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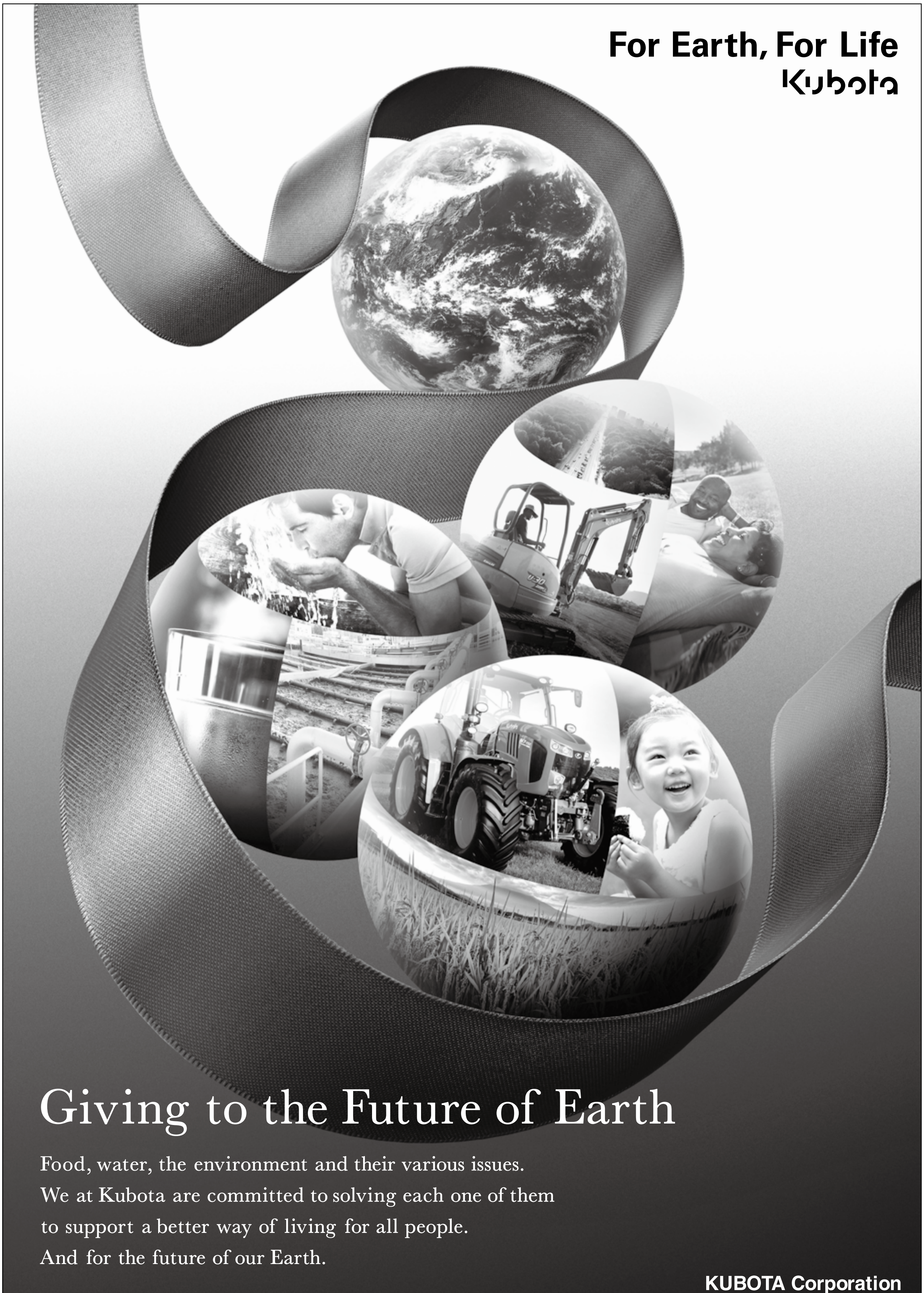
FARM MACHINERY INDUSTRIAL RESEARCH CORP.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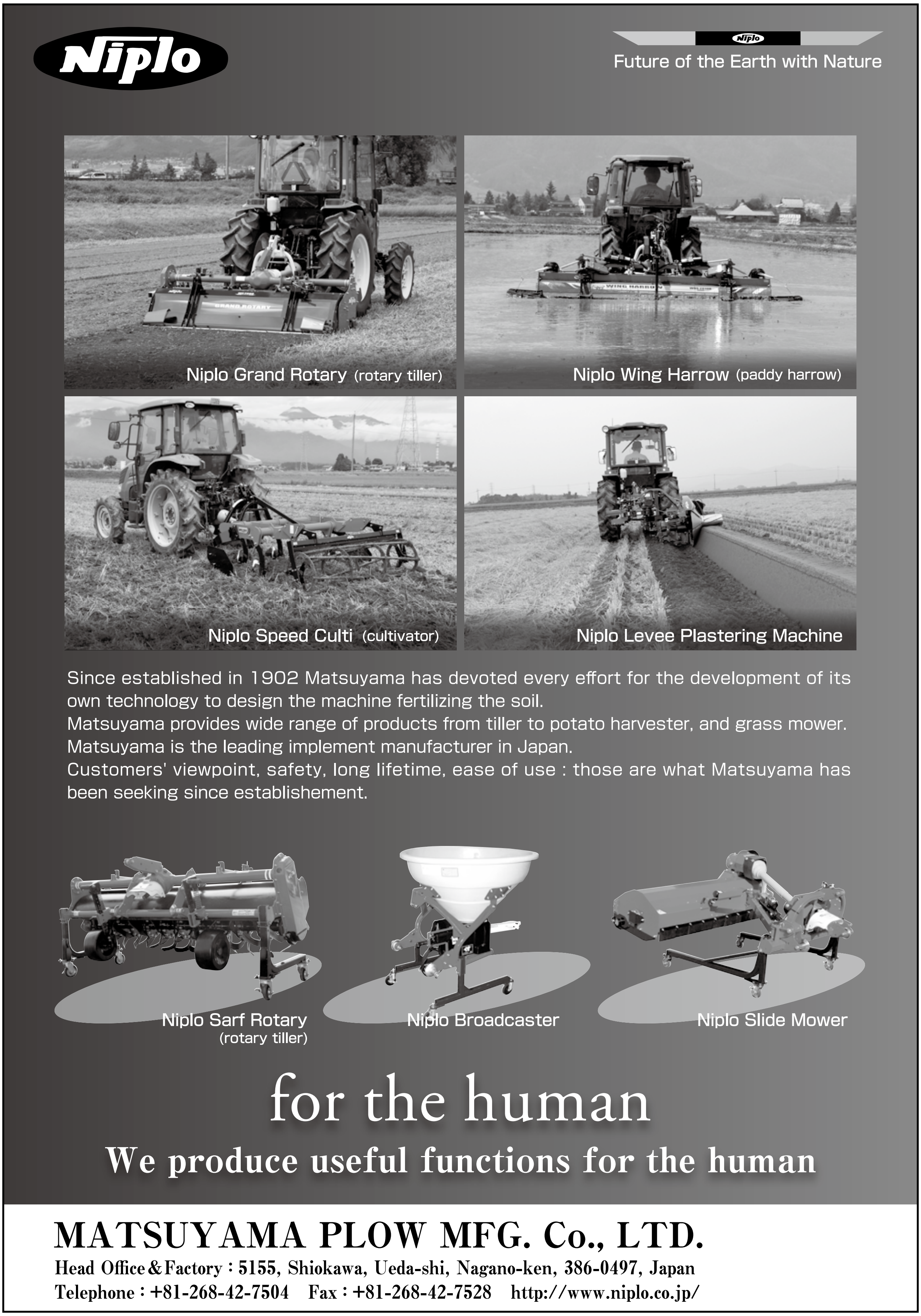
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EDITORIAL

Last spring, we published a special issue focusing on agricultural machinery industry and research in Asia. It received many positive responses and high praise from all over the globe. Since we couldn't cover all Asian countries in it, on this occasion we publish the second special issue titled "Agricultural mechanization and industry in Asia" focusing on the rest Asian countries, Russia and some middle-east countries.

In Asia, there are various countries in very vast land where agriculture has been done under various conditions. Beginning from mechanization of major agriculture, I was impressed that agricultural mechanization has been promoted enormously compared with 1971 when we launched AMA even though its pace is different from country to country. For example, China and India has become important countries which occupy the top 2 in the world in the field of tractor production. World population has already exceeded 7.4 billion and keeps increasing towards more 9 billion. Food production must be done with limited farmland, water and labor force for feeding the increasing people. Enhancing land productivity is necessary at first. For that, timely and precise farming is necessary and agricultural mechanization is also really necessary. When considering future agricultural mechanization, we need to consider what is appropriate in modern new technology.

In 1970s, simple design that farmers were easy to use, local manufacturers were easy to make, and dealers were easy to repair was regarded as important. Even now this principle applies. But as seen from the current situation that production of tractor with more than 30 horsepower reaches 700,000 units in India, the most important issue is how to utilize new science and technology.

There are plenty of middle-mountainous areas and small farms in Asia. For pest control, human-power sprayer, power sprayer and recently self-propelled sprayer have been used. But in near future it must be controlled by unmanned machine such as drone.

We have to promote automation and robotization of agricultural mechanization by using artificial intelligence. In recent years, research on agricultural mechanical robots has been conducted in various countries, and these technologies must be developed in a way that is beneficial for developing countries. In order to produce more foods in limited farmland, further new agricultural mechanization is indispensable.

Yoshisuke Kishida
Chief Editor

March, 2017

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.48, No.2, Spring 2017

Present Status and Future Trends of Engineering Science in Mongolian Agriculture

by

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Abstract

An agricultural machinery industry is not widely developed in Mongolia, however small size enterprises undertaking assembly of tractors and machinery have launched recently. Farm equipment imported from European and Asian countries, as well as from North America have been employed in various branches of agriculture. Comprehensive mechanization has been reached in grain crop production, partial mechanization in potato production, as well as in some vegetable production. Tractors ranging from 50 hp up to 500 hp are in use on farms. These developments merit an Engineering study focused on the elaboration and testing of new designs for farm machines; increasing the economic and performance efficiency of imported tractors, self-propelled combine harvesters, and other agricultural equipment; as well as indicating the direction of engineering policies for Mongolian agriculture.

Introduction

The main foundation of Mongolia's economy, livestock husbandry on natural pastureland, still plays an important role in the economy. By the end of 2015, in total 55.957 million head of livestock were counted, with a sheep accounting for 44.7%, goats for 42.3%, cows 6.6%, horses 5.8%, and camels 0.7%.

In the branch of pasturing livestock husbandry, mechanized processes are not yet fully adopted and even today most herders use manual tools and equipment based on small engines, such as 15-20 hp tractors, 3-5 kW internal combustion engines, and renewable energy sources.

In 2016, farmers cultivated 367.9 thousand hectares, which consisted of 377.2 thousand hectares of cereals, 14.5 thousand hectares of potatoes, 8.2 thousand hectares of vegetables, and 28.0 thousand hectares of fodder crops. Due to soil and metrological conditions, grain crop production in Mongolia is dominated by zero tillage conservation techniques.

Today, scientific research into agricultural engineering and mechanization technology, as well as the design of new machines are performed at the State University of Agriculture (school of Engineering and Technology), as well as the Agricultural Machinery Research and Industry Institute and the "Initial Plough Co., Ltd".

Objectives of cultivation technology in Mongolian crop farming consist of reducing wind erosion and drought consequences: in other words, it is necessary to apply conservation and zero tillage technology in plant crops production systems.

The scope of research activity and development of agricultural machinery includes:

- Design and modification of farm machines and equipment,
- Innovation to improve the performance and efficiency of machinery
- Field performance, fuel consump-

Table 1 The specifications of potato cultivation and harvesting machines for small tractor

	plough	cultivator	planter	digger
Matched power, hp	18-20	18-20	15-20	18-20
Working width, cm	45	140	70	70
Inter row width, cm	-	70	70	70
Number of cultivated row	-	2	1	1

Table 2 The specifications of horse cutter bar mower

Specifications	
Number of drag horse	2
Working width, cm	138
Working speed, km/hour	4-5
Weight, kg	278

tion and drawbar power tests of tractor and self-propelled machines and other machine-tractor units,

- Assessment of engineering, ecological and economic aspects of technology adoption and machinery use.

Some Achievements in Engineering Science in the Last Ten Years

In the Area of Designing New Machines and Assembly of Tractors and Field Equipment

In recent years, drawings and models have been developed for a mould board plough, herbicide sprayer, and a vegetable seed planter for a 15-25 hp tractor suitable for Mongolian soil and climatic conditions. Likewise a mower and hay dump rake with parameters according to the draught force of Mongolian horses have been designed. The Agricultural Machinery Research and Industry Institute has assembled and delivered to market about 200 small tractors with 12-18 hp, 1.5 ton trailers and 180 horse cutter bar mowers and hay dump rakes, in cooperation with Russian and Chinese farm machinery plants, during the last 10 years. A new cutter bar mower and hay dump rake for compact 20 hp tractors was designed and produced by the "Initial Plough" Company Ltd. More than 30 newly designed mower and hay dump rakes are in use at farms in recent years. The "Initial Plough" Company Ltd. designed a set of potato cultivation machines (**Table 1**), too. A new design of building for dairy cow which may be heated by animal energy was developed by engineers and scientific researchers of MULS.

