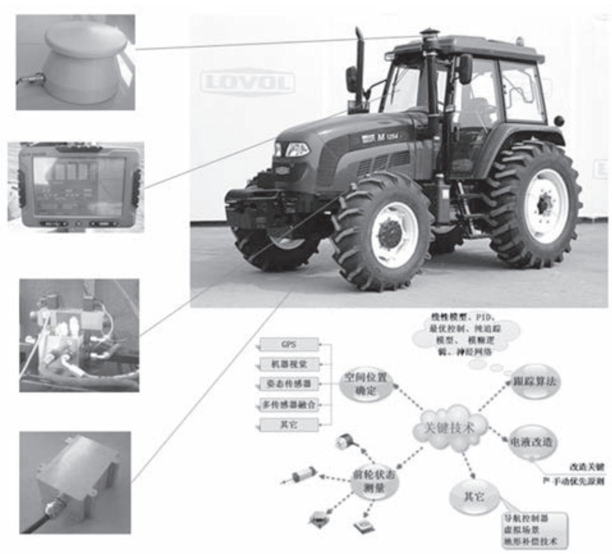

Fig. 1 Tractor Automatic Navigation System

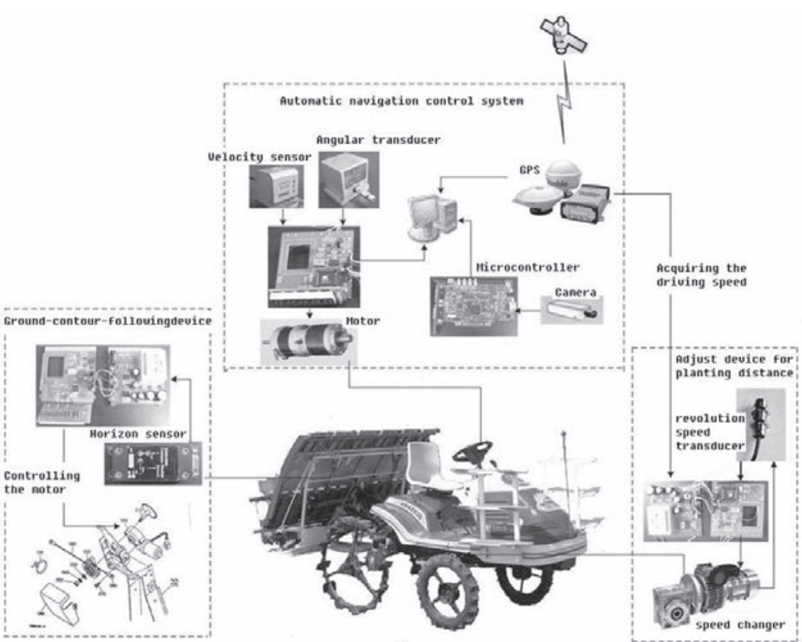

Fig. 2 Intelligent Rice Transplanter

Development of Major Technologies and Products

Precision Farming and Intelligence Technologies

Researches on precision farming and intelligent technologies such as soil and crop information acquisition, variable sowing, precise pesticides spraying, and field data collecting were conducted. The breakthrough technologies of automatic navigation and unmanned tractor and rice transplanter were developed. The development of agricultural robot technologies was deployed in advance to solve the problems of high-risk operations in agricultural production. The application of intelligent control and information technologies provides advanced technical support for upgrading agricultural machinery products and improving their performance and reliability. **Fig. 1** shows the tractor automatic navigation system with yaw control accuracy of ±5 mm combined with monitoring and dispatching system of agricultural machinery, which can capture the operating parameters and video information and display these in real time. **Fig. 2** shows the unmanned transplanter developed by CAAMS. The unmanned transplanter can auto-walk by following the rows, auto-adjust the row spacing and auto-control the balance of transplanting depth with the precision of auto-following the rows less than 10 cm. The apple picking and bagging robot was also developed by CAAMS. The robot can carry on a series of actions including GPS navigation, autonomous walking, and apple detection, position, picking or bagging. China Agricultural University developed the cucumber and strawberry picking robot, integrated with vision identification, maturity detection and other advance technologies. (Li, 2011; Ji, 2011; Shen, 2010; Zhang, 2011).

Farm Power and Tractors

The technologies in direct-coupling energy-saving micro-tractor and 180 hp tractor were upgraded and the products were applied in industry. The power load shifting technology with intellectual property rights and integrating bussing technique were achieved. The 200 hp and 300 hp power load shift tractors were developed and the hydraulic CVT heavy tractor is being researched currently. To meet the requirements of field management, the high-clearance self-propelled power machines were developed. (Li, 2011).

Multifunctional Working Machines

A series of agricultural machines were developed and achieved an advanced level inside and outside the country, such as the complete scarified-plow, the non-tillage fertilizer planter, the pneumatic original wheat precision seeder, the precision plant protection machine and the large self-propelled variable rate sprinkler. **Fig. 3** shows the precision variable rate fertilization seeder developed by CAAMS. The variable rate operating prescription map was drawn by smart decision-making system with the acquired information of soil nutrient distribution and crop growth nutrition requirements to realize variable rate seeding control and variable rate fertilizing control. (Li, 2011)

Fig. 4 shows the intelligent precision sprayer developed by CAAMS, which is using the ultra-low altitude UAV remote sensing, GPS precision position and machine vision technology. The sprayer can automatically detect weed position, make the spraying prescription map and spray herbicide on weeds. The nozzle flow was adjusted in variable rate by the prescription map combined with information of walking speed, flow and pressure feedback.

Fig. 5 shows the large self-propelled irrigation machine developed by CAAMS, which has been industrialized comprehensively in China. A series of new technology were used for each cross synchronized walking control, including control mode of variable frequency speed of ground wheel, navigation and positioning with GPS and machine vision system, fuzzy decoupling control of multi-wheel speed and automatic zeroing by swing angle feedback to achieve the functions of unmanned automatic operation, variables irrigating according to the prescription map and each cross synchronized walking control. The width of large sprinkler is 800 m, and the amount of saving water is up to 30-40 %.

Harvesters

Axial-Flow combine harvester with above 6 kg/s feed rate assembled with multifunctional header for rice, wheat and soybean was developed to improve the efficiency of cross regional work, and the breakthrough technology in whole machine of large intelligent grain combine harvester (**Fig. 6**) with 10 kg/s feed rate was achieved. A special structure corn combine harvester suitable for different planting of agronomic crops was originally developed with no spacing restrictions. Furthermore, technologies on combine harvesters were used for the cotton, rapeseed, linen, medical herbs and so on, so that it achieved a comprehensive upgrade of the harvesting technologies for farm

Fig. 3(a) Precision Variable Rate Fertilization Seeder

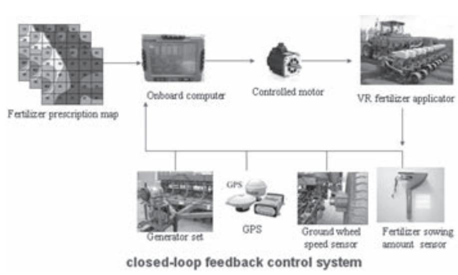

Fig. 3(b) Closed-loop Feedback Control System

Fig. 4 IRS Intelligent Targeting Herbicide Sprayer

Fig. 5 Large Irrigation Machine.

Fig. 6 Large Intelligent Grain Combine Harvester with 10 kg/s Feed Rate

production in China. Especially, a self-propelled cotton picker was developed and successfully applied in the main cotton producing areas in Xinjiang, and this technology is initiated in China. The “bottleneck” problem in the potato production in large-scale was successfully solved by the potato combine harvester develop by CAAMS. (Li, 2011)

Livestock Machinery

Forage harvesters for single-row, double-row, 3-row planting, and self-propelled mode were developed to improve efficiency in feed crops harvesting. The complete sets of machines for forage production were developed, including natural grassland improvement machinery, the forage precision planter, the intelligent mower, the wide-width rake, the automatic hay baler, the chop truck for scattered grass, and the milk cow feeding production line. A number of projects for large scale intelligent animal husbandry farming were developed, which can promote employment and development of the animal husbandry industry and improved people’s life quality.

Agro-products and Food Processing Equipment

CAAMS has created the engineering technology system from planting to processing for the fourth major grain crop, potato, in China and developed series of complete set of production lines for starch, modified starch, whole powder, potato sticks, potato chips, and its comprehensive utilization, which has filled the blank in China of the large complete sets of equipment for processing potatoes, and archived the export of the complete sets of potato processing machines. Some new advanced machines such as the dried noodle production line, the germ rice processing equipment, the vegetable production line, the large scale modified starch production equipment, the complete set of pretreatment for oil and fat expanding line with capacity of 30-5000t/d were created. (Li, 2014)

Agro-forestry Biomass Utilization Equipment

In China, the 51 % output of agricultural production is straw. CAAMS has developed some straw harvesters for the cotton straw, the wheat, the rice, and the corn. The integrated technology of the straw harvester filled the blanks in China, and built the unitized equipment technology system with the Chinese characteristics for the straw comprehensive utilization from collection to storage and transportation, which promoted the level of the industrial utilization of agricultural biomass in China, remarkably. **Fig. 7** shows the Straw Direct Fired Power Generation Project. (Li, 2015)

Future Priorities of Development

Nowadays, China is undergoing a critical stage for building up a well-off society in an all-around way and an accelerating period for transforming into the modern agriculture. The newly-introduced “Four Modernizations” are accelerated, since the scale management has become the mainstream of agriculture that has entered into a new era of mechanization with a simultaneous reform of means of production and productive relations. A handy tool makes a handy man. Considering the new requirements from the modern agriculture, it is quite urgent to develop the farm machines and technologies in the integration with modernized industries, capitals and markets, promote the combination of sci-tech research with application, technologies with economy, industries with capitals in the farsighted vision of large-scaled agriculture, so as to speed up the transformation of production patterns and the final realization of modern agriculture.

Strengthening Basic Research and Original Innovative Capacities

The industry and research organizations may take the basic applied research of information perception of agricultural machinery operation and precision production management and control, break through the mechanism of action of agricultural machinery operation on soil quality and structure and the mechanism of effect on plant growth, the information perception mechanism of ani-

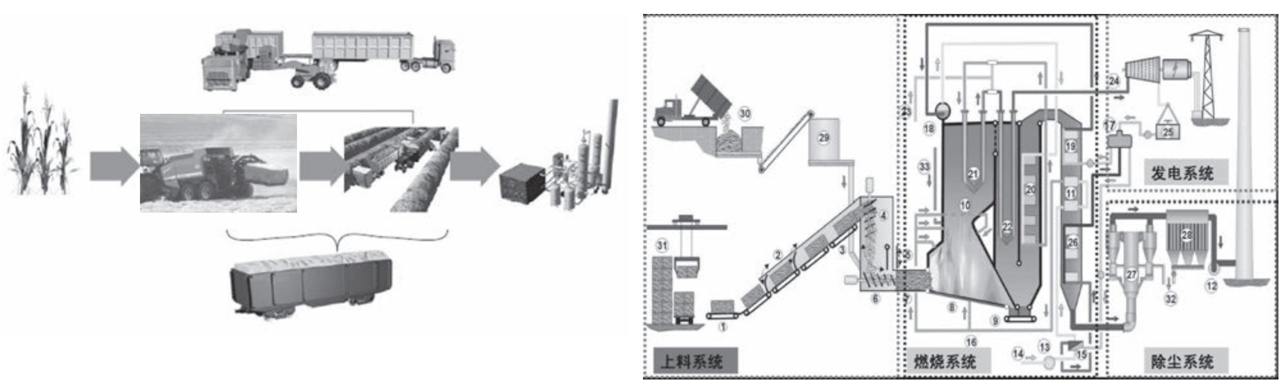

Fig. 7 Biomass Power Generation Project

mal and plant and the identification and characterization methods of feature parameters, material input during the fine production, management and control mechanism of growth and development and digital modeling of intelligent control, and test methods of machine operation parameters in key production links open condition, etc. to achieve the independence of key core technology.

Developing Key Common Technologies and Equipment for Sound Supply of Domestic Agricultural Machinery

The current focuses include developing intelligent farm power, multi-function operation with high efficiency, precision and environment protection, cereal harvesting and economical crops harvesting, precision production with facility intelligence, intelligent handling of agro-products and agricultural robots.

Upgrading the Productivity and Quality of High-end Equipment

Taking the advantage of “Made in China 2025”, and aimed at the high level of safety, reliability and adaptability of high-end agricultural machinery, the industry shall propel the profound integration of digital, intelligent and mechanized agriculture, develop environmental protection products with the advanced, user-friendly, low emission, low pollution, high energy efficiency and high working efficiency qualities. In the meantime, the industry may strive to push forward a complete plan based on the operation, service and information of agricultural production, and progressively upgrade of agricultural mechanization industry, which would turn China into a more competitive producer of farm machineries in the world.

Accelerating International Cooperation and Overseas Investment in Agricultural Engineering

Through improving the intergovernmental cooperation mechanism, the agro-indutry shall expand scientific and technological communications and upgrade the level of foreign cooperation. Under the “One Belt and One Road” strategy, the country may also encourage our enterprises to export their complete sets of agricultural engineering, including the four-in-one system of crop farming, animal production, agro-processing and biomass energy utilization, realize the newly-introduced concept of Four Modernization, namely mechanized plantation, welfare-focused animal production, organic food popularization, and residue transformation, promote the overseas investment of the chain of manufacturing, marketing, maintaining, training and services, so as to maintain a sustainable development of the national industry and make due contributions to the socio-economic development in local areas and food security in the whole world.

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TAIWAN

Present Status and Future Prospects of Agricultural Machinery Research and Industry in Taiwan

by
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Introduction

Taiwan is a subtropical island characterized by high temperatures and heavy rainfall. There are typhoons in summer and autumn. The island measures 370 km long and 142 km wide at its widest points, with a total area of about 36,000 square kilometers. Seventy three percent of land in Taiwan is either mountainous or hilly. The amount of land available for crop and livestock production is limited to some 850,000 hectares. The average farmland is about one hectare. Typhoons frequently visit the island during the summer and autumn seasons, and torrential rains and earthquakes are a common occurrence. The average temperature is 22 ºC in the north and 24.5 ºC in the south. Summer runs from May to October, and a mild winter from December to February. Rainfall is abundant, averaging 2,500 millimeters annually. The staple rice is usually grown two crops within one year in Taiwan. The planted area of paddy totaled 271,051 ha in 2014, of which 166,602 ha were of first crop and the remaining 104,449 ha the second.

Taiwan government vigorously promoted mechanization of agriculture since 1970. The four-year accelerated mechanization program (1970-1973) and intensive program for rice drying mechanization (1975-1978) were enforced successfully to upgrade the degree of mechanization in Taiwan. These programs were included in the national twelve major construction projects. Four billion New Taiwan dollars (NT $) was raised by the government through the years for supporting agricultural mechanization fund and loans used for farmers, agricultural machinery subsidies, extension education and training, agricultural contracted farming, research and development of the agriculture and related measures in line with mechanization. As a result, the rice cultivation in Taiwan now is highly mechanized, second only to Japan in Asia. It also contributed to the booming business of development of agricultural machinery and related component manufacturing industry.