A new field sprayer for compact tractors of 15-20 hp was designed at the School of Engineering and Technology. The field sprayer consists of a 6 m boom, 200 L tank, 50 L/min capacity centrifugal pump, and the machine can operate in the field with a speed up to 9.0 km/hour and cover 15-20 ha per hour. A horse mower and cutter bar mower for small tractors, designed and produced by "Initial Plough" Company Ltd. are successfully in use at farms. New machinery has increased field capacity 4-5 times in comparison with hand work in the hay making process (**Table 2**). Our researchers made some machines for Potato cultivating and harvesting by themselves (**Fig. 1**).

In the Field of Farm Machinery Selection Problems and Scientific Decisions

In 2016, farmers sowed 367.9 thousand hectares, which consisted of 315.49 thousand hectares of cereals, 11.29 thousand hectares of potatoes, 5.0 thousand hectares of vegetables, and 5.9 thousand hectares of fodder crops. Grain crop production in the soil and climate conditions of Mongolia should prioritize conservation and zero tillage versions of cultivation technology. According to the medium-term reform program for 2016-2020, farmers in grain crop production in Mongolia should have equipment that may be finished grain crop seeding in 10-14 days, harvesting in 21-28 days, and cultivating for fallow 7-10 days. Therefore, selecting the proper power level of tractor, self-propelled combine and optimum width of field machines is a significant problem for farmers. A professor of MULS is studying the machinery selection problem and is preparing a recommendation paper for the Ministry of Food, Agriculture and Light Industry, as well as for farmers.

To determine the optimum machinery set for a given farm size, one should perform the next procedures:

- Establish cropping practice and the expected grain crops yield per hectare and values.
- Establish the required machine field operations and secure real or representative data for energy and labor requirements.
- Analyze tractor and machinery parameters.
- Select optimum parameters for tractor and machinery and find the permissible range in implement sizes.

A new recommendation on the suitable parameters of tractor and other machines based on results of research work in 2014-2016 appears in **Table 3**.

In the Field of Scientific Solutions for Farm Machinery Use

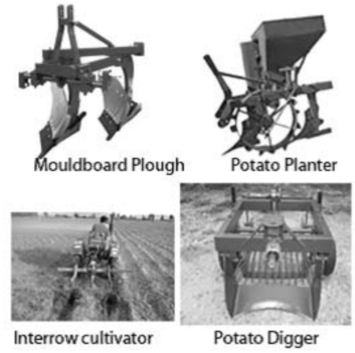

Fig. 1 Set of potato cultivation and harvesting machines

Table 3 Recommended parameters of machinery set for grain crops depending on the farm field size

Set of machinery	Field size, ha			
	400-800	1000-1500	2000-3000	More 3000
Tractor	130-175 hp (1)	180 -275 hp (1)	275-335 hp (1)	About 350 hp
Field cultivator	4-6 m	4-6 m (2-3)	10 m	10-15 m
Seeder and drill	2 m (2-3)	2 m (5-6)	10 -12 m (air seeder)	10-15 m (air seeder)
Self propelled combine harvester	150-160 HP (1)	150-200 HP (2-3)	230-270 HP 6.0-7.5 m (2-3)	230-270 HP. 6.0-8.5 m
Field sprayer	-	15 m	18-24 m	18-24 m

Economic farm management requires a careful matching of tractor capability to the farm's power need depending on the soil condition, volume of expected grain crop yield and other special features of the region. There are five agricultural regions in Mongolia. Crop farming in Mongolia depends upon the gross size of field (plot) up to 200 hectares with a furrow length of 1000-2000 m. Therefore, machine field efficiency is the most important information item needed by farm machinery managers, and researchers from MULS conduct field experiments jointly with farmers. For example, large companies are using John Deere (430 hp) and New Holland (425 hp) tractors with 15 m Air seeder attachments and a field capacity of 10 hectares per hour and a fuel consumption of 5.67 litre per hectare.

Testing of a small tractor determined that the approximate operation width of the mower is 194.2 cm instead of 2 m, working speed is 3.39 km/h and fuel consumption is 3.19 L/ha. Field testing of large machine shows, a field capacity and fuel consumption dependant on the furrow length of the field: as the length of field is increased the hourly capacity of machine per hour will rise and fuel consumption decrease. For example, the correlation coefficient between the field capacity and field length is 0.89 for a 1076 John Deere combine harvester in direct cutting of wheat.

In the Field of Biotechnology Development

The Mongolian Biochar Research Institute of MULS introduced new technology and equipment for producing biochar from cow (and horse) dried dung, feedstock, crops and wood. Researchers are developing low tech biochar ovens (gasifier or pyrolysis apparatus) of 10-150 gallon capacities for family and smallholder level use. The beneficial potential of biochar as a soil amendment to enhance plant growth is significant. For example, after application of biochar on a potato field, the yield per hectare increased 23.5%, 2014.

Waste cooking oil (vegetable oil and fat from animals) is one of the most economical sources for diesel fuel fabrication. Therefore, a research team from the Engineering and Technological School is focused on developing a process to obtain biodiesel from Sunflower waste cooking oil. Methanol is used in the application of recycled vegetable oil. Biodiesel production is completed through the transesterification process, which consists of three consecutive and reversible reactions.

Transesterification of fats or vegetable oil with alcohols forms biodiesel esters and glycerol. The properties of petroleum based diesel, biodiesel from pure sunflower oil and biodiesel derived from sunflower cooking oil are given in table 4. It can be seen clearly that B100 had very low sulphur content compared with petroleum diesel. The cloud point of the various methyl esters ranged from +5°C to +9°C.

Next, application of biodiesel in diesel engines was tested for fuel consumption. The results of the experiment show fuel consumption of biodiesel is increased by 6.5% in the 20% blend biodiesel compared with petroleum diesel and by 32.6% in the 100% biodiesel. The Cetane number of biodiesel from waste oil was 49 units, 2 units higher than petroleum fuel. It may reduce the fuel burned completely and increase the amount of toxic gases.

In the Field of Animal Husbandry and Farm Mechanization

Cow milk farms are operated in the vicinity of large cities and Ulaanbaatar, in 2014 numbering 1,554 alongside 351 meat production farms.

Farmers in the rural areas are generally small and as individuals cannot afford farm equipment to mechanize their farms. At the same time, they do not like to come together

Table 4 Compared properties of petroleum diesel with biodiesel derived waste cooking oil

Specifications	Unit	Diesel fuel petroleum	Biodiesel from pure sunflower oil	Biodiesel from waste cooking oil
Density	kg/m^3	814	865	888
Viscosity	mm^2/s	2.331	4.862	8.432
Cetane index	-	47	59	49
Pour point	°C	-35	-6	-3
Cloud point	°C	-5	+5	+9

to form cooperatives and pool their resources to invest. Because of their individualistic approach, they are unable to have access to credit facilities from commercial houses or government.

Teachers of the Engineering and Technology School who made a hay cutting machine for small tractor BJ-200 of China, and tested it in hay fields (**Fig. 2**).

In the Field of Agricultural Electrification and Automation of Farm Processes

The department of Electrification and Electronics has done research on reduction of insects by high voltage electric fields using solar energy. This new method has been successfully tested in 2012 at the "Nart" training and research centre of MULS in Tuv province. The solar equipment has been successfully working through now. Approximately, 2 to 3 kg of insects were killed per day and these insects were prepared for chicken feed. The capacity of equipment is determined as 1 to 3 ha. The last 10 days of June to the first 10 days of July is the most prolific time for insects. As such there is need for a research on insects depending on the landscape.

There are also tests on the influence of Low-Temperature Plasma on Seed Germination Characteristics of Lotusc orniculatus. The low temperature plasma (LTP) technology is used for pre-sowing seed treatments. In this experiment researchers used the new LTP technology equipment "low-temperature plasma modified instrument" and applied different doses in LTP technology to explore its effect on seed germination and other related characteristics on Lotusc orniculatus crop seeds. The maximum Lotusc orniculatus seed germination percentage and germination vigour percentage were recorded at 120 W followed by a 160 W LTP treatment, while maximum plant height and root length were recorded at a 160 W LTP dose.

Fig. 2 Testing process of tractor BJ-200 (China) for hay cutting

Mongolia has mainly nomadic populations in the countryside. Therefore we aim to equip the water supply system with automatic controls to save manpower, money and time. An automated controlling block is fixed to an ATMEGA 32 board and programmed by SI system. System operation information is transferred to an LCD display. Movement sensors and water levels sensors send the information to a control board through relays and control the pump. The system worked reliable during the duration of the experiment and the researchers are focused on developing the innovation now.

Since the Engineering and Technology School of MULS is a leading scientific center of Mongolia, the scope of research activity is wide and trends in engineering science include:

- To take a leadership role in defining engineering policy in agriculture.
- To develop research in uncultivated pasturing Animal husbandry to replace human labor and to improve living standards of herders and rural laborers.
- To strengthen research participation in machinery management and service at farms, jointly with commercial dealers.
- To increase the amount of assembly of farm equipment for mechanization and the modification of imported machines.
- To facilitate the adaptation of suitable technology and machines to Mongolian condition.
- To develop laboratories purposed for tribology, nano and bio technology engineering.

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■■

Agricultural Machinery in Kyrgyz Republic

by

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Explanatory notes: The author supports development of the Kyrgyz agriculture from 2009, or more specifically, "The Project for The Support for The Dissemination of Biogas Technologies" (2007-2011), "Dissemination of organic farming in Kyrgyzstan" (Grass-roots co-operation project) (2013-2015), and "Dissemination of Organic Farming and Increase in Added Value of Agricultural Products in Kyrgyz" (2016-)

The text refers to 2 following documents overall;

1) The Kyrgyz Republic data collection survey on agricultural mechanization (March 2014 Japan International Cooperation Agency; JICA)
2) The Kyrgyz Republic Farm mechanization and agricultural productivity (2009 Food and Agriculture Organization of the United Nations; FAO)

Overview

Kyrgyzstan, officially the Kyrgyz Republic (hereinafter Kyrgyz) is a republic of former Soviet Union located in the Central Asia. It is a landlocked country and bordered by Kazakhstan, China, Tajikistan and Uzbekistan. Kyrgyz is the mountains nation where more than 80% is covered in Tian Shan. Country area is 199,900 km^2 (about half of Japan). Population is 5,482,000 (about the same with Hokkaido in Japan). Kyrgyz is a mountain country where 94% of the total land area is at an altitude over 1,000 meters, and 40% is at an altitude over 3,000 meters. Only one-sixth of the land area is at an altitude below 1,500 meters and these areas are mainly the outskirts of the northern mountain area, a moisture-laden windy area, and the southwest Fergana Basin peripheral area. In Kyrgyz, forest areas are just only 3% of the land area.

The agriculture is the key industry that accounts for 31.6% (2014) of GDP US$1,113 (the world 157th place; 2015) and 66% of total population. In Kyrgyz, former kolkhoz and sokhoz farm system collapsed after the collapse of the Soviet Union in 1991. And the privatization of land was carried out, but the farmer was not able to receive the technical assistance and the support to farming such as distribution of agricultural materials (chemical fertilizers, pesticides, etc.) required to farmers as the administrative services. This agricultural reform caused some negative effects such as the disappearance of sales channels due to the elimination of government purchase system, loss of financial access, and the decline of investing in agriculture. As a result of this transformation, inefficient small-scale farming became the mainstream of agriculture of Kyrgyz. Furthermore, the agricultural yields due to the drop of soil fertility considerably decreased and the quality degradation of agricultural products is also notable. The chemical fertilizer is not produced in Kyrgyz. Currently, the chemical fertilizers depend on imports from neighboring countries such as Russia and Uzbekistan. According to the Ministry of Agriculture, imported chemical fertilizer is 30% of the required amount. Because of this decreased soil fertility wheat yield drops from 3.5 t/h to 2.0 t/h (40% down) in the 25 years after the Soviet Union collapsed. Furthermore, it is said that the harvesting loss of the combine harvester is added to this. Then, it is also said that 50-60% of total agricultural products have decreased. These are unbelievable values.

The agricultural sector occupies the largest part of the economy in Kyrgyz. The sector accounts for 14.7% of the total gross domestic product and approximately 13.0% of the total export value in 2014. But since 2002, agricultural production in Kyrgyz is stagnating, and the proportion of the agricultural sector contributing to the GDP has decreased from 34% in 2000 to below 20% in 2010. In Kyrgyz, nearly 70% of the population lives in rural areas, and half or more of the work force of this country engage in agriculture. Agriculture plays an important role in the sustainable development of the economy. Despite these situations, the income of farmer is at a low level, which is approximately 35% to 50% compared with other industries. As a result, most of the rural population lives in lower than the poverty line level (In October 2015, the World Bank updated the international poverty line to US$ 1.90 a day). Therefore, poverty reduction in rural areas is considered one of the most important themes in this country.

Agricultural Machinery

The main cause of weak agriculture is mainly low private investment for the agricultural machinery. The Kyrgyz has fewer tractors per hectare than any comparable country, including Moldova, Tajikistan, Georgia and Armenia. For over 25 years after independence in 1991, the number of agricultural machinery has been decreasing. In particular, the number of tractors declined from 30 thousand to 20 thousand units. Then the spread number per arable land becomes around 150 to 200 tractors per 100 square kilometers (10,000 ha). When the age of agricultural machinery is taken into account, this underinvestment appears even more acute: according to the statistics of Ministry of Agriculture, the renewal of tractors within 25 years is approximately 10% in around 20 thousand total spread. Although the durable period of the tractor changes according to the size (engine output), seven years are established as legal service life in Japan. In the case of a tractor, design life is decided by the size (engine output) of the tractor. A tractor of 80 PS that is used a lot in Kyrgyzstan will have the design life for around 6 thousand hours. Then, although affected by a year at use time, tractors will be used the number of years of approximately 3 times of the durable time. Of course, the performance degradation is certainly caused. The drop of the engine output in particular will be remarkable (**Figs. 1** and **2**).

Popular machines among farmers are Belarusian tractors (80 PS) and Chinese tractors (90 PS) which are selected by price, performance, availability of parts and ease of operation. The tractor of the same output can be purchased with a one-third price of tractor made in Japan. Also, in small numbers, large-scale farmers use European or American tractors (220 PS) which have high power for large area.

Farmers can purchase Belarusian and Chinese tractors' spare parts not only from official agency, but also from parts shops at the bazaar where farmers can buy genuine parts and cheap imitation parts. Most farmers can repair and maintain agricultural machinery by themselves. A repair technology of this farmer supports the long-term life of the agricultural machine. The person who specialized in repair of the agricultural machinery in the kolkhoz and sovkhoz farm system of the village instructs a repair technology to farmers. Even the disassembling of the clutch housing of the tractor is carried out in a farmyard. An unbelievable scene is seen in any place.

Vocational school which there is more than 100 in the whole country contributes also to the maintenance of the agricultural machine and there are several training courses, such as an electrical engineering, information-communication, industrial technology, and service industry and so on (**Fig. 3**). For the first and second years of study, general education subjects are mainly held here. There are many agricultural course subjects, such as horticulture, livestock, orchard, veterinary and so on. On the subject of agricultural machinery, students study the basic structure of machinery, the operation of a tractor with implements, and maintenance of machinery. The students obtain a tractor's driving license after completing the course.

The vocational schools conduct a 6-month course in agricultural machinery as short-term training. The training schedule is arranged accordingly. The course subjects are not only for studying the mechanism of machines and operation techniques, but also students can obtain a tractor's driving license. Therefore, there are many students taking the short-term training course for the purpose of obtaining the license (**Fig. 4**).

As stated above, in vocational school, the lectures of structure, disassembling and assembling for agricultural machinery are carried out. However, the teaching materials are not updated only with a thing of Soviet Union Era at all. Neither the

Fig. 1 Old tractor

Fig. 2 Transporting alfalfa

Fig. 3 Teaching material in Vocational school (Engine piston)

teaching materials nor the training machine is updated at all. It is hard to think that enough education is provided.

The agricultural policy of the former Soviet Union Government increased food production based on the Kolkhoz and the Sovkhoz farming system. The agricultural machinery played an important role in carrying out agriculture effectively. In this agriculture system, there was the maintenance and repair plan that farming work did not stop by the trouble of the agricultural machinery in the busy season.

At that time, the Government supplied spare parts and materials needed for maintenance, and repair services were carried out smoothly in accordance with the proper plans, and agricultural machinery was periodically renewed around every ten years. Furthermore, the government made the facilities of three scales to carry out maintenance and the repair of the agricultural machinery. The three facilities mentioned above were established in the strategic farm areas of (1) Provinces, (2) Districts and (3) Villages. These facilities were usually called "a machine station" or "machine center" because it was that the purpose of facilities carries out maintenance and repairs the service of the agricultural machinery. Training education for operators and engineers was implemented sufficiently at the time. After independence, engineers who had been working at the machine stations were indispensable to currently implement the operation, maintenance and repair of agricultural machinery in Kyrgyz.

Fig. 4 Teaching material in Vocational school (Tractor transmission)

But, after independence, large-scale farmland was divided into individual farmland depending on the number of family members, and the agricultural machinery, equipment and buildings of machine stations controlled by the Government were sold, according to the privatization policy. Therefore, presently there are no public maintenance and repair services of agricultural machinery.

This is the reason why many agricultural machines which this was introduced into for the former Soviet Union era are still used. However, this does not mean that an agricultural machine is used effectively. Machine stations have already been privatized and incorporated as private companies since independence. And facilities and the machine tool of a machine station used from Soviet Union period become too old. Therefore, the renewal of facilities and machine tools are required to solve this problem in the future.

While considering about the agriculture mechanization of the developing country, the small-type mechanization is generally considered. However, in Kyrgyz the farmer used an 80 PS class tractor normally from the former Soviet Union era. In addition, originally farmer was a nomadic tribe, and the farmer used a horse. And as for the principal cause, tillage depth becomes shallower with the performance deterioration of the tractor, and only around 15 cm is average tillage depth now. When the tillage depth becomes shallow, the stones increase at the same time and the deep cultivation becomes hard. For reasons like these, the thinking that because a division area is small, walking tractor is suitable or a small tractor is suitable is not appropriate. It is necessary to build an agricultural mechanization system in consideration of these elements. The horsepower of the tractor needs the examination that is with care because it influences all attaching implements.

The lack of agricultural machinery is not only a tractor. The Kyrgyz has a severe deficit in agricultural machinery, particularly combine harvesters. The spread of combines is 2,400 but more than 80% has passed 25 years. As an inevitable result, the crop loss is big and it is said that the loss reaches 40%. If it is Japan, it is several percent. The decrease in agricultural productivity affects also the grain production. Because the wheat is the staple food and plays an important role in food security, these losses are big problems. Because an old small combine must cover 160 ha per season, the scenery which they move performing convoy formation to the north from the south in harvest season, is always seen. The convoy of such an old machine catches even the strange feeling when we watch this scene first. The machine is such old and no wonder 40 percent of the harvest losses also. It is considered that a significant deficit in agricultural machinery is hindering the productivity of agricultural sector. The Kyrgyz has fewer tractors per hectare than any comparable country, with a deficit estimated at 40 percent. Plow, harrow and seeder are hardly renewed for 25 years, too.

Kyrgyzstan is a dry zone, and alfalfa cultivation is prosperous. The alfalfa is exported to the neighboring countries. However, most of mower, rake, baler and forage harvester are not renewed. Therefore, it causes a drop of the quality without being able to harvest it suitable time for a crop.

Thus, the Ministry of Agriculture calculates it as a test how much agricultural machinery is necessary. The needs for farm machinery were estimated on the basis of the following parameters: one combine harvester for every 200 ha of grains; one medium-sized tractor for every 40 ha; and one seeder for every 200 ha of sown area.

So the deficit of combine harvesters, estimated at 45 percent, is even more critical. The lack of the agricultural machine affects the agricultural production directly. For example, the following things are thought about:

(a) Delay of the tillage and seedbed preparation
(b) Harvesting losses by harvest delay
(c) Harvesting losses by the performance degradation of old machinery
(d) High mechanical services costs for land preparation and especially, harvesting work
(e) Loss of forage yield and its nutritional value by disorder of the harvest time

It is thought that a significant deficit in agricultural machinery is hindering sector productivity. And for fertilizer use is decreasing year by year, the change in soil fertility also make this difficult to compare. Farmers do not have sufficient knowledge, skills and experience in agricultural machines, farm management and cultivation techniques.

The use of organic fertilizer made from livestock manure to solve these problems is examined now by JICA and KNAU (Kyrgyz National Agricultural University). FAO also promotes organic agriculture as an alternative approach that maximizes the performance of renewable resources and optimizes nutrient and energy flows in agroecosystems.

Here is the explanation of the test result of the organic fertilizer (digestive slurry from the biogas plant, compost, green manure (alfalfa) slightly. KNAU and JICA conducted field research for several years. The result was beyond expectation. The following is the results of five-year field research from 2010 to 2012 and 2014 to 2015. The test was carried out on sugar beet and potatoes, which are considered the main crops in the country. Application rate of digested slurry, compost and green manure were decided on the basis of the nitrogen rate of Kyrgyzstan standard. The yield of a chemical fertilizer ward and the digested slurry ward was approximately similar to 1.7-1.8 times of no-fertilizer ward. But, for the most important sugar content in beet cultivation, the digested slurry ward showed 11.3% better results from the chemical fertilizer ward. And with the real sugar amount of production, the digested slurry showed the value that was 1.8 times of the no-fertilization ward and was 3.6% higher from the chemical fertilizer ward. The sugar content of the digested slurry is the same with the Japanese. The test results in 2014-2015 that increased compost and a green manure was good.

The test result of the potato was unexpected, too. Organic fertilizers ward exceeded the value of mineral fertilizer ward with a significant increase in starch content. The yield largely in comparison with a no fertilization ward improves and can watch the remarkable effect of the organic fertilizer. From the examination that added a compost ward of 2014-2015, the advantages of the effect of the organic fertilizer were shown in the points of a yield, starch content and quality.

In particular, in the difficult situation of the purchasing the chemical fertilizer, the utilization of animal manure is only means to sustain agriculture. And, during these days the organic produce is important, it can be considered as favorable conditions to the contrary.

Fig. 5 The compost windrow-forming car (Developed by KNAU and JICA)

As stated above, by testing several organic fertilizers, effectiveness of organic fertilizer as an alternative to chemical fertilizers was confirmed. The unexpected results were obtained. In addition to research, reviewing of the test results will continue. Chemical fertilizers are not produced in Kyrgyzstan. To develop environmentally sustainable food production by utilizing the right amount of organic fertilizer is expected.

However, influence of the lack of machine appeared here. Farmer can make the compost by manual labor in small scale, but compost making cannot do by manual work when farmer increase cultivation area with the understanding the effect of the organic fertilizer. A simple compost windrow-forming car and a compost turner was designed to develop low cost manure management systems by KNAU and JICA (**Fig. 5**).

The compost windrow-forming car enables the formation of windrows in a short time. In order to pulverize and mix manure by upper and lower beaters in the process of windrow forming, conditions such as aerobic respiration and mixing of materials which play a major role in composting were fulfilled. This car can also be utilized as a manure spreader by folding the windrow-forming cover. The compost turner is equipped with a tractor on the rear right side. Two beaters for mixing and pulverization are equipped to the front parts. Windrows with a width of 2.5 m and height of 1.5 m are turned at the speed of 4.5-5.1 m/min. Combination of the compost windrow-forming car and the compost turner enables to construct a simple composting system for individual farmers or a low cost. However, even this simple and low-cost machine is not available for many farmers who do not have a tractor.

The agriculture mechanization of Japan has a big help by the agriculture mechanization promotion law and influence of the financing system. Kyrgyz does not have the system like this at all.

Under these situations, the renewal of tractor and combine harvester, and the maintenance of the grass cropping system are required.

Machinery Policy

There are several signals that an active private sector (including dealers, representatives, country branches and assemblers of agricultural machinery) is beginning to emerge in the Kyrgyz. The farmer of Kyrgyz purchases the used goods machine for spare parts who know technically well cheap parts as well as brand products (**Fig. 6**).

Presently, there is no manufacturer producing agricultural tractors and combine harvesters in Kyrgyz. Agricultural machinery importers in Kyrgyz are based in Bishkek or the suburbs of Bishkek. They usually have machinery parking area and spare-parts storage attached to their sales shops. Tractors and combine harvesters which were imported from Belarus before independence in 1991 are still widely used among individual farmers. Since farmers have been using them since the Soviet era and their basic design has not changed for a long time, the farmers themselves usually undertake the machinery maintenance and repair work.

Leasing in Kyrgyz started developing in 2002, and by the end of 2003, 165 leases had been financed for a total value of around USD 1 million. Three banks were involved in leasing, as well as FCCU (Financial Company for Credit Unions), which works exclusively in the credit union system. The lease amount of money was heavily tilted towards the agriculture sector. However, since then, leasing activities have slowed down significantly, and from 2005 to 2008 only 238 leases were provided for a total of USD 3.8 million. A lease system was considered as a replacement thing superior in a traditional loan, but this lease system did not work in Kyrgyz.

Fig. 6 Agricultural machinery dealer in Bishkek

In “The Government’s Program and Plan on Transition of the Kyrgyz Republic to Sustainable Development 2013-2017”, “provision of services and market infrastructure for agricultural production” is indicated. According to this plan for agricultural investment projects, the aims for agricultural mechanization, such as “funding for financial leasing of agricultural equipment” and 2.5 million USD are calculated for the budget of 2013 to 2014, as an estimated cost. Although Ministry of agriculture designed development policy about agricultural sector by cooperating with FAO in 2012, the government did not approve of the policy plan due to the lack of concreteness of the investment plan. It is hard to say that the financing system is administrated smoothly.

The policy of the Ministry of Agriculture (Agricultural Mechanization and Electrical Supply part) often changes, and, only four people in this ministry are in charge. Under the current institutions, it is hard to cover all operations of the department. In addition, there was one office staff for each district around the country before the organizational change in 2012. As a result of this change, 29 staff members are covering 40 districts even personnel of the Ministry of Agriculture are less than 100. Besides, it is likely that the number decreases year by year. By the way, the number of the staffs of Japanese Ministry of Agriculture, Forestry and Fisheries is 22 thousand people.