The first step of Taiwan agricultural mechanization initiated in 1957 as the Sino-American Joint Commission on Rural Reconstruction (JCRR) distributed thirteen improved Japanese Merry Tillers to agricultural improvement stations, farmer's associations and vocational schools for demonstration and promotion of mechanization. Later on different sizes of Japan-made power tillers were then imported by traders which increased the market competition. Encouraged by good reactions from farmers, domestic machinery factories started mimicking imported power tiller models and produced them locally. There were a total of about twenty-two factories that manufacture power tillers, and among them four factories manufactured gasoline or diesel engines in 1970s.

At present, the mechanization of field operations has been efficiently promoted in Taiwan. Due to the aging of agricultural population, shortage of rural labor and the deceasing of individual farmer's production size, demands of farming machinery are decreasing. Therefore, over the past decade, Taiwan agricultural machinery industry has gradually shifted domestic market to foreign markets, The booming economic developments and large scale in agriculture production size in China and Southeast Asian countries in recent years induce a large demand for farming equipment which further strengthen the export-oriented market of Taiwan agricultural machinery industry.

According to statistics of Taiwan Agricultural Machinery Industry Association, there are 215 agricultural machinery corporations and its related parts manufacturers in Taiwan. Most of the agricultural machinery companies are operated in a small or medium scale business as compare to international market. The products include paddy and grain dryer, rice mill, refrigerated storage tank and silo, harvester, transplanter and seeder, branches shredder and chopper, farm field truck, cultivators (**Fig. 1**), weed mowers (**Fig. 2**), horticultural machinery, chemical blowers (**Fig. 3**) and sprayers, fruit cleaning machines and graders (**Fig. 4**), tray feeding and nursery systems, husbandry equipment, etc. Large scale field machinery such as tractor, combine, and rice transplanter are imported from other countries. At present, agricultural machinery R&D is engaged by researchers and engineers allocated in six national district agricultural research and extension stations, one national agricultural research institute and five national universities.

Research and Current Industry Development of Taiwan Agricultural Machinery

In the development process of Taiwan agricultural machinery, one thing worth mentioning is the development of peanut harvester (**Fig. 5**). The way to harvest peanuts in Taiwan is different from the way in United States where plants are turned and exposed under the sun for a few days before being threshed. In Taiwan, plants are threshed directly after being pulled out which increases injury rate of peanut pods. Nowadays local made peanut harvesters are widely acceptable by farmers and the problem of time-consuming harvesting work was solved.

Other agricultural machinery developed by government-funded programs can be classified (by the usage) as followings.

1. Vegetable seeding and transplanting machinery: vegetable seeders, consistent automatic vegetable plug tray sowing machines and plug seedling transplanters.

2. Rice seedling nursery and handling machinery: continuous rice seed warm water sterilizing machine, rice seedling machine, automatic pallet handling system for trays and automatic tray-discharging system for rice seedlings.

3. Dryers: condensate desiccant dryer, batch circulating paddy dryers and rice husk furnace (**Fig. 6**).

4. Cultivating and weeding machinery: inter-tillage cultivating machine, self-propelled agricultural mower and paddy field plowing rake.

5. Harvesting machinery: Napier grass harvester, tea picking machine, corn snapper, peanut combine harvester, soybean combine har-

Fig. 1 Cultivator

Fig. 2 Weed mower

Fig. 3 Chemical blower

Fig. 4 Fruit graders

Fig. 5 Peanut harvester

Fig. 6 Husk furnace paddy dryer

Fig. 7 Sweet potato combine harvester

Fig. 8 Farm field truck

vester, harvesting machine of flower bulbs, sweet potato diggers and self-propelled sweet potato harvesting machine (**Fig. 7**).

6. Post-harvest processing machinery: fruits and vegetables grader, citrus grading machine, fruit cleaning machine, fruit and vegetable weight sorting machine, lemon bagging machine, eggshell crack inspecting machine and tea stalk sorting machine.

7. Management equipment: fruits tree trimmer, tree branches shredder, tree twigs choppers, fruit bagging machine, boom type chemical spraying machines, fertilizing seeder, fertilizer spreader, air-assisted spraying machine, blast sprayer, knapsack sprayer, electric fruit tree scissors, indoor electric self-propelled lifting carrier and self-propelled soil vapor-sterilization processor.

8. Transportation and handling machinery: farm field truck (**Fig. 8**), crawler type field carrying machines and monorail conveyor system.

9. Husbandry equipment: tray feeding system and piglets nursery milking machine.

Starting from imitating foreign products in the early 1970s, Taiwan now is able to independently develop agricultural machines whose qualities are of international standards. Mature and popular products such as soil preparation machinery, field management machinery and post-harvest processing machinery from R & D of governmental research and extension units, universities and private vendors can meet the needs of farm mechanization in Taiwan. Taiwan now exports a lot of farm machines overseas and among those, paddy dryer (20 to 100 ton capacity) is one of the major exported items. Current status of domestic development and industrial demand in the research area of agricultural machinery are stated as follows:

Crop cultivation management machinery

Soil preparation, planting, fertilizing, cultivating, managing, and harvesting operations of rice and grains have mainly been fully mechanized (Tien *et al*., 2014). One good example is the establishment of rice nursery centers and contracted farming centers. Large-scale mechanized contracted farming operations are implemented successfully. Future improvement and development for demanded machines are listed as followings.

1. Coarse grain machine, horticulture and special crops machine, post-harvest processing and handling machine, storage machine, livestock machine, slope land machine and applications of new technology on agricultural machinery.

2. Automated operations of fruits and vegetables harvesting and processing. Consistent operations that include self-cleaning, grading, sorting, packing and other processes automation system can save a lot of manpower.

3. Field work automation: a broad range of field operations include the entire production processes from land preparation, planting, irrigation, management to harvesting.

Agricultural produce processing and treatment machinery

Development of agricultural produce processing and treatment machinery for harvesting and drying rice and grains have been highly mechanized and automated in Taiwan (Chiu, et. al., 2010). Cleaning, sorting, grading, packing, storage and other process operations of fruits and vegetables are also quite developed. In addition, there are some other development of post-harvesting handling and processing machine for different crops. Furthermore, quality evaluation instrumentation is available for some crops. The current development focuses on precision processing of agricultural products, and utilization of biomass. The development of online real-time, non-destructive quality testing and classification technology of fruits and vegetables has yet to be developed with a low-price approach.

Environmental monitoring and facilities engineering

Agricultural facilities engineering can improve the yield per unit area, reduce impact from seasonal changes and produce superior product quality. The most popular greenhouse facilities in Taiwan adopt temperature, humidity, light intensity, etc., as control parameters. Cooling methods mainly are natural ventilation with side curtains opened or forced ventilation using pad and fan evaporative cooling system. The environments of plant factories are monitored by precise microprocessor automation system for controlling temperature, humidity, light, CO_2 concentration, nutrient solutions and other environmental conditions. The outcome of the system is a high-performance agricultural facility with steady annual crop production and less influence by the natural weather conditions. Health management of crop production can be used to produce safe fruits and vegetables with low nitrate, low quantity of microorganisms, no pesticides, and no heavy metal. The idea of local produced products with low-carbon food mileage and energy saving is expected to be implemented.

With frequent occurrences of rapid weather changes, storm and cold temperature and other severe conditions, facility cultivation can ensure production quality and stabilized livelihood commodity prices. In order to compensate high initial facility cost in a long period of time, adequate mature technologies and management strategies for reducing damage and operating cost of cultivated crops in facility are strongly demanded by local growers. Therefore, a greenhouse management decision system that can adjust greenhouse environment by taking into accounts of crop physiology and energy-saving mode is needed and well developed in Taiwan.

Application of emerging technologies in Taiwan's agricultural machinery

With the help of world-famous Taiwan precise processing machinery industry, Taiwan agricultural machinery quality and durability catch up with those advanced countries such as Japan, America and European Union. Besides the domestic markets, most Taiwan farm machinery products are exported overseas to Japan, Southeast Asia, India, Latin America, Europe, Central Asia, Africa and other international markets. There are many highly well-developed commercial agricultural machines for soil preparation (power tiller, cultivator and rotary tiller), seeding and fertilizing (seeder and fertilizer applicator), weeding (cultivator and mower), pest control (manual spraying machine, self-propelled sprayers, high and low pressure water pump), harvesting (rice combine harvester and tubers diggers), drying (rice drier), post-harvest processing and conditioning (hulling machine, rice mill and rice polisher), storage and transportation (paddy cold storage silo (**Fig. 9**) & equipment and field transporting vehicles) and machines for other special crops. Through the long-term export of farm machinery to Southeast Asian region, Taiwan has achieved excellent quality recognition and trust in that region. Most machines produced by local manufacturers usually get certified performance test report issued by Taiwan Agricultural Research Institute. Therefore, machine that passed performance test has better advantages in promoting its market in other countries (Shyu and Lin, 2014). Some examples of new emerging technologies applied on agricultural machinery systems in Taiwan are electronic and photoelectric sorting and grading for fruit, unmanned automatic spraying as well as quality evaluation technique for fruit and vegetables.

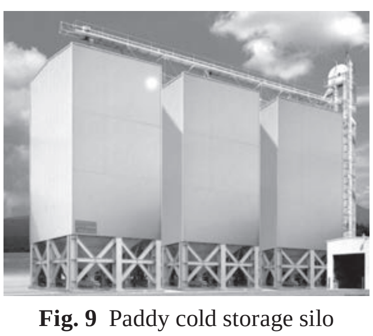

Fig. 9 Paddy cold storage silo

Technological Layout of Taiwan Agricultural Machinery

Research on agricultural machinery in Taiwan has made a big progress for decades. Advanced technologies in the seeding or grafting, post-harvesting handling and electromechanical integration technology are fully applied on traditional field machinery, processing and treatment machinery to achieve the goal of reducing field labors.

The taskforce for promoting agricultural automation in the crops, fisheries, livestock production and service was initiated in 1991 in Taiwan. The total amount of investment in crop production automation was about US$ 30.2 million during 1991-1998. In 1999, Taiwan Agricultural Research Institute (TARI) initiated a pilot project on precision farming system for rice crop in Taiwan. Three multi-disciplinary research teams were organized for the purposes of developing techniques required for monitoring growth status and environmental conditions for rice crop; integrating the elements necessary for fertilization recommendation system and pest management system; and developing machinery for yield monitoring and mapping system, field-based remote sensing system, variable-rate pesticide spraying system, and variable-rate fertilizing system. More than fifty researchers engaged in the precision agriculture project of US$ 3.5 million budget during 1999-2003.

To enforce agricultural knowledge economy, Taiwan implemented the automation and computerization in agriculture, fisheries, and animal husbandry as one of the eight national agricultural technology programs in 2005. Beginning in 2010, Taiwan agricultural research units began to involve in upgrading plant factories and facilities and have achieved promising results. Since Taiwan is about to promote agriculture via agricultural productivity 4.0 project. It is a quite good opportunity for developing and advancing agricultural machinery research now, therefore, future prospective of agricultural research in Taiwan is described in the following four directions.

Coping with industrial immediate demands

At present, in response to the needs of local industry, R & D of Taiwan agricultural machinery is focusing on developing special purpose-oriented machinery (Huang, 2010). Although the local market for special machinery in Taiwan might not be high, the machinery demanded by farmers still need to be developed quickly. The accumulated R & D experiences and databases over decades are beneficial to rapid developing special machinery in Taiwan. On the other hand, the agricultural product-processing industry also has high demand for supplying planting and harvesting machinery such as sweet potato cultivation machinery and consistent harvesting machinery. These kinds of machinery should be developed to adapt local cultivation practice.

Application of new technologies on production or post-harvest handling

Emerging technologies can be applied in agricultural production or post-harvest handling. Some examples of these technologies are non-destructive testing, extraction, energy-saving operation (refrigeration or drying) and commodity packaging technology. Our goal of applying emerging technologies is to emphasize processing of turning raw agricultural crops into primary products, advanced functional products and commercialization of sophisticated packaging. Agricultural machinery study and research results are requested to be open to the publics and encouraged to find ways for application. Further improvement and testing are also required to enhance operating efficiency and durability of the machinery in order to achieve greater economic efficiency.

Focusing on energy-saving, environmental protection and resource processing engineering

Research teams are focusing on developing processing systems or renewable energy technologies to effectively transform discarded biomass in fields into valuable resources (Wen, 2007). To achieve automation of the precise greenhouse cultivation, some measures applied to greenhouses are as followings: using solar energy as main power source, combining double-effect heat pump technology to regulate environment and operations, implementing crop physiological sensing, and implementing wireless sensor network system for energy saving operations. For effective management of water resources, water-saving irrigation using water-saving pipes, rain water harvesting and water recycling engineering facilities, etc. are scheduled to be installed in Taiwan.

Main thrusts of agricultural productivity 4.0

To modernize Taiwan agriculture, national policy of agricultural productivity 4.0 was initiated in 2015. Main themes of agricultural productivity 4.0 related to agricultural machinery include development of labor-saving assisting equipment, further evolution of agricultural automation in line with post-harvesting processing, automation of seedling production, automation of greenhouse cultivation and management operations, development of intelligent robots, enhancement of internet of things, adopting smart farming technologies and application of big data. Advanced technologies such as integrate high-precision sensors, real-time wireless transmission, satellite communications and ICTs are highly emphasized in Taiwan agricultural machinery R&D in next decade. Optimal utilization of resources will be achieved through the successful implementation of agricultural productivity 4.0.

Agricultural Machinery Trading

As to agricultural machinery trading, Taiwan not only imports but also exports agricultural machinery and related spare parts. The export and import amounts in 2014 were respectively about 6.4 billion and 2.6 billion. The trading transitions between 2001 and 2014 demonstrated a steady growth for both import and export amounts as shown in **Fig. 10**. Due to global financial turmoil and stuffy economy, the net export amounts dropped from 4 billion to about 2.8 billion NT$ in 2009 and 2013, respectively.

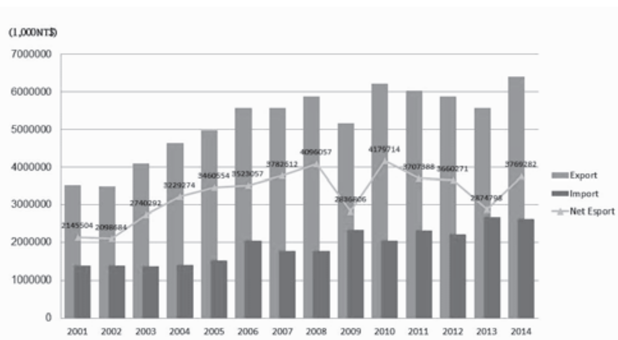

Fig. 10 Import and export of Taiwan agricultural machinery and spare parts over the years from 2001 to 2011 (Original data from Customs Administration, Ministry of Finance, R. O. C. (Taiwan)).

Conclusions

Agricultural machinery made in Taiwan possesses high technical standards with good quality and good management system. Taiwan agricultural machinery industry is characterized by small capital, small-scale, few product types with great diversity. The domestic market is near saturated with limited volume for promoting new model of agricultural machinery. Therefore a steady increase of agricultural machinery export trading is resulted by effort of opening overseas markets in Southeast Asian region and China during past 10 years.

Acknowledgments

The authors express appreciation to Dr. Fu-Ming Lu, Professor Emeritus, Department of Bio-Industrial Mechatronics Engineering National Taiwan University Taipei, Taiwan who have made contributions and suggestions to this article.

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EVENT CALENDAR

◆ **GCARD3**
—Connected Off-Highway Machines 2016—
April 5-8, 2016, Johannesburg, SOUTH AFRICA
http://www.gfar.net/news/gcard3-global-event-be-held-south-africa

◆**常州農業機械展覧会 2016**
April 15-16, 2016, Changzhou, CHINA

◆ **VDI Conference**
—Connected Off-Highway Machines 2016—
May 10-11, 2016, Düsseldorf, GERMANY
www.vdi-internaional.com/offhighwaymachines

◆ **ISMAB 2016**
—International Symposium on Machinery and Mechatronics for Agriculture and Biosystems Engineering—
May 23-25, 2016, Niigata, JAPAN
http://www.ismab2016.jp/

◆ **DLG-Feldtage**
June 14-16, 2016, Bavaria, GERMANY
http://www.dlg-feldtage.de/en/news/news/?detail/feldtage2014/16/2/8322

◆ **The first International Precision Dairy Farming Conference**
June 21-23, 2016, Leeuwarden, NETHERLANDS
http://www.precisiondairyfarming.com/2016/

◆ **4th CIGR International** —AgEng Conference 2016 Robotics, Environment and Food Safety—
June 26-29, 2016, Aarhus, DENMARK
http://conferences.au.dk/cigr-2016/

◆ **ASABE 2016 Annual International Meeting**
July 17-20, 2016, Orlando, Florida, USA
https://www.asabe.org/meetings-events.aspx

◆ **AGRICONTROL 2016**
—The 5th IFAC Conference on Sensing, Control and Automation for Agriculture—
August 14-17, 2016, Seattle, Washington, USA
http://ifac.cahnrs.wsu.edu/

◆ **The 4 th Edition of INAGriTech 2016**
August 25-27, 2016, Jakarta INDONESIA
http://www.inagritech-exhibition.net/#axzz3zFynVBGC

◆ **3rd Conference Biogas Science 2016**
September 2016, Szeged HUNGARY

◆ **VII International Conference on Agricultural Statistics (FAO)**
October 26-28, 2016, Roma, ITALY
http://icas2016.istat.it/

◆ **CIAME 2016**
—China International Automotive Manufacturing Technology & Equipment Exhibition—
October 28-30, 2016, Wuhan, CHINA
http://www.ciame.net/

◆ **EIMA International 2016**
November 9-13, 2016, Italy, BOLOGNA
www.eima.it

◆ **BICET 2016**
—6th Brunei International Conference on Engineering and Technology 2016—
November 14-16, 2016, Bandar Seri Begawan, BRUNEI
http://www.itb.edu.bn/bicet2016/

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December 14-18, 2016, Pune, INDIA
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◆ **XIX. World Congress of CIGR**
April 22-25, 2018, Antalya, TURKEY
http://www.cigr2018.org/

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KOREA

Current Status of Agricultural Engineering Research in Korea

by
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Agricultural Engineering of Korea has played an important role in the improvement of food self-sufficiency rate to develop the country from the poorest countries to the rich countries. It has a leading role in the phenomenal development to overcome the barley hump, a serious food shortage until the 1950s in just 50 years. However, now there are many efforts to teach our Agricultural Engineering-based agriculture rural development technology and experience based on the accumulated technology and compressed experience, and economic strength of the country to the international community. Before it is too late, we need to globalize valuable development experience and technology to promote the country, to aim to national interests, to create new employment, and, to contribute to the securing of overseas food base that can be ready for the future.

In Internet Wikipedia, globalization is a word that refers to the fact that is progressing as a single system as increases of the mutual dependence on the international community. Boundaries of each nation and state are weakened, a phenomenon which will continue to integrate mainly global socioeconomic status as world is connected to one. It means that the interdependencies among them will deepen. In promoting the globalization of Korean Agricultural Engineering, it is necessary to consider what mutual dependence and a single system of Agricultural Engineering means.

From this point of view, in this paper, the present position of Korean Agricultural Engineering was considered by reviewing peer-review papers published on journals of Korean Societies of Agricultural Engineering (KSAE) and Agricultural Machinery (KSME). Additionally,

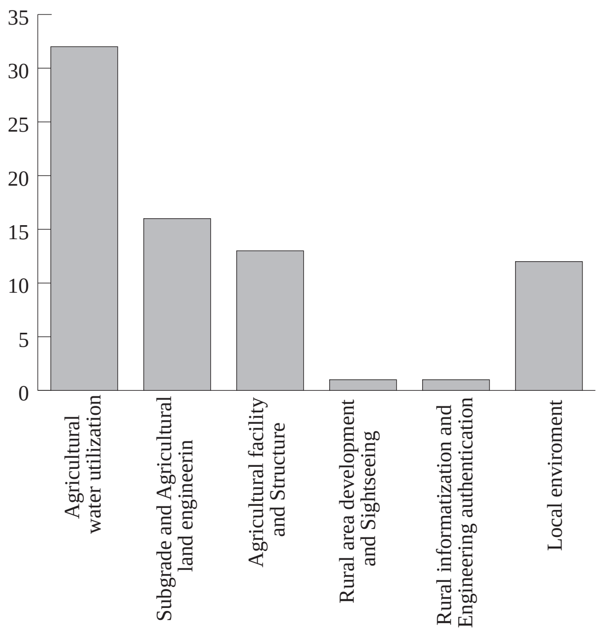

Fig. 1 KSAE published papers for totally 6 research fields from 2014 to 2015

recommendations have been made for the globalization of Korean Agricultural Engineering.

Past and present of Korean Agricultural Engineering

After the 1900s in Korea, Agricultural Engineering can be distinguished by another five era features as shown in below.

1. 1900-1945 was the time that modern irrigation works waere established with some irrigation association, and agricultural water management system was introduced to farmers at that time. Mainly it was a colonial era of Japan, but it was time that laid the foundation for the modernization of the agricultural base that has lagged behind. However, agricultural infrastructure modernization during this period was mainly dark time, and it was used as a means of food exploitation of Japan's colonialist.
2. 1946-1969 was the time that water management works for the overcoming of poverty and food shortages after release. Because of an insufficient agricultural infrastructure, the serious food shortages were experienced every year. Because of floods and drought, the infrastructure development and reclamation projects were very actively conducted in full-scale since the 1960s.
3. 1970-1989 was the time to achieve self-sufficiency of rice that is an agricultural base to expand promotion of large-scale agricultural development projects and ongoing agricultural base business.
4. 1990-1999 was the time to focus on strengthening agricultural competitiveness as investment and maintenance of agricultural production base in order to correspond to the era of globalization to strengthen. Investment for the

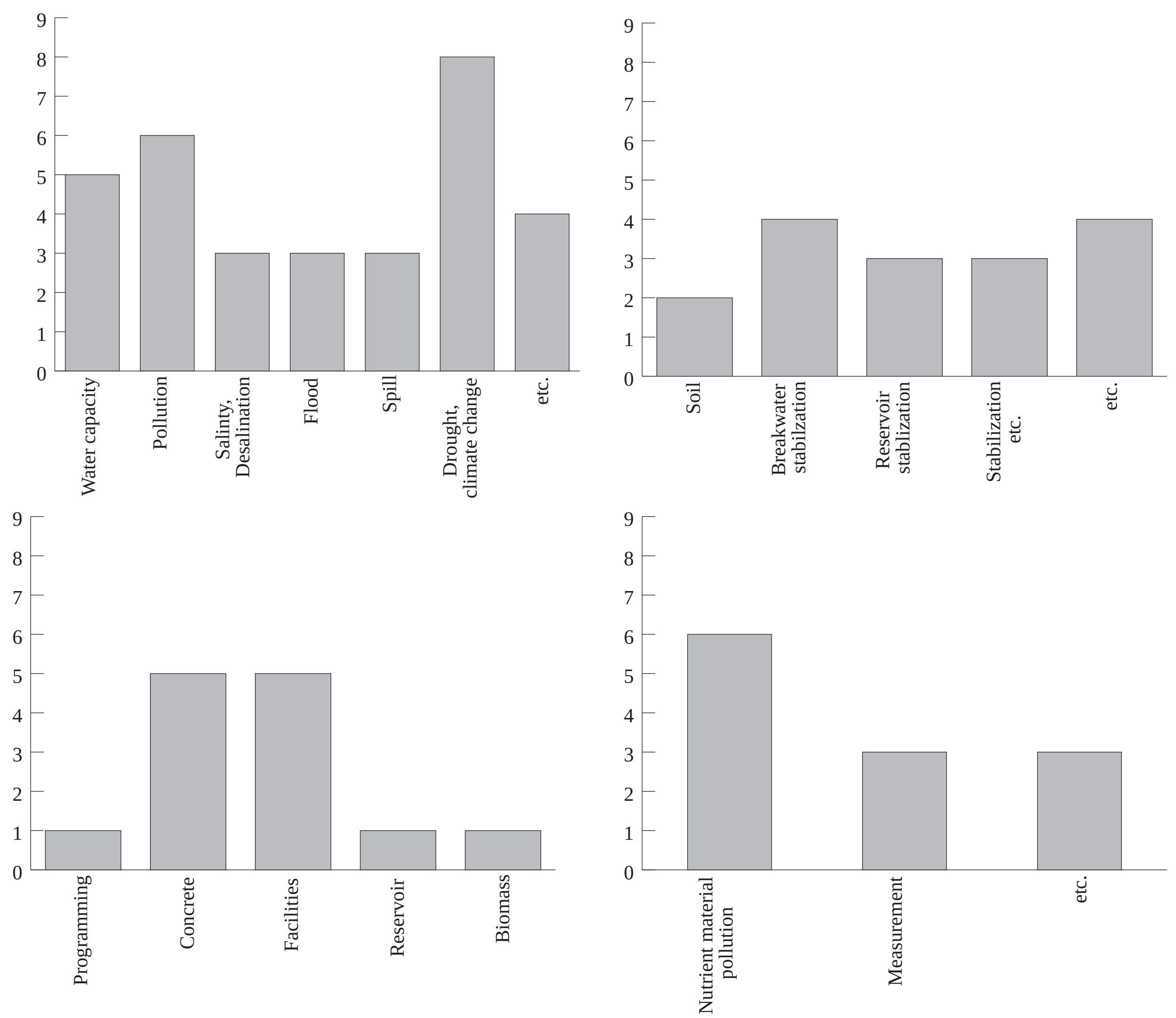

Fig. 2 KSAE published papers of 4 research fields categorized using some typical keywords

improvement of large-scale farming and farming and fishing community life environment also took place.

5. 2000 to date, while human and agriculture and nature are coexisting, the focus has become to ensure the quality of the rural life. For this reason, it has placed farming and fishing community development, restoration of the natural and ecological environment that has been damaged in the development with full commitment, and the emphasis on the top facility agriculture in order to develop export agriculture.

The time of 1 and 2, the financial state after liberation and colonial rule was not enough, so accordingly it was not carried out to full-scale agricultural development. However, there is a margin for successful finances of the state, and some portion of these was expanded to rural areas and development investment in the economic development plan from time 3). The agriculture and industry technology dramatically developed to let us live well to the diffusion of the Saemaul Movement showing that civic movement could be promoted to vigorous agricultural development. For this reason, Korea was able to succeed in agriculture and rural modernization in which the Agricultural Engineering technology had greatly developed within a short period of time that is not passed 50 years. There are also efforts for restoring, protecting and conservation the natural ecosystems with the farming and rural advancement at the same time.

Researches of Korean Agricultural Engineering

Like many other Asian countries, there are Korean Societies of Agricultural Engineering (KSAE) and Agricultural Machinery (KSME) in Korea separately, and they have made significant contribution on development of rural area as well as agriculture for last more than 50 years. In this subchapter, publications on those two journals will be introduced to show current status of researches actively conducted in Korea. **Fig. 1** shows the major sessions of KSAE with number of published papers for 2014-2015. KSAE has totally 6 working groups such as water management, soil engineering, agricultural buildings, rural development, rural information, and local environment. About 42 % of KSAE published papers were on the Agricultural water utilization while 21 % and 17 %, respectively for Subgrade and agricultural land engineering and Agricultural facility and structure. Especially, studies on agricultural buildings such as greenhouse and livestock houses have been greatly supported by Korean government recently because more than 70 % of land is mountain area with very distinguishable 4 seasons. There are many important limitations to increase productivity of agricultural products in these areas. Only protected cultivation can guarantee annually stable production of high-quality agricultural products. **Fig. 2** shows that the published papers of each working group were categorized using some typical keywords.

Fig. 3 shows the major sessions of KSME with number of published papers for 2014-2015. KSME has totally 5 working groups; Off-road machinery system, Agricultural environment system, Agricultural process and food engineering, Biological engineering, and Information and complex technologies. About 33 % and 37 % of KSME published papers were involved into Off-road machinery and Process and food engineering showing those two research fields are the leading groups. While studies on off-road machinery have been led by commercial companies more than universities, food processing has been very hot topic. It is because it makes a lot of benefits to farmers and related industries, much more than selling agricultural products simply. **Fig. 4**

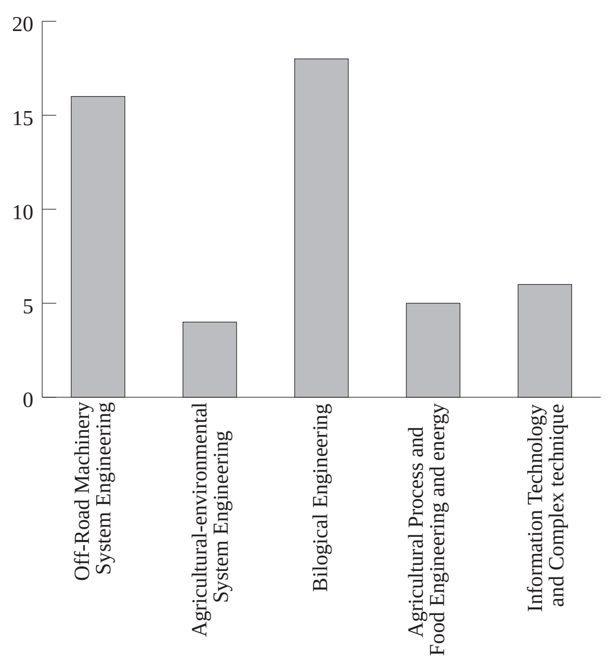

Fig. 3 KSME published papers for totally 5 research area from 2014 to 2015

shows that the published papers of each working group were categorized using some typical keywords.