Kyrgyz National Agrarian University is the only agricultural university in Kyrgyz, and there is the agricultural machinery course. Currently the faculty is using decrepit machines of the former Soviet Union for researches, lectures and practical trainings without enough of a budget allocated; hence there are difficulties in launching new research activities and the development of human resources using new machines and equipment.

Kyrgyz has no public extension service. It is difficult for farmers to access technical information on cultivation, and operation and maintenance of machines and equipment. On the other hand, various vocational schools exist countrywide, and some schools have agriculture and agriculture machinery courses. These schools could be utilized for the re-education of farmers on cultivation techniques. Since most schools were established in the Soviet Union era, teaching facilities and equipment are old-fashioned and do not meet the needs of farmers. Improvement of teaching facilities and equipment for capacity development of farmers should be considered.

To urgently solve the issue of agriculture mechanization, the discussion of finance and an administrative system in parallel is needed. Furthermore, it is thought that the improvement of agriculture education by the practical fusion of the Ministry of Agriculture and the Ministry of Education is the new first step of the agriculture development.

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Agricultural Machinery Market of the Russian Federation

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Abstract

This paper presents briefly the current status of agricultural machinery industry of the Russian Federation. Trends and dynamics of the Russian agricultural machinery market have been presented in this study. The authors analyze the structure of the market of agricultural machinery and determine the current state of the distribution of agricultural machinery in Russia.

Introduction

One of the main sectors of the economy in Russia is the agricultural machinery market. Russia has historically been an agricultural country and it has the potential to increase food production. As agricultural development nowadays has become one of the government priorities, the importance of high-quality agricultural machinery provision is increasing. Effective functioning of the agro-industrial sector has a positive effect on the country's food security, because technical support for agricultural production is one of the key elements in the formation of food security in any country. Therefore the issue of sustainable development of agricultural machinery industry is extremely important.

The purpose of this article is to analyze the current status of agricultural machinery industry of the Russian Federation, trends and dynamics of the Russian agricultural

Table 1 Fleet of main agricultural machinery in Russia (th. units)

Types of equipment	1990	2000	2010	2011	2012	2013	2014	2015
Tractors*	1,365.6	746.7	310.3	292.6	276.2	259.7	247.3	233.6
Plows	538.3	237.6	87.7	81.9	76.3	71.4	67.8	64.1
Cultivators	602.7	260.1	119.8	114.1	108.7	102.2	97.9	93.2
Seeders	673,9	314,9	134	123,6	115,4	107,5	100,7	93,6
Harvesters:	579.8	275.9	105.4	99.9	94	87.8	83.3	78.9
Grain harvester	407.8	198.7	80.7	76.6	72.3	67.9	64.6	61.4
Forage harvester	120.9	59.6	20	18.9	17.6	16.1	15.2	14
Corn harvester	9.7	4.4	1.1	0.9	0.8	0.7	0.7	0.8
Flax harvester	9.1	3.2	0.7	0.7	0.6	0.5	0.4	0.4
Potato harvester	32.3	10	2.9	2.8	2.7	2.6	2.4	2.3
Mowers	275.1	98.4	41.3	39.3	375	35.6	33.9	32.2

*Without trailers (e.g., without mounted earthmoving, reclamation, and other trailers) (Source: Federal State Statistics Service, 2016)

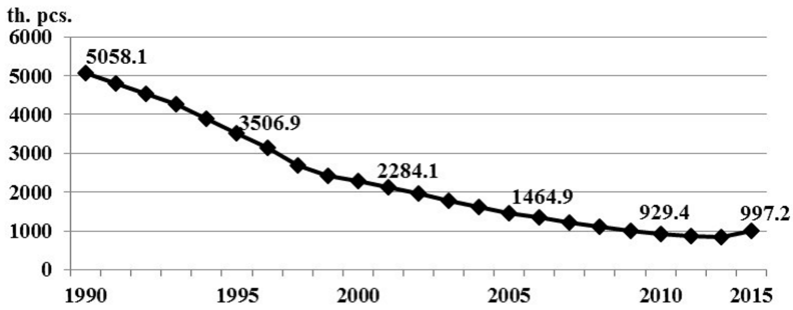

Fig. 1 Agricultural machinery (th. units) manufactured by domestic enterprises (Source: Federal State Statistics Service, 2016)

machinery market. This paper gives the structure of the market of agricultural machinery and determines the current state of the distribution of agricultural machinery in Russia.

Details

Current Situation of Agricultural Machinery Industry in Russian Federation

Table 1 shows that during the period 1990-2015, Russian motor and tractor fleet worsened and the availability of the main types of farm machinery decreased from year to year. About 60% of the tractors and 50% of the grain harvesters in Russia were over 10 years old in 2015, which means that agricultural fleet in Russia is outdated (Ministry of Industry and Trade of Russia, 2016).

Russian domestic agricultural machinery industry experienced a significant reduction in both fleet and equipment in the period from 1990 to 2014. For example, the amount of required equipment was over 6.5 times lower in 2014 in comparison with 1990 (**Fig. 1**). This has affected the lack of equipment and the decrease in labor productivity in agriculture. However subsidy program, which allows to upgrade of outdated agricultural equipment, has led to the domestic production of agricultural equipment increasing by 30% (The Federal State Statistics Service, 2016).

On September 2016, 28 thousand people were employed in the industry (less than 0.1% of the total number of people employed in the Russian economy), and the number of people employed in the industry has a constant downward trend. Thus, companies producing domestic agricultural machinery currently contribute only 0.08% to its gross domestic product (GDP) (Rosagromash, 2016; Snimschikova and Semenenko, 2014). The low GDP share is caused by several factors affecting the agricultural engineering in Russia. Low solvency of Russian agricultural producers, for example, leads to the equipment manufacturing plants experiencing a low domestic demand for machinery and equipment. As a result, agricultural machinery plants operate at 30%-40% of their production capacity (Chernoivanov *et al.*, 2012).

Nowadays tentatively two thousands Russian companies are involved in the production of agricultural machinery and its components, and for 57 of these companies it is the main activity (Rosagromash, 2016).

Russia has three main manufacturers of agricultural equipment: Combine Plant Rostselmash Ltd., Concern Tractor Plants, and JSC Petersburg Tractor Plant. Overall, 92% of the equipment produced by these three companies is manufactured in Russia (localization level of 92%).

Combine harvesters sector, in turn, is represented by 12 plants, with only 4 manufacturers producing domestic models (e.g. Cheboksary machinery plant -100 units, “Nazarovoagrosnab” -6 units, JSC “Remselmash” -46 units).

Among the manufacturers in the Commonwealth of Independent States (CIS) countries, the leading position is occupied by Belarusian companies. For example, Minsk

Table 2 Consolidated table of indicators characterizing the development of machinery market and equipment for agriculture and forestry

	2012	2013	2014	2015
Russian market of agricultural machinery, bn. rub.	115	107	106	93
Russian agricultural machinery market changing in actual prices,% to previous year	16	-7	-1	-12
Tractor sales dynamics for agriculture and forestry, th. units.	46.7	45.6	44.2	26.9
Combine harvester sales dynamics, th. units.	5.0	5.9	5.4	5.1
Import dependence level:				
The share of imported agricultural machinery in the agricultural market, %	39	48	48	49
Export development level:				
The ratio of agricultural machinery export to sales on the domestic market, %	3.8	4.1	3.9	7.0
Number of agricultural machines, units per 1000 ha of arable land:				
Tractors	3.9	3.6	3.5	3.3
Combine harvesters	3	3	2	2
Upgrade technology ratio (index value for the year), %				
Tractors	3.3	3	3.2	3.1
Combine harvesters	4.9	4.7	5.2	5.3

Source: Federal State Statistics Service, 2016, Russian association of agricultural equipment “Rosagromash”

Tractor Works produces approximately 30 farm tractor models and has three assembly plants in Russia with localization levels up to 15%, and Gomselmash, which produces grain and forage harvesters, has localization levels up to 25%. The Ukraine has several manufactures, the leader being Kharkiv Tractor Plant, with localization levels below 10%.

Among the global foreign manufacturers of agricultural machinery are John Deere, CNH Industrial, Claas and AGCO. All of these companies have assembly facilities in Russia; however, their levels of localization do not exceed 5-10% (excluding Claas, at 17.30%) (Ministry of Industry and Trade of Russian Federation, 2011; Radishevskii, 2011). **Table 2** lists consolidated indicators characterizing the development of machinery market and equipment for agriculture and forestry.

Trends and Dynamics of The Russian Agricultural Machinery Market

According to the Russian Association of Agricultural Producers "Rosagromash", the volume of Russian agricultural machinery market was estimated at 93 billion rubles (about USD 1.5 billion) in 2015. The main share of the market still holds for import (50%) (**Fig. 2**).

In terms of commodity structure, the major share of the agricultural equipment sales value in the Russian market takes only two positions: wheeled tractors and combines (60%) (Butov, 2016).

As seen from the **Table 3**, the imported machinery takes the main share in the structure of sales (including supply from Republic of Belarus). However, sales of domestic companies are increasing: it has grown for two years from two to ten percent. On the other hand, against falling market the import of used equipment consolidated its position. Sales of Belarusian tractors occupy half of the Russian market. The second most important channel of machinery supply for the Russian tractor market is the import of other (apart from the Republic of Belarus) countries, almost 90% of the channel to account for only three countries: China, Japan and Ukraine (**Tables 4** and **5**).

Russia does not have a techni-

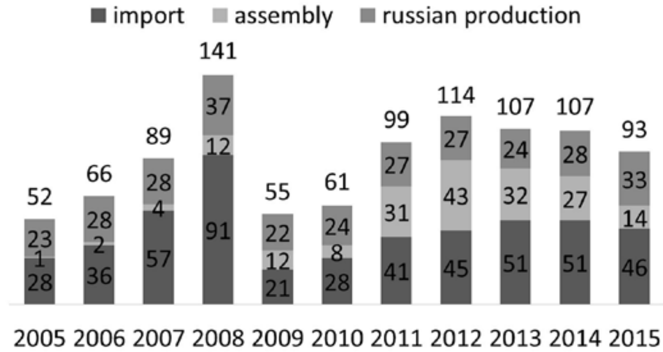

Fig. 2 Market structure of the agricultural machinery, bn. rub. (Source: Russian association of agricultural equipment "Rosagromash")

Table 3 The dynamics of tractor sales for agriculture and forestry, units

	2013	2014	2015
Domestic brands	934	3 ,447	2, 610
Foreign machinery assembled in Russia	2, 683	2, 255	1, 473
MTZ tractors assembled in Russia	3, 539	2, 574	2, 455
Import from the Republic of Belarus	23, 246	18, 248	11, 709
Import of new without the Republic of Belarus	11, 913	14, 038	5, 814
Total new	42, 315	40, 562	24, 061
Imports of used cars	3, 244	3, 626	2, 791
Total	45, 559	44, 188	26, 852

Source: Federal State Statistics Service, 2016, Russian association of agricultural equipment "Rosagromash"

Table 4 Import of wheeled tractors for agriculture and forestry (excluding supply from the countries of the Customs Union), units

Country	2014	2015	2016
China	8, 997	11, 100	4, 187
Japan	3, 076	3 429	2, 589
Ukraine	826	916	611
France	36	67	261
Hungary	0	186	190
Germany	356	264	130
India	54	5	120
South Korea	582	225	98
USA	397	615	90
Italy	55	129	49
Lithuania	45	40	36
Finland	53	93	29
Turkey	185	134	22
Canada	5	40	18
Great Brittan	43	95	12
Others	101	88	15
Total	14, 811	17, 426	8, 457

cal capacity that is adequately self-sufficient for its food security, for example, in 2014 the share of the imported machinery in Russian agricultural equipment stock was 65% for tractors, 19% for grain harvesters and 22.9% for forage harvesters (The Federal State Statistics Service, 2015).

According to the Development Strategy of Agricultural machinery industry of Russia until 2020, one of the main problems of Russian agricultural machinery market is the lack of stable purchasing power in the domestic market demand. Sales of agricultural equipment on the Russian market declined from 2012 to 2015. Thus, its capacity was estimated at 114 billion rubles in 2012 and it was only 93 billion rubles in 2015. From the standpoint of sales in volume terms, sales of tractors decreased from 46.7 thousands units in 2012 to 26.9 thousands units in 2015, while sales of combine harvesters fell from 5.9 thousands units in 2013 to 5.1 thousands units in 2015.

Export of Russian agricultural machinery is carried out mainly to Kazakhstan, Uzbekistan and Kyrgyzstan, but it does not resolve the problem of production distribution for manufacturers. The main kinds of exported products are combines, tractors and seeding machines. Agricultural exports of Russia for the 2015 amounted to 12% of total output which on 5% greater than for the 2014, and had an export value of 6.7 billion rubles (Rosagromash, 2016). However, the ruble devaluation against the dollar and euro had a considerable impact on trade. Imported agricultural machinery is becoming less competitive in price. Therefore, sales of domestic agricultural vehicles are growing.

At the same time, there is no developed service network, there are difficulties with currency conversion; there are complicated political relations with Ukraine; and foreign competitors invade the market of Kazakhstan.