Considerations of the Globalization

Globalization at Agricultural Engineering field has brought the era of inevitable infinite competition. There is need to solidify scaffold that can be put into the world by our development experience, technical capabilities and utilizing such public assistance. Globalization can be a product of economic, science and technology, socio-cultural and political power. It is also receiving criticism that the world restructuring is focused on economic powers.

Globalization, it is also true that is made to deepen the exclusive economic and technology focused on a huge capital, technology, and service. There are also lots of typical cases that more and more huge globalization is happening such as smartphone, electronic components, automobile, pharmaceuticals and agricultural seeds. A result of globalization, as well as interpersonal problems, it has allowed to deepen the gap between rich and poor between nations. Therefore, globalization in the future, it will be possible to provide a cause of regression to protectionism from the free trade principle. Thus, cooperation of collaboration between all stakeholders from experts from agriculture and industry areas in order to develop as an independent field by ranking up the Korean Agricultural Engineering with the world Agricultural Engineering.

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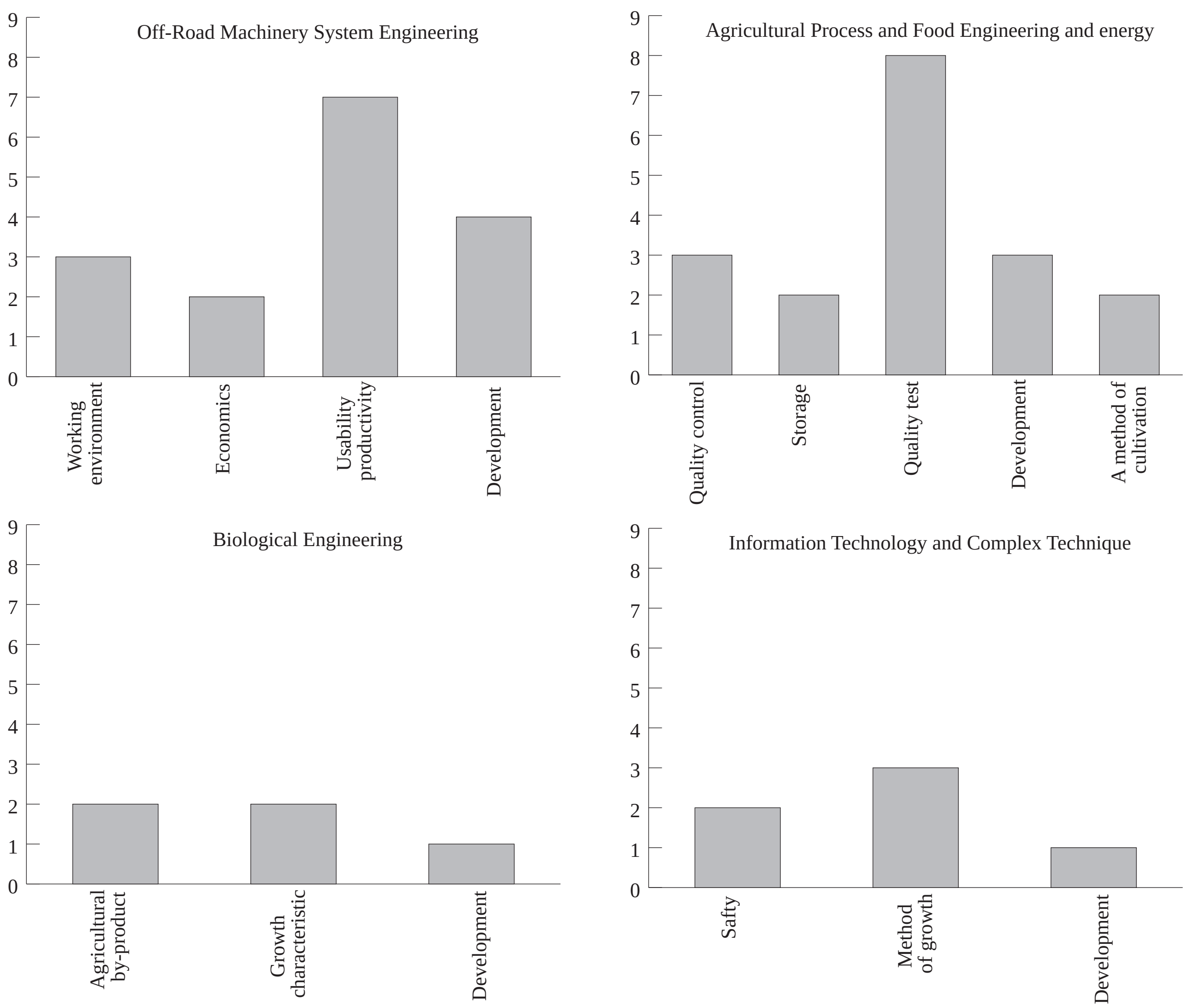

Fig. 4 KSME published papers of 5 research area categorized using some typical keywords

JAPAN

The Present State of Farm Machinery Industry in Japan

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Outlook of Agriculture

Trend of Agriculture

In 2013 agricultural total products was ¥4,881 billion, accounting for 1.0 % of GNP. The agricultural products imports was ¥5,442 billion in 2012, ¥6,137 billion in 2013, ¥6,320 billion in 2014. The agricultural products exports was ¥268 billion in 2012, ¥314 billion in 2013, ¥357 billion in 2014.

Japan depends on imports for large part of domestic consumption of feed cereals, soybean, wheat. Food self-sufficiency rate was 39 % by calorie base in 2013, 28 % for cereals, almost the same as preceding year.

Population mainly engaged in farming has been decreasing yet, 2.07 million in 2013, 3.3 % of total working population. The number of commercial farm households decreased to 1.41 million in 2014. Total arable land in Japan was 4.52 million ha in 2014.

Japanese have been getting to enjoy more a variety of food since 1970's. The production of rice, oranges, milk, eggs has exceeded domestic consumption. Under such circumstances, GATT New Round Agreement gave great impact to Japanese agriculture. In order to get world competitive power, saving of production cost became the urgent issue. Other big issues in Japanese agriculture are, to have enough people engaged in farm work to maintain stable agriculture, production of high quality and safe products to meet the needs of consumers, and preservation of natural environment in rural areas.

In July 1999, Japanese government enacted the New Agricultural Stable Law, which aims to assure constant food supply by raising domestic production, to encourage multi-functions of agriculture, to have sustainable development of agriculture and to promote the development of rural areas. In the "New Basic Plan for Food, Agriculture and rural Areas" established in 2010, the government set the target for food self-sufficiency ratio to 50 % on calorie basis, 70 % on productive value basis by 2020. "Rice and Vegetable Farming Management Stabilization Program" started in 2007 to

Table 1 Major farm machinery on farm (Unit: thousand)

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Grain reaper	Combine	Rice dryer
1970	3,269	183	32	2,178	261	45	1,227
1975	3,426	501	740	2,607	1,327	344	1,497
1980	2,752	1,471	1,746	2,139	1,619	884	1,524
1985	2,579	1,854	1,993	2,151	1,518	1,109	1,473
1990	2,185	2,142	1,983	1,871	1,298	1,215	1,282
1995	1,344	2,123	1,650	1,714	836	1,120	1,052
2000	1,048	2,028	1,433	1,269	583	1,042	861
2005		1,943	1,244	1,206		991	
2010		1,678	1,026			799	

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries" by the Ministry of Agriculture, Forestry and Fisheries.

Table 2 Shipment of major farm machinery (Unit: number)

	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Grain reaper	Combine	Rice dryer
2008	142,330	48,911	37,868	140,375	3,432	23,188	26,160
2009	151,445	45,439	29,327	118,453	2,660	21,922	21,191
2010	147,866	45,316	30,506	121,924	2,782	21,460	18,171
2011	136,748	45,035	27,671	119,514	2,816	20,809	16,402
2012	129,640	46,823	28,427	118,760	2,483	20,551	21,125
2013	129,357	51,778	29,710	112,837	2,277	24,839	19,526
2014	122,145	43,847	27,142	106,462	1,756	21,096	16,268
2015	118,137	48,440	23,377	100,925	1,458	17,125	13,560

Source: "Survey of Shipment of Agricultural Machinery" by the Ministry of Agriculture, Forestry and Fisheries. 2013-15; JFMMA statistics

Table 3 Yearly plrduction of farm machinery (Unit: number, million yen)

Year	Total		Walking type tractor		Riding type tractor		Rice transplanter		Power sprayer		Running type sprayer	
		For domestic	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2006	494,990	312,099	166,856	21,418	203,262	256,745	50,562	46,881	164,722	9,083	3,247	5,456
2007	459,223	275,117	196,000	24,208	190,908	238,334	43,050	43,188	161,513	9,172	2,803	5,053
2008	496,404	282,098	188,336	23,520	211,242	261,531	48,098	51,619	170,790	9,676	2,836	5,408
2009	429,116	291,321	181,776	22,560	140,095	202,607	43,033	44,992	149,333	8,638	2,505	4,918
2010	429,137	265,449	193,966	24,171	158,029	213,246	42,996	42,336	135,464	6,479	2,392	4,621
2011	405,331	252,894	160,292	20,387	149,116	213,186	46,165	41,142	135,306	7,050	2,473	4,578
2012	425,028	272,865	164,198	20,889	151,750	224,263	33,486	37,785	127,469	6,396	2,568	4,889
2013	477,833	322,165	145,799	18,485	152,962	256,509	33,633	40,458	144,128	6,785	3,120	5,561
2014	476,940	303,084	146,132	19,165	148,226	261,697	32,882	41,447	126,950	5,955	3,001	6,259
2015	436,342	255,572	113,697	15,289	151,312	257,589	22,662	30,525	122,565	5,576	2,988	6,004

Year	Grain reaper		Bush cutter		Combine		Rice husker		Grain dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2006	5,097	1,392	973,807	19,153	33,049	89,779	21,372	7,561	25,282	20,990	25,188	1,394
2007	3,217	910	1,233,084	25,060	25,969	74,049	17,585	6,660	21,205	17,341	23,475	1,389
2008	3,100	910	1,270,111	26,310	26,033	77,913	18,216	7,144	21,006	18,507	17,613	1,029
2009	3,159	960	1,337,549	23,972	25,073	79,151	18,613	7,618	22,273	22,012	18,882	1,109
2010	2,938	865	1,494,160	25,668	23,636	76,844	15,457	6,271	17,871	17,374	17,333	983
2011	2,618	779	1,234,049	22,125	20,847	64,892	13,898	5,613	15,581	14,775	17,861	969
2012	2,792	844	1,098,366	17,340	23,108	75,471	15,313	6,564	18,658	18,008	17,254	1,253
2013	2,141	844	1,174,835	17,371	24,403	89,107	16,800	7,453	19,927	20,542	15,628	1,106
2014	1,910	596	1,215,548	18,298	23,786	85,894	14,195	6,390	16,843	16,736	14,445	973
2015	1,092	341	1,238,873	19,252	18,927	71,221	11,326	5,259	13,125	13,025	12,012	791

Source: JFMMA statistics

Table 4 Farm equipment distributor and sales value (Unit: million yen)

Year	No. of retailers (1)	Employees	Annual sales value (2)	Inventory	Square meters of shop, m^2	Annual sales value (2)/(1)
1985.6	9,142	43,921	946,507	144,837	985,453	103.5
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5
1991.6	9,480	45,705	1,158,924	170,104	984,700	122.2
1994.6	8,838	43,112	1,128,087	166,298	978,788	127.6
1997.6	8,820	45,090	1,265,902	170,350	901,851	143.5
2002.6	8,123	40,441	979,066	145,725	982,529	120.5
2007.6	7,429	35,275	853,938	111,598	888,507	114.9
2012.6	5,335	25,924	583,214	72,958	840,693	109.3

Source: Ministry of Economy, Trade and Industry

Table 5 Handling of Farm Equipment by Agricultural Cooperative Association (2013 Business Year) Unit: Million yen

Year/Prefecture	Total number of coops surveyed	Value of current supplies procured	Of which purchased through coop channel	Value of current supplies handled	Purchasing profit
2006	844	210,181	144,140	239,119	28,479
2007	818	199,934	138,510	227,754	27,358
2008	770	205,654	141,100	141,100	141,100
2009	741	210,102	210,102	210,102	210,102
2010	725	196,108	136,267	224,571	26,273
2011	723	198,987	136,941	225,618	26,332
2012	717	206,028	142,160	232,977	26,793
2013	712	260,384	183,045	292,955	30,805

Source:"Stastics on Agricultural Cooperatives -2013 business year" by the Ministry of Agriculture, Forestry & Fisheries strengthen domestic agriculture and improve self-sufficiency ratio. In this program conventional measures to encourage production individual commodities such as wheat, barley, and soybean are replaced by new farm management stabilization programs targeted at principal farmers. In 2013, because the Japanese Government placed the importance on ggressive Agriculture" as the focus of agricultural growth strategy, the policy has turned in other direction. The policy consists of 4 strategies:

Table 6 Export of farm equipment 2015 (Unit: CIF million yen)

	Unit	Value	Ratio	Major destinations
2008		287,263		
2009		187,221		
2010		213,202		
2011		192,047		
2012		188,712		
2013		207,601		
2014		240,720		USA, KOR, FRA
2015		251,648		
Seeder, planter	6,864	7,268	2.9	KOR, TWN
Power tiller	42,054	2,401	1.0	USA, VNM, BEL
Wheel tractor	111,370	173,922	69.1	USA
Power sprayer	35,063	1,527	0.6	CHN, KOR, USA
Lawn mower	31,188	9,768	3.9	FRA, GBR, DEU
Bush cutter	688,144	16,921	6.7	USA, FRA, ITA
Mower	37,392	1,372	0.5	FRA, KOR
Combine	3,034	6,718	2.7	KOR, TWN
Grain separator	607	1,108	0.4	KOR, USA
Chainsow	286,148	5,934	2.4	ITA, FRA, USA
Others		24,709	9.8	

Source: Ministry of Economy, Trade and Industry. Totaled by JFMMA

Table 7 Import of farm equipment 2015 (Unit: CIF million yen)

	Unit	Value	Ratio	Major destinations
2008		41,294		
2009		36,723		
2010		42,323		
2011		43,403		
2012		47,202		
2013		69,029		
2014		78,681		CHN, DEU, FRA
2015		61,680		
Wheel tractor	1,554	11,988	19.4	GBR, FRA, DEU
Pest control machine		2,973	4.8	CHN
Lawn mower	427,882	9,593	15.6	USA, CHN, THA
Mower	96,691	1,271	2.1	CHN, USA
Hay making machine	755	922	1.5	FRA, DEU, NLD
Bayler	510	1,988	3.2	DEU, FRA, POL
Combine	51	973	1.6	DEU, BEL
Chainsow	109,225	1,405	2.3	CHN, SWE
Others		30,567	49.6	

Source: Ministry of Economy, Trade and Industry. Totaled by JFMMA

1. Energizing the agriculture, forestry and fisheries industry and rural areas: Doubling agricultural and farm village income
2. Doubling exports: Increasing exports of agricultural products and other food items to JPY1 trillion by 2020
3. Sixth industrialization of the agriculture, forestry and fisheries industry: expanding "ixth industry" dimension market from the current JPY1 trillion to JPY10 trillion by 2020
4. Accumulation of farmland: Accumulating farmland to increase productivity, strengthening and utilizing the intermediary organization for farmland (Farmland Accumulation Banks)

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. Now rice production is almost mechanized from planting to harvesting. In 2010, average working hours on 10 a paddy field reduced to 26 hours from 118 hours in 1970. In recent years farm machines for rice crop is developed to be larger-sized, higher-efficiency and more commonly used. In addition, farm machinery for field crops and live stock farming is being developed and improved, which had been lagged behind so far.