Besides for this particular market seasonality is of current importance, hence, there are gaps in the flow of funds. The real situation is made worse with the following factors. Stereotypes concerning the necessity of repairing the equipment made by foreign manufacturers create difficulties while obtaining adequate economic evaluation. For that reason untested and outdated equipment, which is in need of constant and expensive repair, very often is imported to the Russian Federation. Lack of information on specific character of technical support for the equipment purchased. Beyond the warranty period agrarians often experience difficulties when buying essential spare parts without direct access to the market, hence resulting in non-scheduled costs. Arrears to budget, financial and personnel problems, market imbalance, i.e. existence of shortage of products and extra amount of them (extra amount of combines, tractors of medium power) reflect mainly general regularities of restricting business activity in the industry.

As for use of marketing and logistics approach in the sphere of technical maintenance of agriculture, this direction is studied not enough in Russia. In recent years, the methods of operating business have significantly changed. These changes have led to a new phenomenon, when, along with product quality and price a decisive factor, determining the success of the company’s activity, growth in sales of their products, became the ability to sell their products, using the integrated chains of supply from manufacturer to consumer, creating additional value for clients and organizing high quality service (Morozova, 2006).

Table 5 The dynamics of combine harvester sales, units

Supply	2013	2014	2015
Domestic brands	3,083	3,056	3,246
Brands of Republic of Belarus, Russian assembly	852	1,085	1,078
Foreign machinery assembled in Russia	890	734	326
Import from the Republic of Belarus	302	343	360
Import of new without the Republic of Belarus	747	208	88
Total	5,874	5,426	5,098

Conclusions

Overall, the significance of the agricultural machinery industry in Russia has greatly increased in recent years. It was promoted by import substitution program, actualized with the devaluation of the ruble.

The tendency of the Russian agricultural market for the last 2-3 years is reducing its capacity. This trend is mainly formed by reducing supplies to the market from the localized foreign manufacturers assembly plants in Russia and import. Production growth in domestic enterprises does not cover the total market decline.

Among the problems of the Russian market of agricultural machinery first of all one should mark out the following: sharp drop of production of agricultural machinery; insufficient level of solvency of farmers; excessively high load of plough land per tractor; rapid promotion of imported machinery and equipment to the national market; insufficient level of technical and servicing maintenance especially of consumers of used imported machinery.

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Government Policy of Agricultural Machinery in the Russian Federation

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Abstract

The article provides a brief analysis of the current state of the Russian agro-industrial complex and highlights its major issues, such as energy supply levels and growing price disparity. The paper covers main government policies and results of their implementation with regard to the agricultural machinery industry.

Introduction

Russian Federation has traditionally been a country with a developed agricultural sector. Despite the difficulties that the agro-industrial complex experienced during the post-reform period, the value of agricultural production has been growing in the recent years. Thus, in 2010 Russian government adopted Food Security Doctrine, which illustrates an increase of attention to the issues of food self-sufficiency at the federal level. In accordance with the Doctrine, Russia shall ensure production of the main volume of the food consumed in the country through its own production. In addition, maintaining and strengthening the current position of the Russian Federation as one of the leading grain exporters also remains relevant.

In the modern conditions, it is possible to address the problems faced by domestic agricultural producers only with the active use of modern agricultural technologies. Implementation of such technologies can be provided by the comprehensive use of agricultural machinery. This is particularly important for crop production, where intensification of production is fundamentally impossible to achieve without applying constantly improving agricultural techniques. In the view of the current political and economic situation, it becomes evident, that the role of the government and its support programs becomes crucial to create a favorable climate for development of agricultural machinery industry, and to minimize the dependence of domestic agribusiness on import technologies and equipment.

Details

Current State of The Agro-Industrial Complex of Russia

Due to its geographical and climatic features, Russian agriculture has a significant potential to provide its population with sufficient quality food products through domestic production.

However, capacity of agriculture is not fully developed owing to a number of reasons, such as for example, deterioration of the material and technical base, low efficiency of the national agro-industrial complex, associated with rising costs of production, high debt load, increasing cost and deficit of credit resources etc.

At present, the share of agriculture in GDP in current prices is 4.3%, while in 1990 it amounted to 15.4%. A declining share of agriculture in gross added value, as well as lack of investment and a decrease in the competitiveness of domestic food products, result in the state being forced to import significant volumes of food from abroad (**Table 1**). This situation hinders development of the agro-industrial complex and poses a threat to the food security of Russia.

Price disparity occupies a special position among the problems which dominate the agricultural sector, hindering its reforming and development. Price difference is growing not only between agriculture and other industries, but also among the members of the agro-industrial complex itself.

Tables 2 and **3** demonstrate that over the past ten years, prices for production resources have rose disproportionately in comparison with the prices for agricultural products. Under conditions of prevailing price disparity when growth rate of prices for fuel and other energy resources essentially exceed prices for crops, agricultural production becomes unprofitable.

Energy supply of agricultural production determines potential crop yields and is measured in horsepower (**Table 4**). Thus, average energy supply in Russia is 148.8 hp per 100 ha of farmland, in comparison in the Republic of Belarus, it amounts to 240 hp. Per 100 ha, and in the European countries the average is 300 hp per 100 ha. At the same time, yield (t/ha) indicators are: Russia: 2.1;

Table 1 Share of agriculture in Russian economy

	2005	2012	2013	2014	2015
GDP, %	5.2	3.8	3.8	4.0	4.3
GDP, bn. rub	-	669,269	710,167	791,997	832,326
Investment in fixed assets, %	3.7	3.5	3.7	3.6	3.5

Source: Federal State Statistic Service, 2016

Table 2 Average prices for main agricultural crops in Russian Federation, th. rub

	2012	2013	2014	2015
Grain and legume	6.42	6.82	6.62	8.68
Wheat	6.40	6.72	6.85	8.77
Rye	4.5	4.91	4.69	5.25
Buckwheat	10.53	7.21	8.37	20.14
Corn	6.75	6.58	5.79	7.85
Barley	5.90	6.37	5.52	7.34
Legumes (including soybean)	8.33	8.39	8.46	13.07
Oats	4.59	5.78	4.96	5.49
Sunflower seeds	12.46	12.02	11.53	20.28
Sugarbeet	1.42	1.53	1.87	3.07
Potatoes	7.64	9.45	12.89	13.19
Vegetables	24.51	31.46	36.31	45.49
Tomatoes	47.68	50.59	57.96	63.17
Cucumbers	54.39	56.25	62.03	67.89
Onions	5.73	7.31	10.59	13.98

Source: Federal State Statistics Service, 2016

Table 3 Average prices for main types of industrial products purchased by agricultural organizations, th. rub

	2012	2013	2014	2015
Combine harvester	5,779.83	6,069.92	6,334.24	6,233.27
Tractor	2,322.51	2,640.676	3,107.81	3,482.639
Car	1,136.6	9,700.73	1,024.58	1,158.931
Truck	1,901.21	1,396.84	1,419.25	1,712.61
Mineral fertilizer				
mineral nitrogen fertilizers, per t	29.83	32.44	34.79	42.35
phosphate fertilizers, per t	31.22	25.11	26.56	29.87
potassium fertilizer, per t	19.87	24.39	24.24	32.61
Fuel				
petrol, per t	28.15	32.18	38.77	38.99
diesel fuel, per t	24.62	31.17	33.01	34.28
lubricating oil, per t	51.05	46.04	62.39	80.99
Electricity, th. kWh	3.51	4.03	4.39	4.59
Natural gas, per th. m^3	4.26	4.95	5.40	5.73

Source: Federal State Statistics Service, 2016

Belarus: 3.2; EU countries: 6.9. The load on one tractor in Russia is 247 ha, in the USA: 38 ha; in France : 14 ha; the load on one grain harvester: Russia: 354 ha; USA: 63 ha; France: 53 ha.

Subjects of the Russian Federation vary significantly in terms of conditions for performing agricultural production. For example, energy supply in the Krasnodar region is 192.7 hp per 100 hectares of arable land, with an average yield of grain: 5.1 t / ha, and in the Orenburg region: 82 hp per 100 hectares of arable land and yield productivity of 1.2 t / ha. Thus, in Russia while load per single machine is much higher than in developed countries, energy supply is several times lower. To curb the tendency, it is necessary to provide agricultural producers with a number of new powerful highly efficient machinery. However, it is a complicated goal, since Russian fleet of agricultural machinery has a very large proportion of outdated equipment, aged over than 10 years: tractors: 59.7%; grain harvesters: 45.6%; forage harvesters: 44.6%. The average age of tractors is 20 years, for grain and forage harvesters it amounts to 8 and 7 years, respectively.

Today, there is a high proportion of imported equipment in the total amount of agricultural machinery. This share has increased significantly in 2016 compared to 2015. Imported tractors share in 2015 was 65%, and in 2016 was 68%. Accordingly, the percentage of imported grain harvesters for the same period amounted to 19% and 22%, forage harvester 23% and 21%, respectively. These figures illustrate that the level of tractor production in Russia is negligible and tractor industry should receive government attention first. According to the data of the regional authorities of the Russian Federation, responsible for regulation of agriculture the demand for agricultural machinery is the following: tractors: 104,249 units in the amount of 176.737 billion rubles, grain harvesters: 3,3875 units (for 546.81 bn rubles), forage harvesters: 4,647 units (for 13.941 billion rubles), sugar beet harvesters: 594 units (for 37,205 rubles).

Table 4 Energy supply in agricultural organizations

	1990	2000	2005	2011	2012	2013	2014
Energy supply:							
Total, mn. hp.	419.7	240.0	156.9	106.3	102.6	98.9	97.6
per one worker, hp	50.5	51.3	58.6	69.0	69.8	72.5	74.7
per 100 ha of crop acreage, hp	364	329	270	212	211	201	201

Source: Federal State Statistics Service, 2015

Government Policy and Measures

Today, the priority of state support is given to the industries that are subject to risks of limited demand, recession in production volumes, as well as those sectors that have the greatest potential to expand to new markets, increase production and improve their efficiency. Therefore, the Russian government in Russia has implemented effective measures to support domestic agricultural production and agricultural machinery engineering.

Under the State program of agricultural development and market regulation of agricultural products, raw materials and foodstuffs for 2013-2020 years, the state provides subsidies to manufacturers of agricultural machinery in order to reduce its cost for agricultural enterprises (Russian Federation Government Resolution dated December 27, 2012 № 1432 "On approval of rules for granting subsidies to producers of agricultural machinery". Subsidies and discounts are available for 59 items of agricultural machinery. During the years 2013-2015 Russian government allocated 7.195 billion rubles. The amount of subsidies allocated to the producers in 2013 amounted to 430 million rubles, 1570 million rubles – in 2014, 5,195 and 1,116 million rubles in 2015 and 2016, respectively (Ministry of Industry and Trade of Russian Federation, 2011).

In the years 2015-2016 in accordance with the Resolution № 1432 Russian government subsidized agricultural machinery producers 25% of cost for domestic agricultural machinery and equipment. In 2016, for instance, the volume of support received by large domestic manufacturers was as follows: Combine Plant "Rostselmash": 645,291.7 mn rubles, St. Petersburg Tractor Plant: 193,966.3 mn rubles, and JSC "Eurotechnica": 55,807.9 mn rubles. Thus, in 2016 Russian machinery enterprises increased their production and sales by 1.5-3.5 times compared to 2014.

As a result, farmers and agricultural organizations received an opportunity to significantly upgrade their fleet of agricultural machinery, and foreign firms became able to actively build and develop machine-manufacturing plants on the territory of Russia. For example, one of the program results is the decrease in volumes of agricultural machinery whose age exceeded 10 years. Thus, in 2015 compared to 2014 the share of outdated equipment declined by 0.7% for tractors, and by 1.8% for combine harvesters amounting to 60.3% and 45.4%, respectively (Kamaldinova, 2014).

Another important state support measure of agricultural machinery manufacturers is purchase of machinery on the terms of the Federal Leasing (company "Rosagroleasing"), where the state subsidizes the interest rate. In the conditions of high inflation, 5-10% per year and an average five-year lease the purchase of machinery at times appear to be even more profitable than the under the program № 1432.

In 2016, Russian government approved a new anti-crisis plan. According to clause 15, 10 billion rubles are going to be allocated for "Implementation of agricultural machinery support programs, including the renewal of the machinery fleet in agricultural universities" in order to stimulate demand for Russian agricultural machinery. The aim is to enhance technological level of agricultural machinery, and substitute imports with high quality domestic equipment.

A major problem impeding further development of agricultural machinery industry and effective implementation of support programs is legal environment. The legal "ground" in Russia, unfortunately, is not only infertile but also hostile to the attempts to grow efficient agro-industrial enterprises. For example, large manufacturing and instrument-making plants which were operating in the early 1990s, nowadays have been replaced by shopping centers and malls. There is no document or law to prevent or slow down this process. One of the main reasons having a negative impact on the availability of manufacturing plants is high refinancing rate of the Russian Central Bank. At times, interest rate on bank loans reaches 25%. Therefore, high price of bank credits acts as a barrier for investment in the construction and development of industrial enterprises. As a result, foreign companies which have an access to cheaper credit resources in the European banks get a significant advantage compared to the Russian manufacturers of agricultural machinery. Apparently, this is the reason which enabled German company Claas to build a new manufacturing plant in the Krasnodar region, where production localization of harvesters and tractors exceeds 50%. At the same time, there are no new agricultural machinery plants that have been built in the recent years.

Therefore, it is an issue of first-priority for the Russian government to improve and provide regulatory and legal conditions which will stipulate adoption of new support programs, favorable environment for investment, and, therefore, in accelerated development of the agricultural machinery industry, as an important sector of Russian economy.