Government has been working on Agricultural Mechanization Promotion with three pillars "Development and Practical Application of High Performance Farm Machinery", "Reduction of Production Material Cost" and "Farm Safety", and seeking for more enhancements. As for high performance farm machinery, a guideline named "Basic Guidance for Research and Development, Practical Application and Introduction of High Performance Farm Machinery" was set up in May 2008.

Based on this guideline, further powers saving of farm work, decrease of environmental burden, and efficient use of agricultural product material have been encouraged.

In addition, regarding the cut down of agricultural production material, in 1995 Ministry of Agriculture, Forestry and Fisheries made a committee which studied method to reduce cost of farm product materials like farm machines. Those farm product materials are major parts of farming cost. Low cost machinery with limited functions has been increasing.

Following are the numbers of farm machines in farm household of Feb. 1, 2010: riding tractor reached 1,677,600 units; rice transplanter 1,025,800; head feed combine 799,300.

Shipments of major farm machinery in the domestic market in 2014 are as follows: riding tractor 43,847 units (under 20 PS were 7,669; 20-30 PS 17,544; 30-50 PS 10,639; over 50 PS 7,995); walking tractor 122,145; rice transplanter 27,142; combine head feed types 20,435; standard types were 1,661; grain dryer 16,268; huller 13,916.

Plans for Farm Mechanization

2014 government budget for farm mechanization was used for;

1. In the “Basic Policy”, out of the high-performance agricultural machinery 12 models that had been the subject of testing and research, based on such that the test study of the 5 models has been completed, as the subject of testing and research a new model in 2014 fiscal year, the new add 4 models are “high-speed ridge standing seed drill machine for soybean”, “high-performance, high durability combine”, “small type mower for orchards stem circumference”, “high mobility levee mower”
2. Reducing the amount of costs for agricultural machinery: Promoting efficient usage of machines. Introducing direct seeding technology and generalizing the dispersion of cropping seasons. Using various ways to introduce agricultural machineries such as rental method.
3. Measures for safe farming: Informing about machineries equipped with safe and secure features.
4. Measures for reduction of environmental burdens: Promoting environmentally-sound agriculture. Researching and developing power saving agricultural machineries, and promoting the usage of biodiesel fuels.

Government Budget for Agriculture, Forestry and Fisheries

FY 2015 Government Budget for Agriculture, Forestry and Fisheries of Japan is 2 trillion and 654.1 billion yen, 14.1 % increase compared with the previous year, in which 803.8 billion to public works expenditure (22.2 % increase) and 1 trillion and 850.3 billion to non-public works expenditure (10.9 % increase). Breakdown of public works expenditure is; 784.6 billion to general public works (22.9 % increase) and 19.3 billion to disaster restoration works (± 0 %). Main points of FY 2015 budget is as follows.

Promoting Structural Improvement of Agriculture by Accumulation and Concentration of Farmland to Successors

1. accumulation and concentration of farmland to successors by the Organization for Temporary Farmland Management (OTFM): full-scale operation of OTFM, promoting large-scale farmland compartmentalization, subsidy for urgent countermeasures against abandoned cultivated lands
2. cultivating and securing various successors: new comers in agriculture, comprehensive support project for farm management successors, support project for successors developing new farm management

Steady Enforcement of New Program to Stabilize Farmers` Incom

direct payment of subsidy for upland crops, direct payment of subsidy for paddy field utilization

[Related measures] livestock machinery lease project to expand the use of feed rice, promoting establishment of mixed feed supply system, direct payment of subsidy for rice, impact mitigation measure for income reduction, examination and research cost of income insurance regime

Making a Base for Strong Agriculture, Forestry and Fisheries Industry

1. maintenance of infrastructure for agriculture, forestry and fisheries industry: improvement of agriculture and rural area; forest maintenance project; forestry conservancy program; subsidy for improvement of rural areas
2. maintenance of facilities for agriculture, forestry and fisheries: subsidy for establishing strong agriculture; subsidy to make a base of revival of forest and forestry; special urgent measures establishing the facilities to prepare for natural disaster
3. promoting structural reform in production area: support project to accelerate next generation greenhouse farming; strengthening the base for processing and commercial vegetables production; measures for production and supply of domestic flowers; upgrading of greengrocery distribution system; experimental establishment of advanced model of agriculture in joint undertaking by agriculture and business communities; volunteers matching support project

Raising Competitiveness of Livestock and Dairy Production

1. growth of livestock and dairy

farming: development of high profit livestock production system; measures to raise profitability in livestock farming; comprehensive measures for livestock farming environment
2. raising productivity in livestock and dairy farming: urgent measures project to raise livestock and dairy production; research and development to support production of Japanese beef (wagyu)
3. raising production of the self-support feed: comprehensive measure project to increase feed production; dairy farming with feed production support project; livestock machinery lease project to expand the use of feed rice; promoting the development of mixed feed supply system; infrastructure development project for grassland livestock farming; research and development to support expansion of self-support feed production
4. feed production technology development to expand the demand for domestic livestock products: technology development support project to expand the market for domestic livestock products
5. stability of livestock and dairy farming management: measures to stabilize livestock and dairy farming management

Promoting the Effort to Make Additional Value of Agricultural, Forest and Fishery Products and Food
1. promoting sixth industrialization: positive use of agriculture, forestry and fishery industrial growth fund; sixth industrialization support measures
2. promoting cooperation among different business categories like medical, welfare, food, agriculture; promoting the products with some advantage: promoting the cooperation among medical, welfare, food, agriculture; support project encouraging rural area to adopt new varieties and technologies; support project establishing local production area of special crops like medicinal crops; promoting "accumulation of knowledge" utilizing private sector vitality; development and distribution of innovative technology like advanced robot; promoting protection and utilization of intellectual properties

Appealing Fascinating Japanese Food and its Food Culture to the World to Promote the Export

the project for appealing fascinating Japanese food and food culture; promoting preservation and succession of Japanese food "washoku" promoting food education at production and distribution sites of agricultural, forestry and fisheries products; strengthening execution of export strategy; comprehensive export support project; promoting global food value chain strategy; promoting marketing plan for international agricultural products; facilities coping with export; maintenance of animal and plant epidemics prevention system to promote export

Measures to Promote Production by Each Item

action to stabilize vegetable price; measure to support production of fruits and tea; support program for sugar crops farmers; livestock farm management stabilizing measure

Ensuring Food Safety and Trust of Consumers

subsidy for consumption and safety measures; comprehensive measures for clean animal husbandary; promoting proper food labelling and ensuring strict compliance with relevant rules; comprehensive measures to reduce food loss

Revitalizing Rural Areas in Declining Population
1. enforcement of Japanese-style direct payment: subsidy for multiple operations; subsidy for hilly and mountainous areas; subsidy for environmentally friendly agriculture
2. establishing net-work system of regions in cooperation with other Ministries and promoting settlement: rural area revitalization support project; subsidy for development of mountain villages
3. symbiosis and convection of urban and rural areas: subsidy for comprehensive measures to promote symbiosis and convection of urban and rural areas; subsidy for rural areas revitalization support project; revival of beautiful rural area support project; agriculture in urban area promoting project
4. introduction of renewable energy: promotion of renewable energy generation using rural resources to invigorate rural areas; promotion of industrialization using local biomass; promoting utilization of woody biomass
5. promoting the plan to prevent the damage by wild animals: subsidy for comprehensive measures for wild animals damage prevention; project to develop intensive technology for wild animals damage prevention

Industrial Growth of Forestry, Conservation of Global Environment through Absorption of CO_2

comprehensive project to generate new demand for wood; measures to encourage multifunctional role of forest and mountainous area; developing human resources engaged in forestry; subsidy for development of mountainous areas; forest maintenance project; erosion control project; subsidy for recovery of forest and forestry

Movement of Farm Machinery Industry

Total shipment value of Japanese farm machinery has been declining since the peak of the year 1985 (754.9 billion yen) and it was 474.0 billion yen in 2015. In addition, domestic sales of 2015 were 284.4 billion yen, which was almost half of the past record in 1976. Those are, considerable decline in the number of farm households and farmers exceeding the farm land decreasing, aging of farmers, decline in the demand for rice and production adjustment by the government. Aging farmers with no successors and small scale farmers have more tendencies to leave their farm works to contractors. The demand for agricultural machines is shifting to larger size, though total demand is going down.

In 2015 domestic farm machinery market continued declining partly in reaction of rush demand prior to consumption tax increase in 2014. The market was expected to restore reflecting the demand before the change of gas emission regulations and also being effected by Agriseed business(for rice farmer) of National Federation of Agricultural Cooperative Associations. However, in autumn, after TPP was agreed in principle the concerns about future demand re-stalled farm machinery market, that resulted in the decrease of shipments of most farm machines except tractors. Meanwhile the export of fam machinery increased due to weak Yen and stable demand in North American market.

Trend of Farm Machinery Production

Farm machinery production in 2015 amounted to ¥436.3 billion (91.5 % of the preceding year) by JFMMA (Japan Farm Machinery Manufacture’s Association) statistics. The production for domestic market was 255.6 billion yen, 84.3 % of the preceding year. The production for export was 180.8 billion yen, 104.0 % of the preceding year.

Production of the major farm machinery is as follows: Riding type tractor 151,312 units increased by 2.1 % than the preceding year. By horse power (wheel type), those under 20 PS amounted to 12,777 units, 20-30 PS 51,251 units, 30-50 PS 39,057 units, over 50 PS 48,227 units. About 70 % of the total production is for export. The production of walking tractor amounted to 113,697 units, which showed a decrease of 22.2 % than the preceding year.

The production of combine, which is next to the riding tractor in production amount, is 18,927 units (a decrease of 20.4 % than the preceding year). The most popular type is with harvesting width of one meter head feed.

Following are the production of other types of farm machinery; rice transplanter amounted to 22,662 units (a decrease of 31.1 % than the preceding year), grain dryer 13,125 units (a decrease of 22.1 %), huller 11,326 units (a decrease of 20.2 %), bush clutter 1,238,873 units (an increase of 1.9 %), power pest-controller 164,946 units (a decrease of 9.3 %), fodder cutter 16,351 units (a decrease of 23.5 %), rice pearling machine 12,012 units (a decrease of 16.8 %), rice sorter 10,770 units (a decrease of 20.3 %), farm carrier 13,277 units (a decrease of 6.2 %).

Trend of Farm Machinery Market

In Japan distribution systems for farm machinery is roughly divided into two major channels; the farm machinery dealers and Agricultural Cooperatives Association. As of June 2012, there were about 5,300 retail shops and about 26,000 employees, and the annual sales amounted to ¥583 billion (¥854 billion in 2007).

According to the governmental survey by Ministry of Agriculture, Forestry and Fisheries, the total sales of farm machinery by Agricultural Cooperative Association was ¥292.0 billion in 2013 (¥233.0 billion in 2012). The number of Agricultural Cooperative was 712 in 2013. Average sales amount per cooperative was ¥411 million in 2013.

About half of private dealers are small firms which less than 5 employees. In a long time view, with less demand for agricultural machines expected in future, improvement of management structure will be needed.

Export and Import of Farm Machinery

Export

In 2015 the export of farm machinery amounted to ¥251.6 billion, which showed an increase of 4.5 % over the preceding year.

By the export destination, ¥122.2 billion for North America (an increase of 17.6 %), ¥49.9 billion for Europe (a decrease of 13.2 %), ¥61.6 billion for Asia (an increase of 0.1 %).

By the types of machines, tractor (excluding used tractor); 111,370 units were exported in 2015, it amounted to ¥173.9 billion. Seeing by horse power, those under 30 PS amounted to 41,386 units, those from 30 to 50 PS 26,397 units, those over 50 PS 43,587 units.

FYI, used tractor; 60,439 units were exported in 2015.Major farm machinery, next to tractor, is bush cutter. The total exports were 688,144 units, ¥16.9 billion. The exports of other farm machinery are as follows; walking tractor 42,054 units; power sprayer 35,063 units; lawn mower 31,188, units; chain saw 286,148 units, etc.

Import

In 2015 the imports of farm machinery amounted to ¥61.7 billion, which means a decrease of 21.6 % over the preceding year.

Major imported farm machines: tractor 1,554 units (those more than 70 PS were 1,452 units of all the tractor); chain saw 109,225 units, lawn mower 427,882 units, fertilizer distributor 12,980 units. Tractors 376 units were imported from France, 360 units from UK, 508 units from UK, and 347 units from Italy.

Trend of Research and Experiment

National Agriculture and Food Research Organization selected following four kinds of machines for Agricultural Machines Urgent Development Project in 2015

1. high speed and high precision multifunctional seeder
2. rice husk burner
3. high speed spot fertilizer applicator for vegetable
4. high performance adjuster for leaf vegetable

Research achievements by National Agriculture and Food Research Organization in 2014 are;

- high precision straight line operation assisting device attachable to tractor
- remote control system for agricultural vehicles like robot tractors
- high efficiency weeding device for paddy field equipped on three wheel riding cultivator by mid-mount method
- high efficiency rice seed disinfector with sequent operation from disinfection to cooling and drying
- tea covering material covering and uncovering attachment equipped on riding type tea piking machine
- light and compact arm raising assisting device usable with no power
- development of inner structure of head-feeding combine to shorten cleaning time of inner part
- microorganism environment control type deodorizing device supporting composting device
- safety requirements for small agricultural machines fueled by cassette bomb butane
- dust invasion prevention device for small scale hydraulic power generation utilizing water channel for agriculture

■■

Latest Activities for Overseas Market (JAMMA)

by
Japan Agricultural Machinery Manufacturers Association (JAMMA)

JAMMA is actively supporting member companies to participate in exhibitions held in Asian countries to promote expanding their market in Asia. The JAMMA participated in some exhibitions in Asia and set up “Japan Booth” as detailed below.

Eima Agrimach INDIA 2013 (December 5-7, 2013)

Five companies (Kubota Ltd., Keibunsha-Seisakujo Co.,Ltd., Taiyo Co.,Ltd., Cjhikusui-Canycom Co.,Ltd., Maruyama-Seisakujo Co.,Ltd.) participated in the exhibition. The number of visitors to “Japan Booth” was about 12,000 in total. Eima Agrimach INDIA is one of international agricultural machinery exhibitions fully supported by UNACOMA, Italian Agricultural Machinery Manufacturers Federation, being held every two years at Indian Institute of Agriculture in New Delhi.

Logo mark “JAPAN BRAND” authorized by Japanese government was everywhere in the booth to appeal excellent quality, performance and design of Japanese products. Besides displaying the products, business talk space was set to promote business matching and marketing activities of exhibitors. Many people from agricultural machinery business visited the booth, which resulted in successful business matchings.

The exhibition was a good opportunity to develop the market in India.

AGROVIET 2014 (November 14-17, 2014)

Six companies (Kaneko-Noki Co.,Ltd. Kanto-Noki Co.,Ltd. Keibunnsha-Seisakujo Co.,Ltd. Sasaki Corporation. Marumasu-Kikai Co.,Ltd. Maruyama-Seisakujo Co.,Ltd.) participated in the exhibition. The number of visitors to “Japan Booth” was about 3.350 in total. At AGROVIET 2014 main exhibitions are domestic agricultural products. To see various agricultural machines from Japan, many people visited “”Japan Booth” including the Minister of Agriculture and Rural Development, media people like TV, newspapers. Most people are very interested in Japanese machines, but the problem is that there is no leading importer and that there are few agricultural machinery dealers in Vietnam.

VIAF 2015 (December 2-6, 2015)

Eight companies (Kaneko-Noki Co.,Ltd. Kanryu-Kogyo Co.,Ltd. Keibunsha-Seisakujo Co.,Ltd. Shizuoka-Seiki Co.,Ltd. Marumasu-Seiki Co.,Ltd. Daishin Industries Ltd. Yamabiko Corporation) will participate in the exhibition in “Japan Booth”. Business matching with import agency and dealers will be made at business talk space in the exhibition site.

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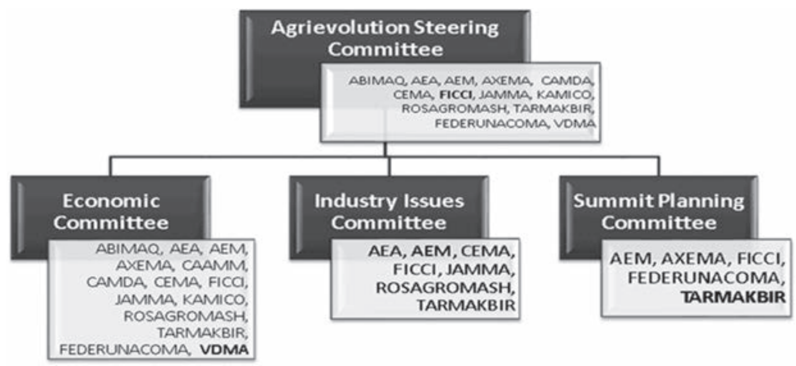

News

Electronic version of AMA journal is now available at "Amazon kindle store"

JAPAN

Global Operations of Japanese Agricultural Machinery Manufacturers

by
Editorial Department, AMA

Most of Japanese agricultural machinery manufacturers are aggressively working on global market and export their products to overseas countries. The situation of their overseas activities is reported below.

Name	Products	Annual sales, billion (¥)	Overseas operations
AGRITECNO YAZAKI CO.,LTD. http://www.agritecno.co.jp/	seeder, various kinds of implements	1.7	2001: contract company Korea Agritecno Agency (KAA) established 2004: contract company China Agritecno Agency (CAA) established 2009: Korea Agritecno Yazaki Co.,Ltd. established, Shanghai Yazaki Trading Co., Ltd. established
ASABA MANUFACTURING INC. www.asaba-mfg.com/	sprayer and accessories	5.0	1998: Asaba Manufacturing Phils,Inc. launched 2002: Asaba Components Phils,Inc. launched 2009: Asaba Manufacturing Phils,Inc & Asaba Components Phils,Inc. incorporated. ASABA has cooperating companies in China, Korea and other countries to expand oversea marketing.
ATEX CO.,LTD. http://www.atexnet.co.jp/index2.html	bush cutter, compost spreader, transporter, lifter	4.6	2007: 江陰四国机械有限公司 established in Wuxi, Jiangsu, China, for manufacturing agricultural machinery and other related components. Current main products are units for combine cutter for Iseki Agricultural Machinery (Changzhou) Co.,Ltd. and grain sorting lifter for ATEX CO.,LTD. (Japan) and related components.
BUNMEI-NOKI CO., LTD. http://www.bunmei.co.jp/	sugarcane harvester, potato harvester and etc.	0.9	1993: exported test machine of sugarcane harvester and leaf cutter to Thailand and Indonesia 2004: license contract established on sugarcane harvester HC-50 with Samart Kaset-Yon Ltd Part in Thailand
CANYCOM INC. http://www.canycom.jp/	carriers, brush cutters, electric vehicles	5.0	The company has actively exported the products, to USA and Oceania for over 15 years, to European countries for a long time, especially from 1980's to Switzerland. Overseas marketing bases are in Switzerland and Philippines. Associated companies: CHIKUSUI AGRICULTURE MACHINES (CHANGZHOU) CO., LTD, CANYCOM USA, CANYCOM KOREA, INC. The company is intensively trying to expand the market in Africa.
DAISHIN INDUSTRIES LTD. http://www.daishin-japan.co.jp/	generator, pump, mini tiller, brush cutter	2.8	1995: KOREA DAISHIN CO. LTD. established. 1999: DAISHIN Europe liaison office established. 2002: DALIAN DAISHIN INDUSTRIES LTD. established. 2005: SHANGHAI DAISHIN INDUSTRIES LTD. established. DAISHIN has customers in more than 100 countries. DAISHIN's HG Hard Gear series of generators, pumps, and brush cutters are distributed to all over the world. Overseas sales offices and production centers are now located in Korea, Dalian, and Shanghai in China. Moreover DAISHIN is developing further sales network in the United States. DAISHIN's overseas operations are steadily on the increase.
DELICA CO.,LTD. http://www.delica-kk.co.jp/en/	manure spreader, forage harvester, manure carrier	2.6	2008: THAI DELICA CO.,LTD. established 2015: new factory of THAI DELICA CO.,LTD was built
FUJII CORPORATION CO.,LTD. www.e-fujii.co.jp/	snow blower, grass mower, boom lift	3.1	1980: launched to export snow blower to Switzerland, both on OEM basis and as Fujii's brand products 1990's: exported Fujii's brand snow blower 2000's: started to export directly, not through trading company to EU nations and started to export to Taiwan 2013: export to 14 countries achieved Overseas sales is currently about 15 % of total sales. The company sets a target to raise overseas sales to 40 %

Name	Products	Annual sales, billion (¥)	Overseas operations
FUJI HEAVY INDUSTRIES LTD. http://www.fhi.co.jp/english/		29 (industrial machinery, overseas sales: 80 %)	Besides main business of manufacturing of passengers' cars, the company is manufacturing industrial products, agricultural machinery, construction machinery, engines and related components. Industrial engine, famous as yellow color "Robin" brand, has been very popular all over the world since its first "M6 type" was released in 1951. Currently more than 2000 kinds of "SUBARU industrial engine" are supplied and exported to more than 100 countries, in the 4th place in the world share of industrial engine supply. Total 30 million units of industrial engine production was achieved in 2012. Engines for snow mobile have been exported to Polaris Industries Inc., The U.S. for 47 years since 1968. Major overseas business sites for industrial products are: -Subaru Industrial Power Products(The U.S.)/ -Robin Europe GmbH (Germany)/ -Subaru Industrial Power Products of China Co., Ltd. (China)/ -Changzhou Fuji Changchai Robin Gasoline Engine Co, Ltd(Chian)/ -Fuji Heavy Industries(Singapore) Pte.Ltd.
HASQVARNA ZENOAH CO.,LTD. www.zenoah.co.jp/	trimmers, bush cutter, chainsaw, blower, pest control machine	492.6 (whole Hasqvarna group)	1910: established as Tokyo Gas Electric Industry Co.,Ltd. 1973: company name changed to Zenoah Co.,Ltd. 1979: company name changed to Komatsu Zenoah Co.,Ltd. 2007: company name changed to Hasqvarna Zenoah Co.,Ltd. Overseas operations: 1973: established Komatsu Zenoah America Inc. 1989: established 台松機械工業股分有限公司 in Taiwan 1999: Komatsu Zenoah Factory in China launched
HONDA MOTOR CO.,LTD. www.honda.co.jp/	two-wheel vehicles, four wheel vehicles, engine, tiller, pump, generator, snow thrower, lawn mower	power products: 314.8	Number of units sold in areas; Japan: 338,000, North America: 2,698,000, Europe: 1,093,000, Asia: 469,000, others: 1,403,000 Major overseas manufacturing sites for power products are; Honda Power Equipment Mfg., Inc. (The U.S.), Moto Honda Da Amazonia Ltda. (Brazil), Honda France Manufacturing S.A.S. (France), Montesa Honda, S.A. (Sociedad Unipersonal) (Spain), Honda-Mindong Generator Co.,Ltd. (China), Jialing-Honda Motors Co., Ltd. (China), Thai Honda Manufacturing Co., Ltd. (Thailand), Honda Siel Power Product Ltd. (India), P.T. Honda Power Products Indonesia (Indonesia), Honda Australia M. & P.E. Pty Ltd. (Australia), There are many other manufacturing sites over the world.
IHI CORPORAATION https://www.ihi.co.jp/	In IHI group, IHI Star Co.,Ltd. is for production and sales of implements for agricultural machines and IHI Shibaura Machinery Corporation is for production and sales of tractors. In June 2015 IHI Corporation concluded the contract on joint venture business of agricultural machinery with Broad Group, one of major companies in Liaoning, China and established joint venture company, Broad IHI Agricultural Machinery (Shenyang) Co.,Ltd. end July for production and sales of corn picker and tractors in China. Corn picker co-developed by IHI Star and IHI Shibaura for Chinese market and some type of agricultural tractors for Chinese market manufactured by IHI Shibaura will be produced in the new factory and sold in China.		
IHI SHIBAURA MACHINERY CORPORATION www.ihi-shibaura.com/	engine, tractor, mowers and etc.	27.3	1985: Long term engine supply agreement with Perkins Engines Ltd in England concluded. 1990: Out front Mower achieved gold title at SIMA trade show. 1994: 200 thousand units tractors production for Ford achieved 1995: Perkins Shibaura Engines Limited (PSEL) founded as a joint venture with Perkins Group Limited in the UK. 2004: Perkins Shibaura Engines LLC (PSEA) founded as a joint venture with Perkins Group Limited in the USA. 2005: PSEL received The Queen's Award. 2006: 400 thousand units tractors production for CNH achieved 2008: Perkins Shibaura Engines (Wuxi) Company Limited (PSEW) founded in China. 2011: Ishikawajima Shibaura Machinery Changsyu Co., Ltd., established in China. Products of IHI Shibaura are exported to over 40 countries in Asia, Europe and Oceania, and receives high reputation for their high quality and reliability.
INADA INC. www.inadainc.co.jp/	crane, battery, carrier for agriculture	1.6	1990: first overseas manufacturing site established in Pusan, South Korea 1998: started to export agricultural carrier to Europe 2002: Shanghai office established 2006: Cambodia office established The company has branch offices in Seoul, Shanghai, Dakka

Name	Products	Annual sales, billion (¥)	Overseas operations
IHI STAR MACHINERY CORPORATION www.ihi-star.com/	fertilizer spreader, tractor implements, forage harvester, round baler		2002: founded joint venture company, Shanghai Star Modern Agriculture Equipment Co.,Ltd. (Shanghai Star)
	Mr. Aoyagi (President) said, "Domestic market seems not to expand, even to shrink, so we are going to work more on overseas market, in China, South East Asia and Middle Asia. We have not achieved the ¥ 10 billion sales in 90 years history. We wish to achieve ¥ 5 billion sales in overseas market, same as current domestic sales , that leads to total ¥ 10 billion sales. Our target is over ¥ 10 billion" in the interview by our Agricultral Machinery News, Weekly in August 2015.		
ISEKI & CO.,LTD. www.iseki.co.jp/	tractors, harvesters, transplanters and other wide range of products and services.	157.4 (domestic: 131.9 (83.3 %), overseas: 25.5 (16.2 %)) North America: 11.1, Europe: 8.2, China: 1.7, other Asian countries: 1.4, Oceania: 0.7 Parts and others amounted: 2.4	Tractors sales in North America: 109 (thousand units) -compact (under 40 hp) tractors, 61 (thousand units) -utility (PTO 40-100 hp) tractors in 2014 1971: established N.V. ISEKI EUROPE S.A. in Brussel, Belgium 2003: established Iseki Agricultural Machinery (Changzhou) Co.,Ltd. in Jiangsu, China 2011: established Dongfeng Iseki Agricultural machinery Co.,Ltd. in Hubei, China 2012: established PT. ISEKI INDONESIA in Indonesia 2013: established ISEKI SALES(THAILAND)CO. Ltd. in Thailand 2014: Dongfeng Iseki and Iseki Changzhou were consolidated to new company Dongfeng Iseki Agricultural Machinery Co.,Ltd. 2014: obtaining 100 % stock of YVAN BEAL, a distributor of Iseki products since 1967, and made it subsidiary of Iseki in France 2014: strengthened the joint operation with N.V. ISEKI EUROPE S.A. in Belgium and ISEKI - MASCHINEN GMBH DEUTSCHLAND in Germany
JONISHI CO.,LTD. www.jonishi.co.jp/	tractor implements, fertilizer spreader, attachments for tractor and tiller	1.9	Established Jonishi Machinery Manufacturing (Shengyang) Co.,Ltd. in Shengyang, China in 2007
KATAKURA MACHINERY INDUSTRIES CO.,LTD. www.katakurakiki.co.jp/	cultivator, transplanter, working carriage, cultivator attachments	0.7	On the way to develop the market in Vietnam and Korea. 2014: exhibited soybean sheller and vegetable transplanter at KIEMSTA 2014 and made demonstration in Korea
KAWASAKI KIKO CO.,LTD. www.kawasaki-kiko.co.jp/	tea processing machines, tea field management equipment	4.6	The company has a group company Zhejiang Kawasaki Tea Machinery Co.,Ltd. in Zhejiang, China to manufacture tea picker, tea field management equipment for Chinese market
KAAZ CORPORATION	lawn mower, bush cutter, hedge trimmer, blower	5.0	Lawn mowers and bush cutters are highly reputed and sold well in overseas market. Started full operation for the development of overseas market in 1970's. Gear box for lawn mower occupies large share in overseas market.
KANEKO AGRICULTURAL MACHINERY CO.,LTD. www.kanekokk.co.jp/kanekokk/	grain dryer and related products	6.1	1997: established Kaneko Agricultural Machinery (Wuxi) Co.,Ltd. in Wuxi, China
KANTO NOKI CO.,LTD. www.kantonoki.com/	wide range of small agricultural machinery, walking type tiller	5.0	Late years intensively working on overseas market to export vegetable transplanter . Established branch office in Suzhou, China. Current sales in overseas market amounts 10% of company total sales.
KAWASHIMA CORPORATION kawashima-group.com/	transport vehicles, industrial implements		The company possesses about 200 patents both in Japan and foreign countries. Having intensively working on the export of the products for a long time and the export ratio as of 1992 was 12.5 % of total sales. (Exported to: France, Italy, Germany, Switzerland and others.) The company is receiving inquiries from many countries as well as The U.S. and European countries.
KEIBUNSHA SEISAKUJO CO.,LTD. www.keibuntech.com/	seeding machine, nursery cabinet	1.0	2007: established 快播農業機械有限公司 in Ningbo, China