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Current Situation, Issues and Trends of Mechanization for Grain Harvesting in the Russian Federation

by

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Abstract

Russian Federation is one of the major grain producers and exporters in the world. The present paper illustrates the current state and identifies trends of mechanization for grain production in Russia based on the example of the Krasnodar region, which is a leading grain producer in the country.

Introduction

Territory of the Russian Federation occupies almost 20% of the planet's land and represents a wide variety of soil types and agro-climatic conditions. Efficient use of agricultural machinery, as well as a complex of tillage and harvesting methods is critical to ensure high quality domestic agricultural production.

Krasnodar region, located in the South of the Russian Federation, is the breadbasket of Russia and the leading agricultural producer and exporter. It supplies large volumes of agricultural commodities to the industrial centers, such as Moscow, St. Petersburg, the Far Northern areas, and other parts of the country. Among 85 federal subjects of the Russian Federation Krasnodar region produces the largest share of agricultural products: corn: more than 40%; rice: more than 80%; wheat: 15%; sugar beet: 20%; sunflower: 17%.

Russian Federation holds the position of one of the biggest world grain exporters with the Krasnodar region (also known as "Kuban") playing a major role in the process. Kuban holds the first place in domestic grain production (**Table 1**). Thus, in 2015, for example, regional farmers and agricultural organizations produced a total of 14 million tons of grain, in 2014: 13.4 million tons. The average yield productivity of grain for the last 15 years amounted to 5 tons per hectare.

Therefore, Krasnodar region provides an opportunity to consider the current situation and trends of the agricultural mechanization development throughout Russia.

Details

Mechanization of Grain Production in Krasnodar Region

Grain accounts for 56% of the total sown area of agricultural crops sown in the Krasnodar region. Agricultural organizations are the main grain producers with a share of 75% and occupying 74.3% of the acreage. At the same time 20.9% of the fields belong to peasant households, and 4.8% belong to private farms. There are 468 agricultural companies operating in the region. An average company owns 5 thousand hectares of sown land, 336 employees, 1 thousand cattle, 2.2 thousand pigs.

Since 1990 to 2010 the amount of technical equipment in the region decreased significantly, especially with regard to seeding and grain harvesting machinery, eventually increasing the load per one machinery unit. Therefore, in the current situation of machinery deficit the necessity to improve efficiency of grain harvesting technologies and enhance the use of existing machinery has become an issue of national importance.

Krasnodar region represents a wide variety of landscape and topographical conditions, soil types and their properties, moisture conditions. The diversity stipulates the need for comprehensive mechanization of agriculture and machinery adapted for all types of field work to comply with the different soil-climatic zones of the region.

Tractor is the key unit of Russian agriculture. The large farms and holding companies in Krasnodar region widely use tractors of Category 5 drawbar with all-wheel drive, such as domestically produced "Kirovets" K-701M, R-744 and R-700A, "Kirovets" ATM-3180, and foreign CLAAS, John Deere, New Holland, Buhler, Challenger, Massey Ferguson and others.

Smaller agricultural enterprises use Category 2 and 3 drawbar tractors, e.g. wheel tractors HTZ-121, T-15K, T-150, VT-130K《Minsk tractor plant》, "Lipezk tractors", and crawler tractors DT-75D, DT-75N, DT-175M, VT-100, HTZ-180, HTZ-200, and others.

Sowing process of grain crops in agricultural organizations of the region is performed using such seeders as SZ, SZT and SZP - 3.6 with double disc coulters. Moreover, when performing sowing process with application of energy-saving techniques, such as minimum and "zero" tillage, agricultural companies use such seeding complexes as "Bereginya", SPP-7,2, Burgo, Gaspardo, John Deere, Agrator and other.

Harvesting is the final and the most labor intensive stage of agricultural production, which accounts for more than half of labor expenses and financial costs in Russia.

National scientific institutions develop, approve and timely update agro-technical requirements for harvesting of grain crops. The main indicators defining effectiveness of the harvesting process are yield quality and the amount of harvest losses. The following general requirements are used for defining quality of grain harvesting.

1. The degree of grain threshing for seed material is no more than 1%; for food purposes and no more than 2.0% for animal feed.
2. Cleanliness of grain from impurities in the harvester hopper must be at least 96%.
3. Total losses of grain during threshing are allowed to be in the limits from 1.5% to 2.0%.
4. Normal height of the cut is considered 15 to 18 cm, depending on the height of the stem and crop lodging (up to 5-6 cm).

Methods and periods of harvesting have a major impact on the overall yield. Research in various regions of Russia has shown that the greatest amount of grain harvest (e.g. wheat, rye, barley, oats) can be obtained by using direct harvesting method in the middle or at the end of the ripening period. The yield decreases rapidly already on the 3-4 day of the full ripeness; harvesting

Table 1 Grain production in the Krasnodar region

	2011	2012	2013	2014	2015
Wheat:					
total production, th. t	7,203	4,493	6,954	7,642	8,452
sown area, th. ha	1,307	1,128	1,387	1,398	1,470
yield, t/ha	5.5	3.9	5	5.4	5.7
Rice:					
total production, th. t	824	857	727	823	845
sown area, th. ha	135	133	126	131	134
yield, t/ha	6.1	6.4	5.7	6.2	6.3
Corn:					
total production, th. t	2,246	2,753	3,293	3,310	3327
sown area, th.ha	470	657	621	622	622
yield, t/ha	4.7	4.2	5.3	5.3	5.4
Barley:					
total production, th. t	836	340	752	789	793
sown area, th. ha	155	92	142	158	133
yield, t/ha	5.4	3.7	5.3	5	5.9

Source: Krasnodar Department of Federal State Statistical Service http://krsdstat.gks.ru

Table 2 Technical availability in agricultural organizations of the Krasnodar region

	1980	1990	2000	2005	2006	2007	2012
Machinery fleet, th. units:							
tractors	53.2	59.8	45.4	35.5	33.3	32.3	29
plows	23.4	22,8	12.9	8.1	8.1	7.2	11.5
seeders	32.4	23.2	13.3	10.3	8.4	8.2	5.1
grain harvesters	19.5	13.6	7.7	5.9	5.8	5.7	5.4
Load of arable land per 1 tractor, ha	79	65	85	118	125	133	128
Crops acreage per one grain harvester, ha	113	120	238	261	267	270	300

after more than 20 days of ripeness results in substantial yield losses of 40-50%.

Direct harvesting remains the main method and is used in 90-95% cases. It is applied when harvesting uniformly ripening, high-yielding cereals without weed infestation. The direct method is also largely used when it is impossible to apply swath (two-phased) harvesting, e.g. when processing thinned out crops (with less than 300 stems per 1 m^2) and undersized crops with a height less than 60 cm. Period of direct harvesting amounts to 5 days, and exceeding this time limit can result in large losses of yield.

The major part of harvesting process is performed using the following types domestic machinery, such as SK-5 by "Niva", "Enisei-950", Vector, Don-1200, Don-1500, "Akros", and foreign combine harvesters Case, CLAAS, Fergusson etc.

According to the studies of the Russian Scientific Research Technological Institute of Mechanization and Electrification of Agriculture grain stripping method is by 3.5-4 times more effective compared to the combine technology. However, its use largely depends on the level of infestation, uniformity and lodging of plants, which are the main factors constraining the volume of its implementation. The advantages of stripping harvesting are reduction of energy consumption of the harvesting process, higher productivity and lowered production costs. Application of stripping method creates favorable conditions for introducing resource-saving no-tillage technology, as well as direct seeding of stubble and green manure crops.

The non-grain part of cereals is harvested by applying two technologies: mulching and baling of hay. Baling is divided to three more options: compressing into bales, using "Quadrant-3400", gathering of straw, using baler TPF-45, and gathering of straw from the bales, mulching and spreading, using rotary chopper RIS-2.

Straw is harvested for household needs only on the 14% of the area. It is usually crushed and scattered across the field, or embedded in the soil after the stripping. It is a widespread practice to use harvested straw as a fertilizer. Thus, for example, 1 ton of chopped straw when mixed with nitrogen fertilizer in proportion of 10 kg per 1 ton of straw is equivalent to 3-3.5 tons of high-quality manure. According to the studies of a well-known Russian scientist N.G. Malyuga, embedding straw in the soil is also an effective method to prevent degradation of Kuban chernozem land.

Table 3 Comparison of economic efficiency of combine harvesters

	Don-1500B	New-Holland TX-65	Mega-208	Case 2366
Country of origin	Russia	USA	Germany	USA
Productivity per 1 hour of operational time, (t/h)/kg·f[1]	2.0	2.84	2.79	2.84
Variable costs per 1 harvester, th. Rub.	431.5	813.5	914.5	662.5
including: depreciation	206.9	530.2	615.5	412.5
labor cost	47.6	46.6	45.3	46.1
maintenance and repair	84.4	149.3	173.3	116.2
harvesting cost, Rub: per 1 t	287	542	609	441
per 1 ha	862	1,626	1,829	1,325
Annual income per 1 harvester, th. Rub.	1,011	660	558	811
Capital investment, th. Rub	4,882	8,759	10,167	6,813
Efficiency of investment	0.41	0.15	0.11	0.24
Payback period, days	42	100	137	63

Harvesting process in Russia is associated with various problems: grain losses during harvesting and transportation reach up to 10% (excluding the physiological losses), grain threshing is 2 to 4.5 times higher than allowed, and in the most regions of the country duration of the harvesting period is longer than the norm by 4-5 times. These problems result in biological losses of grain up to 10-13 kg per 1 ton of crop. In this regard, agricultural machinery industry is challenged to develop combine harvesters aimed at addressing these issues.

Foreign Agricultural Machinery for Grain Production in Russia

At present, Russian agricultural machinery is not fully able to meet the needs of the agricultural producers and farmers. The model range and characteristics of domestically produced machinery require update and improvement. Decrease in the domestic fleet of agricultural machinery and increased load per one combine harvester from 178 to 304 hectares resulted in increasing import levels of foreign machinery and equipment to fulfill the urgent need for agricultural modernization.

In the last five years import of combine harvesters amounted to more than 4 thousand units. Modern highly productive combine harvesters such as Lexion-600, Case, New Holland have changed the view of domestic experts on machinery in terms of speed, quality, operating conditions. However, contemporary powerful harvesters have a serious disadvantage. Due to their large size and mass (up to 20 tons), plus weight of grain (about 10-20 tons) the combine harvesters contribute negatively to soil compaction, which is further aggravated by the necessity to use heavy grain carts, thus, resulting in reduction of soil fertility and decrease of yield.

Russian machinery was found to be more economically efficient under the conditions of domestic agriculture. Economic efficiency calculations have shown that although foreign combine harvesters have higher reliability compared to the Russian models, its implementation is associated with larger operating costs. Data in the **Table 3** shows that harvesting cost using foreign machinery is 1.5 to 2 times higher, while annual revenue is significantly lower than that of the domestic Don-1500B harvester. At the same time investing in purchase of a Russian model is supposed to be 1.7 to 3.7 times more effective than investment in the foreign analogue. Therefore, application of combine harvester Don-1500B is considered more economically efficient.

Table 4 provides a comparison of major efficiency indicators for domestically manufactured combine harvesters Don-1500B, Don-2600, SK-5M, Vector and foreign (US, German and Belarusian) models of harvesters. Don-1500B was used as a reference standard for comparison. Thus, based on the majority of indicators Lexion-480 by CLAAS has shown the best results among other models. Rostselmash SK-5, Vector and Claas Mega-208 appeared to be less competitive compared to the performance of the reference standard model.

Development of Grain Production Technology in Russia

Technical development of grain production is primarily aimed at enhancing efficiency of the industry. Thus, research focuses on the modernization of machinery fleet and mechanization technologies to increase agricultural productivity, reduce energy and fuel consumption and labor costs.

In Russia cultivation of grain crops involves multiple operations, which are associated with passage of tractors and machinery in the field. Moreover, all operations, tillage, fertilization, pre-sowing cultivation, harrowing, and suppression of soil are performed separately. In some cases, the gap between technological operations creates favorable conditions for growth of weeds and general infestation.

Moreover, repeated exposure of soil to pressure of machinery units results in deterioration of natural soil structure and reduction of its fertility. According to calculations, the total volume of tracks made by tractor wheels and crawlers per one cultivation cycle exceeds the cultivation area itself. Thus, e.g. in 10-12% cases various machinery passes the field up to 6-20 times, and in 65-80%: up to 1-6 times. Depth of the compacted soil layer reaches up to 0.6-0.8 m. Therefore, resistance of the compacted soil to tillage operation is increasing, for crawler and wheel tractors: by 25% and 40%, respectively; for heavy machinery: by 60%.

Therefore, to minimize tillage process, it is important to develop combined units able to perform several operations at one pass, to apply soil herbicides, moldboard technology etc. At present, one of such machines applied in Russian agriculture is Vector with working width of 4.2 m, which simultaneously performs 5 operations (Maslov and Heifez, 2016)

Research shows that the optimum technique of pre-sowing cultivation needs to include two passages of machinery. At the first passage, cultivator fertilizes the land, and the second involves a repeated pre-sowing cultivation in the transverse direction, alignment and suppression of soil, and seeding. Studies show that the use of combined machinery units reduces labor costs by 30-50%, fuel consumption by 20-30%, and increase yield productivity of many crops by 10-15%.

Another important direction aimed at mitigating negative impact of machinery on soil is minimization of soil cultivation. New technological methods and machines for soil conservation are being developed. Thus, introduction of headers and reaping machines with enlarged capturing width reduces harvesting time and grain losses by 1.5-2 times, and helps to preserve soil fertility due to a sharp decrease in the number of passes over the field.

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Table 4 Competitiveness level of domestic and foreign grain combine harvesters

Harvester brand	Labor productivity t/man-h	Direct costs Rub/ha	Required number of harvesters per 1000 ha, units	Work quality effect, Rub/ha	Labor safety ratio	Competitiveness indicator
Don-2600	17.8	980	3	692.3	0.85	1.43
KZR-100	11.2	1,102.2	4	285.0	0.85	1.18
Lexion-480	19.0	1,616.3	2	326.3	0.95	1.72
CTS	18.3	1,409.1	3	326.6	0.90	1.33
SK-5M	5.3	1,412.5	9	-165.0	0.90	1.27
Vektor	7.2	1,573.7	6	-165.0	0.85	0.87
Mega-208	9.8	2,653.8	5	-165.0	0.95	0.87
Don-1500B	9.0	1,328.1	5	-165,0	0.85	used as a reference standard

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NEWS

In Memorium – William Chancellor

Dr. William Chancellor passed away on February 16. He was 85 years old. He served AMA as a Co-Editor for 46 years from 1972 to 2017. We wish to express our sincere condolences to his family. The following is a quotation from Inside ASABE - Member News for February 2017.

"Chancellor received a bachelor of engineering degree from the University of Wisconsin-Madison, and masters and doctoral degrees from Cornell University. He joined the University of California-Davis in 1957, and he worked and taught topics relating to soil mechanics, soil-machine relations, vehicle stability and traction, forage harvesting and handling, rice production and processing, economic optimization of farm equipment use, agricultural technology for developing nations, energy relations in agricultural production, and many others. He was a global authority on smallholder-farm mechanization. Following on his early interests in information theory, he was one of the first to recognize the interconnection and substitutability of information and energy in developing more advanced, efficient, and sustainable food production systems.

With an encyclopedic knowledge of everything in the agricultural engineering field, and many other fields as well, he was also the author of a pioneering searchable database of articles and other information that earned him a Presidential Citation from ASABE in 1996. He held a deep concern for the needs and welfare of his students, who have continued his work and influence around the world. Few would have noticed his retirement, in 1994 after 37 years with the university, as he remained a notable presence in the department and on campus, and if approached for advice or assistance, selflessly provided the benefit of his experience, insight, and wisdom.

Chancellor was the recipient of numerous awards serving as testament to the wide recognition and significance of his work, including election to the National Academy of Engineering in 2005. In honor of his great service to the campus, he was recently informed he would be presented with the UC-Davis Medal.

Chancellor was a brilliant scholar, teacher, and mentor. His passing is a great loss for the department and the University. He is survived by his wife and daughter and the rest of his family and friends who have been steadfast in their support."

■■

Role of Agricultural Education for the Development of Agro-Industrial Complex in Primorsky Krai, Russian Federation

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Location of Primorsky krai

Primorsky Krai is a fastest growing region, which is rightfully considered the Russia's gateway to the Asia-Pacific Region: international cooperation developments, enterprises jointly created with foreign companies, large-scale international events would take place. The major investment projects are implemented and the infrastructures are growing rapidly in the region.

Primorsky Krai occupies the south-eastern outskirts of Russia. Its land area is 164.7 thousand sq. km. Primorye refers to the medium-sized territories of the Russian Federation and it is a part of the Far Eastern Federal District (FEFD) (**Fig. 1**).

The region is washed by the Sea of Japan in the south and the east; it is bounded in the north by Khabarovsk Krai, in the west – by China, in the south – by North Korea.

Primorsky Krai is a region where transit trade routes run between Europe and Eastern Asia, between the North-Eastern Asia and North America. Here all transport junctions converge, linking the ports of the region, and land border crossings Russia-China.

The TRANS-Siberian railway, the largest in Russia and in the world, crosses the whole territory from north to south. The main line approaches the sea and ends in Vladivostok, and two more branches approach the ports of Nakhodka, Zarubino and Posyet.

Russia across the territory of Primorye for more than 1000 km bor-

Fig. 1 Location of Primorsky Krai

ders with dynamically developing North-Eastern regions of China and Northern Province of DPRK (about 30 km). Across the Sea of Japan it borders Japan, South Korea and other Asia-Pacific Region countries. Not only Primorsky Krai but other regions of Russia carry out export-import relations with the countries of the Asia-Pacific Region (APR) through the main ports of Primorye to which the branches of the main Trans-Siberian railway approach.

Regional Policy in Primorsky Krai

The unique geographical location determines the special role of the region in realization of strategic and economic interests of Russia in the Asia-Pacific Region. Free access to the Pacific Ocean, peculiarities of geopolitical location, the high significance of transport responsibilities, the vastness and diversity of the territory form a favorable economic and geographical position of Primorsky Krai.

The agro-industrial complex and its primary industry – agriculture – are the most essential and integral part of the economy of Primorsky Krai, where vital products for people are produced, and enormous economic potential is focused (Department of Agriculture and Food Supplies in Primorsky Krai, 2015).

The basic directions of the regional policy in the sphere of agro-industrial complex development are defined by the state program of Primorsky Krai "Development of agriculture and market regulations of agricultural products, raw materials and food supplies for the period till 2020".

Primorskaya State Academy of Agriculture

Nowadays the training of personnel for agro-industrial complex (A.I.C.) of the Far East is one of the priorities. According to the development program of Primoskaya State Academy of Agriculture, the University should become a center of the agricultural educational cluster of the Russian Far East and a driver of the commercialization of applied development (Komin, 2016).

Primorskaya State Academy of Agriculture, the most Eastern Agricultural University in Russia, was established in 1957 by a special resolution of Council of Ministers in the USSR for the transfer of Yaroslavl Agricultural Institute to Voroshilov (in 1958 it was renamed as Ussuriysk), "in order to expand the training of specialists in agriculture in the Far East".

This mission, i.e. the training of specialists for the whole Far Eastern Region, initially entrusted on the Academy by the state, remains relevant today.

The positive prospects of the development in A.I.C. of the Far Eastern Federal District are determined by the state for rapid socio-economic development of the Far East adopted and fixed at the APEC Summit-2012 a few years ago.

Main Priority of the State in the Far East

The purpose of this development was set by V. V. Putin at the Eastern Economic Forum (EEF) in Vladivostok in the end of 2015: to make the Far East "one of the key centers of socio - economic development of the whole country, which must be effectively integrated into the fast-growing Asia-Pacific Region." In addition, the Russian leader mentioned "the expansion of economic freedom and the providing for domestic investors the best conditions for doing business" as the main priorities.

The Minister of Agriculture of the Russian Federation A. N. Tkachev repeatedly emphasized over the past two years that the main priority of the state in the Far East is the realization of the agricultural potential of the Primorsky and Khabarovsk territories, the Amur and the Sakhalin regions through "creating conditions for attracting investors in agriculture and infrastructure projects".

According to A. N. Tkachev, the whole country has the Far East in its sights since the arrival of big investors and nationalized preferences for agriculture are aimed not only to feed the population, but also to enter export markets of the Asia-Pacific Region countries, where today 40% of the population of the planet live.

Priority Development Areas and Free Port of Vladivostok

PDA ("priority development areas") and Free Port of Vladivostok, which are established in accordance with the Federal law in the Far East, should provide a powerful inflow of investments into A.I.C. of the Far Eastern Federal District. Under this law, currently, in the Far East, 12 PDA have been established, 5 of which consider investments into A.I.C. and introduction of the most advanced production technology and agro-processing: PDA "Nadezhdinsky", Primorsky Krai; PDA "Mikhailovsky", Primorsky Krai; PDA "Belogorsk", the Amur Region; PDA "Yuzhnaya", the Sakhalin Region; PDA "Kamchatka", the Kamchatka Region.

The main tasks set before the "agrarian" PDA are the following:

- Strengthening economic positions of Russia in the competitive markets of the Asia - Pacific Region;
- Production of import-substituting products;
- Ensuring food security of the country.

The Geography of the Far Eastern PDA of "agricultural orientation" shows that a special role in these plans belongs to Primorsky Krai, where A.I.C. is growing at priority rates (14% over the last 5 years) as it is, but in gross output of agricultural products according to the results of 2015, Primorsky Krai takes only the 2nd place among the territorial subjects of the FEFD after the Amur Region.

With a focus on the agricultural

sector of PDA it is supposed not only to fully meet domestic demand, but also to establish the growing exports of meat and dairy products to foreign markets, especially to the countries of the Asia-Pacific Region, where today, due to the growth in the living standard, the consumption of healthy foods with the protein content has increased dramatically. **Table 1** shows gross production of agricultural crops in Primorsky Krai in 2015.

According to the forecast of Vladimir Miklushevsky, the Governor of Primorsky Krai, Primorye would have completely satisfied domestic demand for meat and dairy products and it would have entered the foreign markets by 2020. It is assumed that being brought into operation by this time 16 pig farms will exceed the needs of the territorial subject threefold (including recycling), and Primorsky Krai would be ready to help in the implementation of the Import Substitution Program to neighboring regions, and the remaining portion of the pork should be exported.

The agricultural strategy of Primorsky Krai also provides for a substantial increase in the production of vegetables, rice, corn, including their processing.

The investors in A.I.C. of Primorye make a special rate for the output of soya oil, soybean isolate, oil meal, lecithin, etc., keeping in mind the demand for these products in the Asia Pacific market.

Table 1 Gross production of agricultural crops in Primorsky Krai in 2015

Crops	Unit (ton)
Spring wheat	32,120
Corn for grain	179,980
Barley	6,890
Oats	27,550
Buckwheat	940
Paddy rice	50,690
Soybean	262,040
Potato	333,180
Vegetable of open and protected land*	155,030
Root crops	410

*vegetables that grow in the field, and vegetables that grow in greenhouses

Source: Primorstat, 2016

Thus, the state agricultural policy in the Far East, being developed under the banner of "import substitution", "food security" and "market development of the APR countries", solves two interrelated problems: firstly, the achievement of complete self-sufficiency by the territorial subjects of the FEFD, including the supply of products from neighboring regions (e.g., from the Amur region, or Primorye to Magadan and Yakutia), and secondly, the transformation of the Russian Far East into the main supplier of agricultural products (primarily, pork and soya oil) for China, Japan and South Korea, i.e. the agricultural business in the FEFD must become the most important source of filling the state budget.

Agro-Industrial Complex in the Far East

The analysis of the modern age in the agro-industrial complex development (A.I.C.) of the Far Eastern Federal District and Primorsky Krai allows to state that updated trends of agricultural development in the Far Eastern Federal District and Primorsky Krai are:

- Significant growth in the demand for agricultural products and foodstuffs;
- Increase in production of agricultural products and foodstuffs;
- Growth in demand for Russian foodstuffs in Asia-Pacific Region countries;
- Need for attracting innovative technologies and high-technology equipment;
- Building up new production on the territory of the FEFD.

Finally, it means that in the short term (5-10 years) the need for skilled workers in agricultural activities will significantly increase, and the question about the current situation with regards to training of such personnel in the Far Eastern Federal District and Primorsky Krai are rising.

Agricultural Education for Agro-industrial Complex Development

In Primorsky Krai there are 10 public universities, and only 3 of them implement educational programs in agriculture.

It is Primorskaya State Academy of Agriculture that has the largest percentage of the student body. So, about 2.5 thousands people have received the diplomas of Primorskaya State Academy of Agriculture in all modes of study over the last 5 years.

It was the years when positive changes of the state agricultural policy took place in the Far Eastern Federal District, which was reflected in the dynamics of graduate employability of PSAA.

The upward trend of professional employment has every reason to become a steady trend for the period of 2017-2025 taking into consideration prospects and the extent of the plans for the development of agriculture in the Far Eastern Federal District and Primorsky Krai. According to the forecast of staffing requirements in agriculture, prepared by the Department of Labor and Social Development in Primorsky Krai, over the next 5 years a higher demand can be expected, even exceeding the current capabilities of Primorskaya State Academy of Agriculture.

The forecasts of staffing requirement increasing in agriculture are also provided by specialists for labor and employment in the Sakhalin, Kamchatka and Khabarovsk regions. Agronomists, agro engineers, veterinarians, veterinary food hygienists, livestock specialists are in deficiency in the PDA outlook of these territorial subjects.

Thus, today the task of staffing with higher education in A.I.C. of the Far East is solved by the three existing agricultural universities in the FEFD: Far Eastern Agricultural

University, Yakutsk Agricultural Academy and Primorskaya State Academy of Agriculture.