Name	Products	Annual sales, billion (¥)	Overseas operations
KOSHIN LTD. www.koshin-ltd.jp/	pump, sprayer, cleaner	12.6	The products are popularly used in 160 countries in the world 1992: established manufacturing factory in Bangkok, Thailand 1993: established manufacturing factory in Zhongshan, Guangdong, China 2002: established Koshin Thailand Distribution Center 2003: new factory at Ningbo, Zhejiang , China launched operation 2005: established new factory in Thailand 2006: established KOSHIN THAILAND CO.,LTD. 2010: established motor factory in Ningbo, Zhejiang, China Group companies: KOSHIN AMERICA CORP. (Chicago), KOSHIN THAILAND CO.,LTD. (Bangkok), 工進利天泵 (寧波) 有限公司 (China), 寧波工進馬達有限公司 (China)
KUBOTA CORPORATION www.kubota.co.jp/	tractor, engine, harvester, transplanter and various related services.	1586.9 (domestic: ¥561.2 overseas: ¥1025.7*)	*North America: ¥443.8, Europe: ¥210.8, Asia except Japan: ¥306 Total sales amount of agricultural machines and engines: ¥1034.7 (domestic: ¥215.1, overseas: ¥819.5). Total sales amount of construction machines (domestic: ¥42.5, overseas: ¥137.8)
	One of the most leading agricultural machinery manufacturer in Japan manufacturing and marketing wide range of products KUBOTA established first overseas distributing company “KUBOTA Tractor Corporation (KTC)” in the United States in 1972 and launched developing North American market. Also established P.T.KUBOTA Indonesia for production and sales of diesel engine in 1972. In order to strengthen local production and enhance operations, KUBOTA established “KUBOTA Manufacturing of America (KMA)”, production and development site for small tractors, riding type mowers and utility vehicles in 1988. Also in 2004 “KUBOTA Industrial Equipment (KIE)”, production site for implements, was established. With the growth of American economy, sales of medium size tractors rapidly increased from late 1990’s. KUBOTA continued aggressively to supply tractors to American market. 1998: established KUBOTA Agricultural Machinery (Suzhou) Co.,Ltd (KAMS) in Suzhou, Jiangsu, China 2006: established new implement factory ”KUBOTA Industrial Equipment corporation (KIE)” in the United States 2009: established first Japanese tractor manufacturing factory in Thailand (SIAM KUBOTA Tractor) 2009: launched operation at agricultural machinery manufacturing factory at Ben Cat District, Binh Duong Province, Vietnam 2010: launched combine production in Thailand (SIAM KUBOTA Corporation), -established pump manufacturing and distributing company in China (KUBOTA SANLIAN Pump(ANHUI) Co.,Ltd.) 2012: made Kverneland subsidiary by M&A. established engine production site in China (Kubota Engine (WUXI) Co.,Ltd.) 2013: established medium tractors manufacturing factory at the site of KUBOTA Equipment Corporation(KIE) 2013: launched production of tractors at KUBOTA Agricultural Machinery (Suzhou) Co.,Ltd. (KAMS) in Suzhou, Jiangsu, China 2013: upgraded productivity of diesel engine at P.T.KUBOTA Indonesia 2014: established large tractors manufacturing company in France(KUBOTA Farm Machinery Europe S.A.S.) 2015: announced introduction of multifunctional tractors for India. The tractors are sold through distributing subsidiary in India(KUBOTA Agricultural Machinery India Pvt. Ltd.) KUBOTA plans to develop the market in emerging countries in Asia and Middle South America and sell about 16 thousand units in 2018. 2015: made up the plan to establish agricultural machinery assembling factory in the suburbs of Yangon, Myanmar		
KYOEISHA CO.,LTD. www.baroness.co.jp/	lawn mower, grass mower	6.5	1992: exported manual thresher to Korea, China, Taiwan, South East Asian countries 2001: established Shanghai Baroness Turf Machinery CO.,LTD. 2007: established Kyoeisha UK 2012: established Baroness (Shanghai) Machinery Manufacturing Co.,Ltd.
MARUYAMA MFG. CO. INC. www.maruyama.co.jp/	pesticide applicators, forestry equipment, brush cutter, other wide range of products	35.82 (Domestic: 27.81 overseas: 8.01)	2008: established MARUYAMA (THAILAND) CO.,LTD. 2008: established MARUYAMA(SHANGHAI) TRADING CO.,LTD. 2012: established business tie-up and joint venture company 山東秋田丸山機械股分有限公司 2015: established ASIAN MARUYAMA(THAILAND) CO.,LTD. The company intends to strengthen international competitiveness and expand overseas market. They plan to establish Belgium office to develop the market in Europe.
MIZUUCHI RUBBER INDUSTRIES CORPORATION www.mzr.co.jp/	rice hulling rubber roll, industrial rubber roll	1.6 (rice hulling rubber roll occupies half of sales)	The company exports the products to overseas countries 1973: licensing rubber roller technology to Indonesia 1984: established hulling rubber roll factory in Myanmar 1987: offered China technical assistance 1988: offered Vietnam technical assistance

Name	Products	Annual sales, billion (¥)	Overseas operations
MATSUI WALTERSCHEID LTD. www.m-w.co.jp/	PTO drive shaft		Affiliates: GKN Walterscheid GmbH 1980: started as joint venture company of GKN Waltersheid GmbH and MATSUI MFG. CO., LTD. 1995: started marketing in Asian countries 1998: participated in the agricultural machinery exhibition in Beijing, China 2002: participated in the EXPO in The U.S. 2003: participated in SIMA in France
MAKITA CORPORATION https://www.makita.co.jp/	electric tools	414.7* domestic: 67.7 (16 %),	*(Europe: ¥175.3, North America: ¥57.2, Asia: ¥39.64, Middle & South America: ¥30.3, Oceania: ¥23.8, Near and Middle East Asia: ¥20.9) Output: 27.61 (million units) in total, domestic: 2.84, Europe: 3.54, North America: 1.31, Asia: 18.67, Middle & South America: 1.25 1970: established Makita U.S.A. Inc (in the United States) After that, acquired air chain saw manufacturers in Brazil, The U.S., U.K. and Germany. Started production of power tools in China, Romania, Thailand and other countries.
MATSUMOTOKIKO CO.,LTD. matsumotokiko.co.jp/	tea field machine, sugarcane harvester	1.6	1981: large type tea harvester for export acomplished. The export started to Papua New Guinea, Ecuador and etc.
MAMETORA AGRIC. MACHINERY CO.,LTD. www.mametora.co.jp/	small type tiller/ cultivator, other small type machines		1975: The export to France, Belgium and other European countries sharply increased. Placed local representatives in overseas countries including South East Asia 1981: started business with Viking Co. in Germany, small tiller on O.E.M. basis
MARUNAKA LTD. http://www.marunaka-japan.co.jp/	power sprayer, knapsack sprayer, water pump	2.0	2001: Established Mex Machinery in Hangzhou China 2013: Established Changzou MEX Machinery Co.,Ltd., moved from Hangzhou
MARUMASU KIKAI CO.,LTD. http://www.marumasu.co.jp/	rice mill, stone remover, flour mill for rice, soybeans and corn	1.0	The products are exported to; Asia (China, Indonesia, Vietnam, Thailand, Philippines, Korea, Mongolia), Africa (Nigeria, Ghana, Mozambique), Europe (France, Italy, Greek), The United States, Mexico, Australia, New Zealand
MITSUBISHI MAHINDRA AGRICULTURAL MACHINERY CO.,LTD. https://www.mam.co.jp/	tractors, harvesters, transplanters and other wide range of products and services.		2013: started supplying tractors on OEM basis to Mahindra USA, a subsidiary of Mahindra Mahindra in India. 2010: concluded the contract on technological tie-up on walking type transplanter with Mahindra & Mahindra in India 2015: Mitsubishi Heavy Industries Group and Mahindra & Mahindra India agreed to conclude the contract of the strategic joint operation in the field of agricultural machinery and started as "Mitsubishi Mahindra Agricultural Machinery Co.,Ltd." on October 1st, 2015 Annual sales of Mahindra & Mahindra is US$16.5 billion, of which sales of agricultural machines and automobiles is US$10 billion. Annual sales of tractors is 260 thousand units, the top in the world. Tractor market share is 41 % in India, 10 % in The United States (0~80 hp), the third rank.
MINORU INDUSTRIAL CO.,LTD. http://www.minoru-sangyo.co.jp/	rice transplanter, vegetable transplanter, nursery seeder and nursery management equipment		2010: concluded technical tie-up agreement with 常州亜美柯機械設備 in China, licensed rice transplanter manufacturing technology
MOROOKA CO.,LTD. www.morooka.co.jp/	rubber track crawler carrier, carrier dump, forwarder, wood crusher	10.6 (domestic: 6.4, overseas: 3.0)	2003: established Morooka USA Corporation 2013: started production of Morooka carrier in Virginia State, USA
NEPON INC. www.nepon.co.jp/	greenhouse heater, green-house heat pump, hot water boiler for greenhouse and others	8.2	2015: established NEPON (Thailand) Co.,Ltd.
NIKKARI CO.,LTD. www.nikkari.co.jp/	monorack, brush cutter, trimmer, cultivator	5.8	Having exported the products for a long time. 2013: new factory of 寧波利豪機械有限公司 in China launched production with twice as much production ability as that of old factory

Name	Products	Annual sales, billion (¥)	Overseas operations
OCHIAI CUTLERY MANUFACTURING CO.,LTD. www.ochiai-1.co.jp/	tea plucker, tea pruner, tea field machinery	2.7	1960's: aggressively approached to overseas market with demonstration and guidance of tea pluckers/pruners 2002: established Hangzhou Ochiai Machinery Manufacturing Co., Ltd. (China)
OREC CO., LTD. www.orec-jp.com/	brush cutter mower, lawn mower, hammer knife	10.7	The company started export of the products to Taiwan more than 30 years ago and has developed the market in Korea and European countries. 2010: established OREC AMERICAN INC. in Seattle, USA
OKANETSU INDUSTRY CO.,LTD. http://okanetsu.co.jp/	tiller, cultivator, carriage, transmission	8.1	2007: established OKANETSU MACHINERY(Changzhou)CO.,LTD. in Changzhou, Jiangsu, China for production of agricultural machinery, power transmission and others
OKAYAMA NOEISHA CO.,LTD. http://noeisha.co.jp/	brush cutter, rice husker and related products	1.8	Exporting the products to many overseas countries through CLEAN KOGYO CO.,LTD.
SATAKE CORPORATION http://www.satake-japan.co.jp/	food processing machinery, country elevator, rice milling unit, biomass plant	37.4	The products are exported to 140 countries. Many production and marketing bases have been established in The United States, Canada, England, Australia, Thailand, China, India and Brazil. Overseas market share of modern rice mills: The Near and Middle East and Africa (60 %), Asia (70 %), North America (98 %), Middle and South America (50 %) Marketing offices are in Myanmar, China, The United States, Brazil, England, India, Bangladesh, Thailand, Indonesia and Australia 1980: SATAKE USA INC. established 2012: formed a comprehensive partnership with DAEWON GSI Co., Ltd. in Korea
SAITO NOKI SEISAKUJO CO.,LTD. http://www.saitonouki.jp/	nursery management and rice cropping	4.0	2011: launched the development of carrot digger (CH201C) for China 2012: established joint venture company 成宏機械有限公司 in China
SANO ATTACHMENT INSTITUTE CO.,LTD www.sano-at.co.jp/	implements attached to tractors and cultivators		Established joint venture company in Korea and licensed technology. The company plans to expand the business in other Asian countries. In order to meet the demands of many varieties and small quantity production, the parts are produced in cooperating companies and joint venture company in Korea and then assembled and packed in main factory.
SANO SHARYO SEISAKUSHO CO.,LTD.	trailer, rail guided vehicles, battery-operated vehicles, transpor-tation vehicles, airless tires	0.7	1978: received the order of trailer carrying generator for China 1981: developed high speed trailer for overseas market 1993: launched production of tank trailer for Africa 1998: launched production of battery-operated vehicle for Shanghai, China
SUNWA LTD. http://www.sunwa-jp.co.jp/agri/	transportation carriage, trailer, portable wheel chair lift and other assisting device	0.96	Export ratio is about 30 %. The company has sales agents in Europe, North America, Korea, China, Taiwan, Hong Kong, Singapore, Australia. 80 % of welfare equipment is exported to Europe and North America.
SANYO KIKI CO.,LTD. http://www.sanyokiki.co.jp/	front loader, hammer knife mower, chipper shredder, lifter	3.6	1981: business tie-up with Buhrs, Germany 1983: business tie-up with Agram, France 1990: concluded with Agram (France) an expanded agreement including sales and technical tie-up. 2008: established overseas subsidiary company of 100% investment (overseas affiliated company) "SIAM SANYOKIKI CO.,LTD." in Kingdom of Thailand
SASAKI CORPORATION http://www.sasaki-corp.co.jp/	tractor implements, fertilizer distributor	4.9	2010: established SASAKI-EXCEL MACHINE (NANTONG) CO.,LTD. in Jiangsu, China
SHIZUOKA SEIKI CO.,LTD. www.shizuoka-seiki.co.jp/	grain dryer, storage, analyzer, inspector	9.3	1995: opened an office in Dalian, China 1998: opened a plant in Dalian, China (中国大連遠江工貿有限公司) 2005: changed the name of 中国大連遠江工貿有限公司 to Dalian Shizuoka Seiki Co.,Ltd. 2005: opened a Beijing office of Dalian Shizuoka Seiki Co.,Ltd. 2010: established sales company SHIZUOKA SEIKI CANADA INC. in Canada The company has global sales network in 35 countries

Name	Products	Annual sales, billion (¥)	Overseas operations
STARTING INDUSTRIAL CO.,LTD. http://www.starting.co.jp/	recoil starter, nylon cord cutter, operating lever	3.9	1994: established Starting USA Corporation 2003: established local entities in Thailand, Shanghai, and Hong Kong.
TAIKI SANGYO CO.,LTD. http://www.taikisangyo.co.jp/	various kinds of drying facilities		2015: started the survey on potential introduction of electric drying facility to onion drying plant in Sudan, Africa through JICA
TAIWA SEIKI CORPORATION http://www.taiwa-seiki.co.jp/	rice milling machines and related products	0.8	2013: started commercial production of rice milling machine for long grain 2013: established TAIWA SEIKI (CAMBODIA) CORPORATION 2013: established manufacturing factory in Cambodia
TAIYO CO.,LTD. http://www.k-taiyo.co.jp/	tillage blade	3.3	2013: established TAIYO INDIA PVT.LTD. 2014: new factory of TAIYO INDIA PVT.LTD opened and the production launched
TAKAKITA CO.,LTD. http://www.takakita-net.co.jp/	round baler, bale rapper, fertilizer spreader, manure spreader and other wide range of products	5.91 (overseas: 0.45)	2014: agreed on technical enforcement licensed contract with Shandong Wuzheng Group Co. Ltd., intending to expand the market in China As total sales of round baler to Korean market reached 600 units, the company is preparing for renewal demand. The company is also promoting market development in India and Pakistanon the opportunity of technical tie-up for small round baler. In Europe the company intends to develop the market on the success in Netherland. Now carrying out the market research in Vietnam, Thailand, Turkety, Russia, Taiwan, Mexico.
TOYO AGRICULTURAL MACHINERY MANUFACTURING CO.,LTD. http://www.toyonoki.co.jp/	tractor implements for harrowing/ plowing/ grading, fertilizer applicator/ broadcaster, potato harvester/ digger, pest/weed control machines	2.7	2008: exported agricultural machines in large quantities to a food processing company in China 2014: started the market research in India in view of introducing potato harvester
WADO SANGYO CO.,LTD. https://www.wadosng.jp/	snow thrower, grass mower, industrial machines	7.3	The company has exported snow throwers to Europe and USA for a long time. 2010: started the export of walking type grass mower to Korea
YAMABIKO CORPORATION www.yamabiko-corp.co.jp/	outdoor power equipment, agricultural machinery (speed sprayer, boom sprayer, potato harvester), industrial machinery domestic sales: 39.2 (37.3 %), USA: 53.9 (51.2 %), Europe: 8.6, others: 3.4	102.5	Yamabiko Corporation, Kioritz Corporation and Shindaiwa Corporation merged into Yamabiko Corporation as of October 1, 2009. The company has the following overseas subsidiaries and affiliate ECHO, Incorporated in Illinoi, USA/ ECHO Power Equipment (CANADA) in Ontario, Canada/ Minnesota, USA/ KPI Kwik Products, Inc. in Arizona, USA/ Golden Eagle Distributing Corporation in California, USA/ Echo Machinery (SHENZHEN) Co.,Ltd. in Shenzheng, China/ Echo Taiwan Co.,Ltd. in Taichung, Taiwan/ Yamabiko Vietnam Co.,Ltd. in Vietnam/ Belrobotics SA in Belgium In order to continue to offer the products and service in the world, the company plans to make further investment for marketing operation in Europe and USA to upraise brand image and expand market share. The company intends to develop the market in Thailand and other South East Asia in the field of agricultural machinery. As for industrial machinery, the company plans to develop the market in USA, the most potential market.
YAMAMOTO CO.,LTD. www.yamamoto-ss.co.jp/	paddy dryer, testing husker, moisture meter, testing mill	9.4	The company is exporting the products to China, Taiwan, Kore, South East Asian Countries, Near and Middle East, South America, Africa 2012: established 蘇州瑞穂機械有限公司 in China
YAMAHA MOTOR POWERED PRODUCTS CO.,LTD. www.ympc.co.jp/	generator, engine, snow thrower and other wide range of products	32.6	2003: established 福州佳新創輝機電有限公司 in Fuzhou, Fujian, China 2012: established 雅馬哈動力機械 (江蘇) 有限公司 in Taizhou, Jiangsu, China

<table>
<tr><th>Name</th><th>Products</th><th>Annual sales, billion (¥)</th><th>Overseas operations</th></tr>
<tr><td>YANMAR HOLDINGS CO.,LTD.
https://www.yanmar.com/jp/about/company/</td><td>tractor, engine, harvester and various services In industrial machinery & equipment department, agricultural machinery, construction machinery, generator, gas-heat pump and etc. are manufactured and marketed.</td><td>655
(overseas: 288.8)</td><td>Agricultural machines are manufactured and marketed by Yanmar Agricultural Machinery (China) Co.,Ltd., YANMAR S.P. CO.,LTD. and P.T.YANMAR AGRICULTURAL MACHINERY MANUFACTURING INDONESIA. Yanmar products are also marketed by YANMAR AGRICULTURAL MACHINERY KOREA CO.,LTD. and other companies. Construction machines are manufactured and marketed by YANMAR CONSTRUCTION EQUIPMENT EUROPE S.A.S. Construction machines are also distributed by Yanmar America Corp. and Yanmar Engine (Shanghai) Co.,Ltd. Industrial engine and related equipment are manufactured and distributed by TUFF TORQ CORP., P.T.YKT GEAR INDONESIA and TRANSAXLE MANUFACTURING OF AMERICA CORP. (transmission and trans axle), by YANMAR ITALY S.P.A.、YANMAR S.P.CO.,LTD., Yanmar Engine (Shanghai) Co.,Ltd. and P.T.YANMAR DIESEL INDONESIA (industrial engine), by YANMAR MARINE INTERNATIONAL B.V. (engine for pleasure boat).
Yanmar launched production and marketing first “Yanmar variable oil engine” used for agriculture in 1921 and started to extend their overseas business aggressively thereafter, establishing Korean branch in 1924 and marketing oil engine in Philippines since 1927.</td></tr>
<tr><td></td><td colspan="3">1960: Open Ceremony of Yanmar Brazil Factory was held
1972: established P.T. Yanmar Diesel Indonesia in Jakarta, Indonesia
1972: signed import and marketing contract for large tractors with Deere& Co.
1975: established P.T. Yanmar Agricultural Machinery Manufacturing Indonesia in East Jawa
1976: started export of small tractors YM155D、YM135D to The United States
1976: established branch offices at London,U.K. and Rotterdam, Netherland
1977: signed OEM contract on Yanmar tractors with Deere & Co.
1978: established Yanmar Thailand Co.,Ltd in Bangkok, Thailand
1980: established branch office in Singapore and North America branch Office near Chicago, USA
1988: established Yanmar Europe B.V. (YEU)in Almere, Netherland
1989: established Yanmar Asia(Singapore)Corporation Pte. Ltd.
1989: established Ammann-Yanmar S.A.S. in Saint Dizier, France
1995: established joint company Yanmar Cagiva S.p.A. with Cagiva Motor S.P.A.
1997: established engine assembling factory in YEU, Netherland
1997: established joint company Yanmar Agricultural Machinery (China) Co.,Ltd. in Wuxi, Jiangsu, China
1998: established Yanmar Manufacturing America Corp. near Atlanta, USA
2001: established joint company PT.YKT Gear Indonesia for parts supply
2002: established Yanmar Marine International B.V. in Almere, Netherland
2003: established Yanmar Engine (Shanghai) Co.,Ltd.
2005: established branch office in Delhi, India
2007: established the first overseas R&D center, Yanmar Kota Kinabalu R&D Center Sdn. Bhd. in Malaysia
2007: Company name “Shandong Shifeng Yanmar Engine Co.,Ltd.” was changed to “Yanmar Engine (Shandong) Co.,Ltd.
2007: established branch office in Moscow, Russia
2011: established new factory in Yanmar S.P., Thailand to start production of tractors
2011: established the first Yanmar R&D site in Europe “Yanmar R&D Europe S.r.L.” in Firenze, Italy
2013: operation started at casting firm “PT.YANMAR INDONESIA”
2014: established YANMAR RUS LLC in Moscow, Russia
2014: established YANMAR COROMANDEL AGRISOLOUTIONS PRIVATE LIMITED in Chennai, India
2014: established YANMAR AGRICULTURAL MACHINERY VIETNAM CO.LTD. in Ho Chi Minh City, Vietnam
2014: established agricultural research center “YANMAR AGRICULTURAL RESEARCH INSTITUTE -IPB” in Bogor, Indonesia</td></tr>
</table>

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J H Chung


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A Q A Mughal


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N A Abu-Khalaf


R M Lantin


R P Venturina


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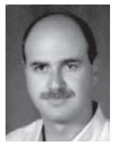
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Shahansha-Uddin Choudhury	Bangladesh	1973	1991
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Chang Joo Chung	Korea	1975	2014
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Co-editor`s name	Nationality	Inaugu-ral year	Retired year
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Back Issues

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol.45, No.2, Spring, 2014-)

◇ ◇ ◇

Vol.45, No.2, Spring 2014

◇ ◇ ◇

Vol.45, No.3, Summer 2014

◇ ◇ ◇

Vol.45, No.4, Autumn 2014

◇ ◇ ◇

Vol.46, No.1, Winter 2015

◇ ◇ ◇

Vol.46, No.2, Spring 2015

◇ ◇ ◇

Vol.46, No.3, Summer 2015

◇ ◇ ◇

Vol.46, No.4, Autumn 2015

◇ ◇ ◇

Vol.47, No.1, Winter 2016

■■

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

Criteria for Article Selection

Priority in the selection of article for publication is given to those that –

a. are written in the English language;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written on CD-R.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
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d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article needs to be sent to Co-operating Editor in the writer's neighboring country.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on CD-R with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copys (A4). Or it must be sent by E-mail with Word File and PDF File attached.
b. The data for graphs and photographs must be saved into piecemeal data and enclosed (attached) with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
   (i) brief and appropriate title;
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   (iii) an abstract following ii) above;
   (iv) body proper (text/discussion);
   (v) conclusion/recommendation; and a
   (vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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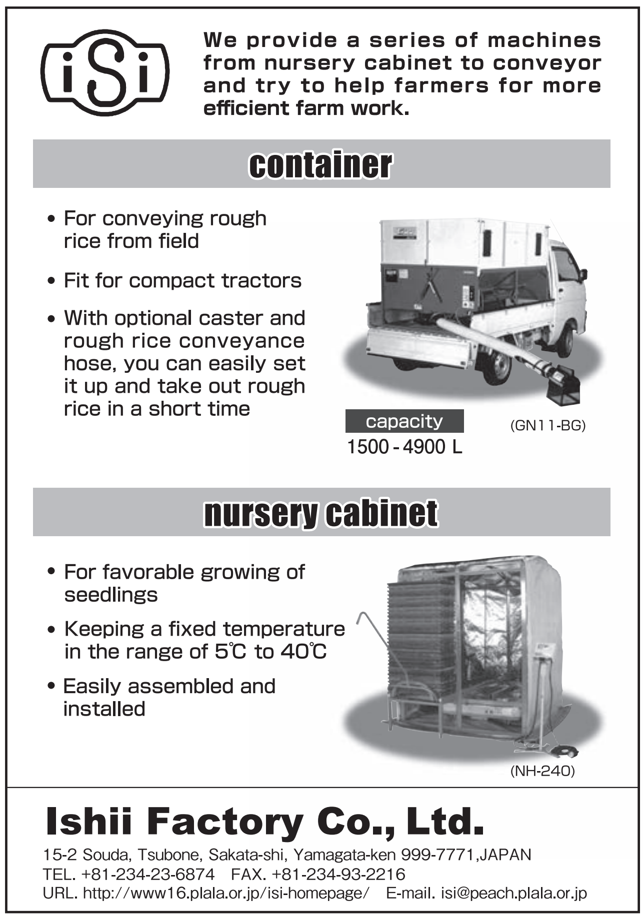


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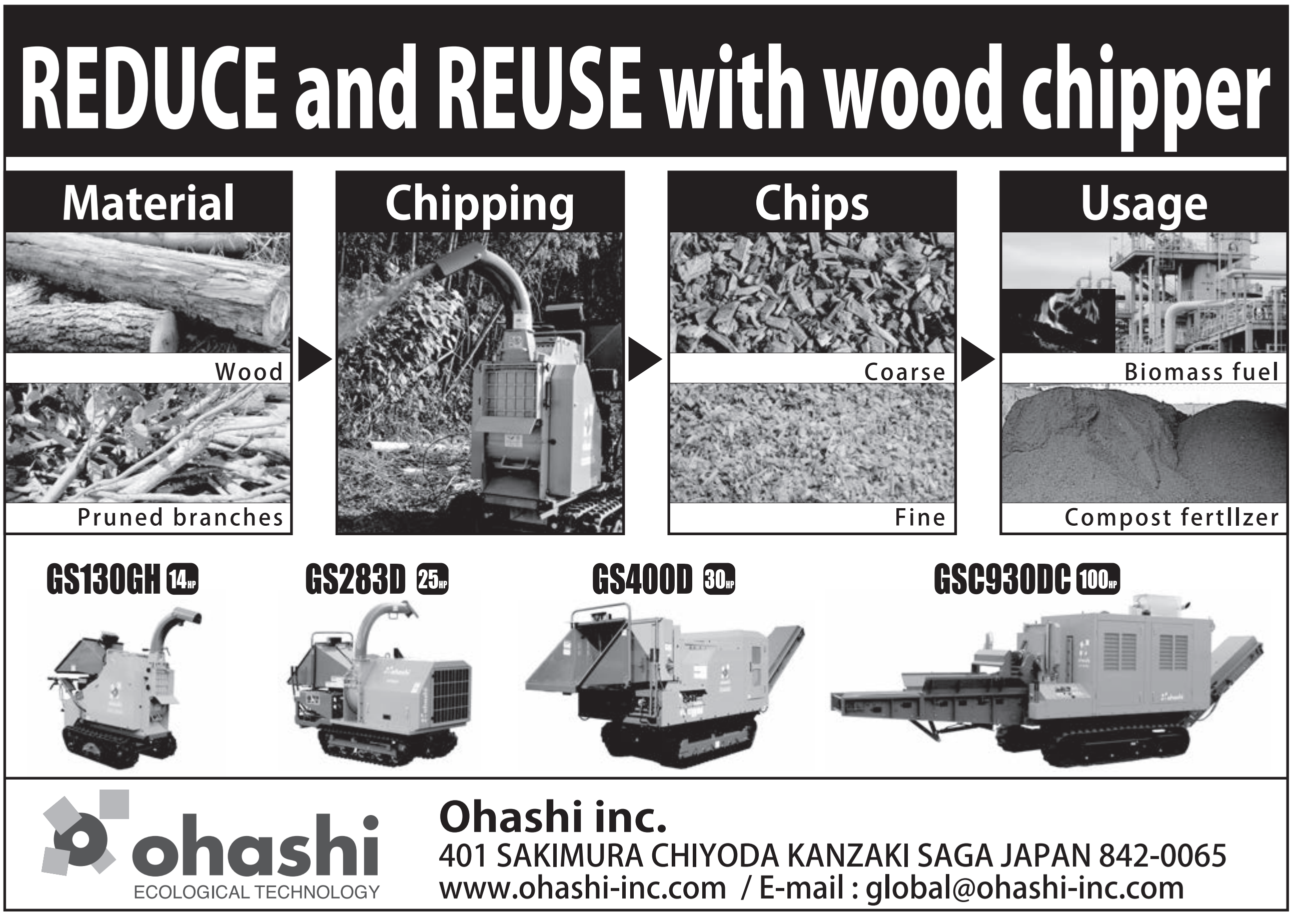
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