Taking into account development trends in A.I.C. of the Far Eastern Federal District and Primorsky Krai and the corresponding staffing requirement increase in agriculture, appropriate scientific and staffing for the development in A.I.C. of the Far Eastern Federal District and Primorsky Krai are essential up to 2021 and in 2025 perspective. The Development of Primorskaya State Academy of Agriculture shall be determined by the following priorities:

- Trans regionality, multi-functionality and interdisciplinary of the Academy, the ability of the University both to generate and to provide the transfer of modern knowledge and agricultural educational technologies in the educational space of the Far Eastern Federal District and the Asia Pacific Region countries;
- High professional level of teachers employed on the basis of competitions, including international ones, and the existence of specialist training system with academic degrees, including the increasing numbers of master's students and post-graduate students;
- Focus on modern trends of science, the development of high technologies and innovation sector in the agricultural business, science and technology of the Asia-Pacific Region countries, the Far Eastern Federal District and Primorsky Krai;
- A high level of transparency and integration into the international system of the agricultural science and education, possibilities to invite leading specialists from different parts of the world on temporary job;
- Global experience adoption and flexibility for new areas of research and teaching methodology, the competition and the selective approach during the admission;
- Formation of special educational and intellectual environment in the Academy to become a center of agricultural-educational cluster of the southern Far East.

Following these priorities, Primorskaya State Academy of Agriculture has adopted a development Program for 2016-2025, which consists of two timeframes associated with the stages of state planning of A.I.C. development of the Russian Far East. In the period of 2016-2020 the modernization of the Academy and its approval as a key participant in the processes of the territorial and sectorial development will be held, and in 2021-2025 there will be an integration into the agricultural-educational space of the APR and the approval as the center of an educational and agricultural cluster of the Russian Far East and a driver of the commercialization of applied development.

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■■

Present Situation and Future Prospect for Farm Mechanization in Bhutan

by
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Introduction

Bhutan is located in the eastern Himalaya sandwiched between two large countries China in the north and India in the south. Bhutan with a total area of 38,394.00 square kilometers has a total population of 783,766 as of December, 2016 (BSB). Farm Mechanization in Bhutan started only from 1983 onwards with introduction of power tiller received under grant from government of Japan. Till then, the farming practices were all traditional in nature and at household level. Agriculture Machinery Centre (AMC) under Department of Agriculture was established in 1983 to promote farm mechanization programme in the country mainly to reduce drudgery involved. A guideline policy was also framed then emphasizing on the need to provide subsidy on machines, transportation, training and backup services for up scaling this programme. The policy has been carried forward till date. From 2010 onwards, a few private sectors had started to participate in strengthening and promoting the farm mechanization programme in the country through sale of farming tools and machineries.

The government promoted farm mechanization programme through reduced cost price of the machines especially power tiller, sale of other farm machinery at cost price. The transportation, installations and trainings were all provided free of cost to the end users. The technical backstopping charges were also very minimal. Regional centres were also established in western, central and eastern regions to increase the efficiency of the services. From 2009 onwards, 8 more Farm Machinery Sub centres (FMSC) were also established by the government to increase the service delivery.

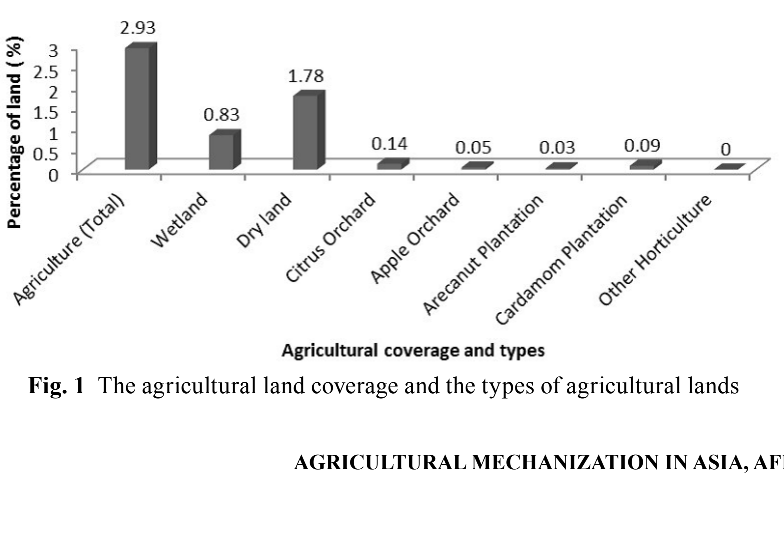

Fig. 1 The agricultural land coverage and the types of agricultural lands

Present Situation

Agricultural Situations

General issues of farmers

Agriculture is one of the primary occupations for Bhutan where more than 60% of the population depend on it even though the agricultural land coverage is just 2.93% over the total area (RNR, 2010) as shown in **Fig. 1**. Tremendous supports for improvements are being provided in this area by the government. Land developments, irrigations, farm mechanizations are the major areas that government is providing support. Farm roads are being built connecting all villages to improve the accessibility and marketing of the produce. Farmers are being encouraged to shift from self-consumption to commercial agriculture where excess produce can be sold. Farmers groups and cooperatives are encouraged to enhance the production.

However, there are still issues that defer farming as an attractive profession even after tremendous support rendered by the government as shown in **Fig. 2**.

Major difficulties faced by farmers are irrigation followed by, lack of farm labourers, wild animal encroachment, shortages of farm machinery and weed control. Interestingly, the lack of labourers is more dominant due to high wages required to be paid to the farm labourers. This clearly indicates there is lack of farm labourer.

Economics Situation in Agricultural Sector

The agricultural situation is also not as lucrative as other sectors even though more hard work is put in as shown in **Fig. 3**.

The factors attributing to these could be from both agronomic and mechanization aspects. Agencies have been working to come up with soil fertility and also the in introducing higher yielding varieties. Irrigations and farm mechanizations are also in steady improvement. However there are small scattered land holdings which impede even mechanization.

Gender contribution in agriculture

Another area is the gender contribution in agriculture development. Bhutan has an almost equal male female ratio in the population. However a study on the agriculture sector particular for rice cultivation shows 61.41% of female are involved (**Fig. 4**). This indicates supports planned should be intended for the benefit of the women folks who occupy this profession as of now in the country.

However, in a few cases especially land preparation, the male involvement is higher.

Farm Mechanization Situations

The Department of Agriculture under Ministry of Agriculture and Forests had set farm mechanization programme as one of the main 11th FYP. Bhutan had been receiving the KR-II grant from the government of Japan in terms of power tiller which had greatly benefited the farming communities. Because of the benefit the machine has in mitigating the labour shortages and inflating higher wages, farmers' demand for farm machinery has been increasing year by year. **Fig. 5** shows the trend of the grant in terms of KR-II received from the government of Japan from 1983 onwards.

Bhutan had been receiving the power tillers through this grant and the machines were distributed at subsidized rates all over the country on set criteria to encourage the continuity of agriculture practice. The demands for the machines especially the Kubota power tiller has been increasing yearly because now farmers have started to observe the advantages of its use from the point of drudgery and time of operations. A few private sectors are also started to involve in this business and the machines numbers are increas-

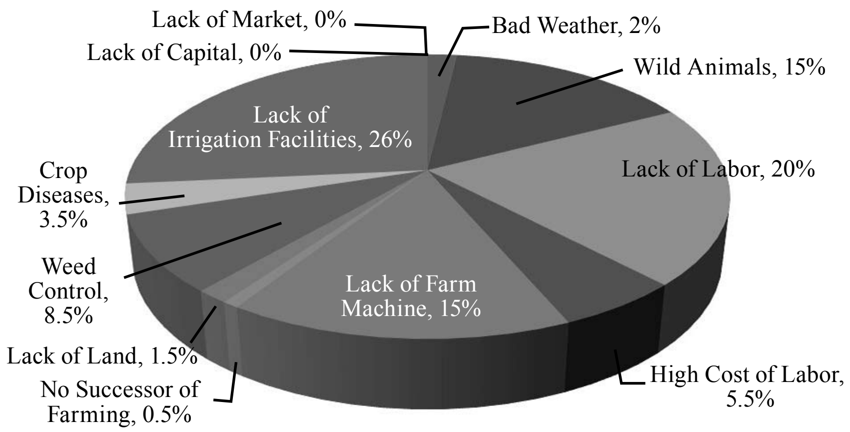

Fig. 2 Farmers issues in agriculture from western Bhutan

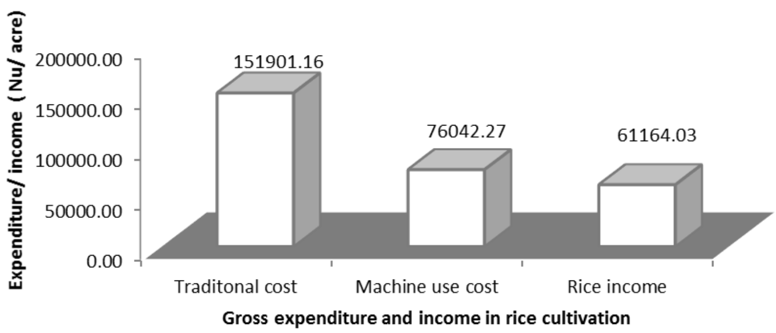

Fig. 3 The gross expenditure and income in rice cultivation

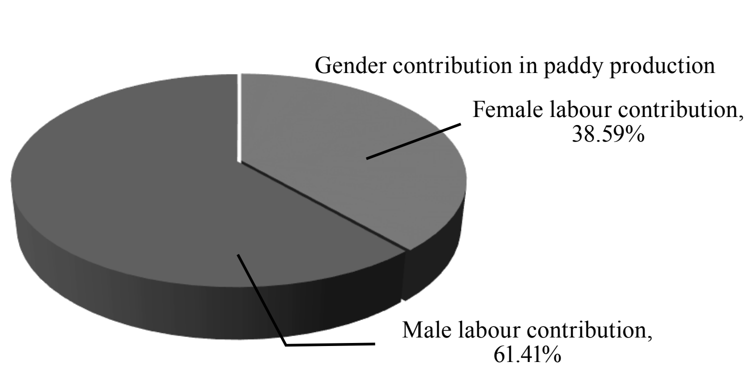

Fig. 4 Gender contribution in rice production

ing as shown in **Fig. 6**.

The annual report of Road safety and Transport Authority, 2015 shows the registered farm machinery numbers as of 2015. The numbers are increasing yearly to meet the demand which is still huge.

Because of the high demand for farm machinery, AMC started to implement hiring services to meet the demand from 2010 onwards. At present all twenty districts are covered with government owned hiring services at subsidized rate. The objective behind was to mitigate the demand and also to instill the need to go for hiring services than individual owning concept because of small land holdings.

Farm machinery under hiring service are power tiller, different hp tractors, 2 row transplanter, water pump, reaper and mini combine harvester. The hiring services by private are not popular. Over the past few years government had supported on this hiring service. The hiring chargers are fairly 50% lower than the actual cost of production on basis of the farmers' agricultural use (**Fig. 7**).

Hence as of now the hiring charges for power tiller is Nu 1,400/day (acre) from Nu 1,200/day (acre) a 2014 from the market rate of Nu 3,000/day (acre). Farmers use this machine only for their own agricultural purpose thus using it for less than a month in a year. The reason is there are no popular hiring services concept and also the non-availability and expensive nature on spare parts deterred then.

※ 1 BTN (Nu) = 0.01468 USD

As shown in **Fig. 8**, the same concept on subsidy has been made on government hiring to encourage the optimum use of the machines and also to deter the individual owing of machines to reduce loss. The tractors are mainly popular in the southern belts due to availability of flat areas. The hiring rates charged to farmers are in between Nu 1,800- 2,500/day depending on the hp variations.

Future Prospects

Since there is tremendous effort from the government side to increase the agricultural land area and production through restoration of fallow land and with other concerted efforts to make it as an economical

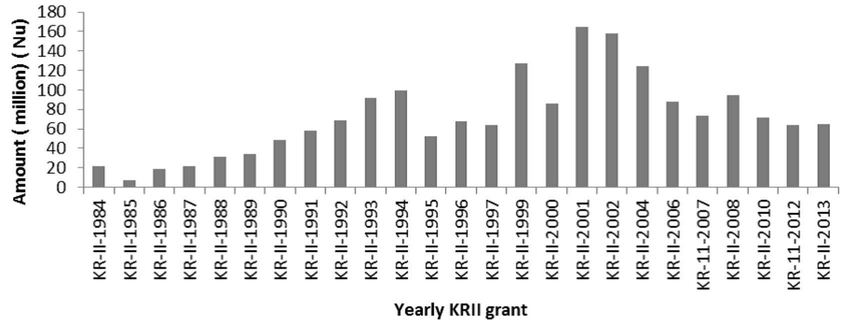

Fig. 5 The KR-II grant support to AMC

Fig. 6 Farm machinery statistic as of 2015

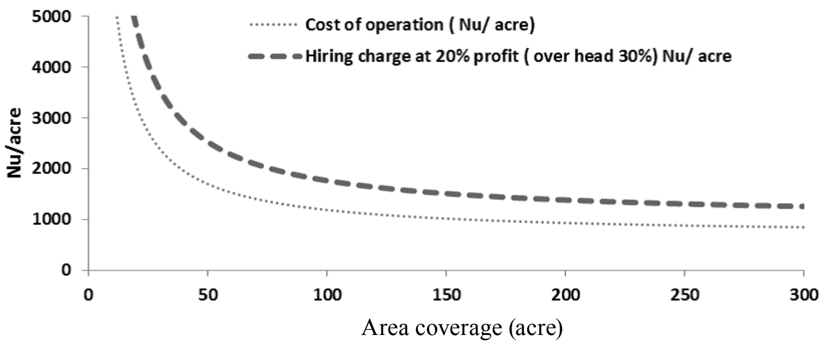

Fig 7 Cost of operation of power tiller

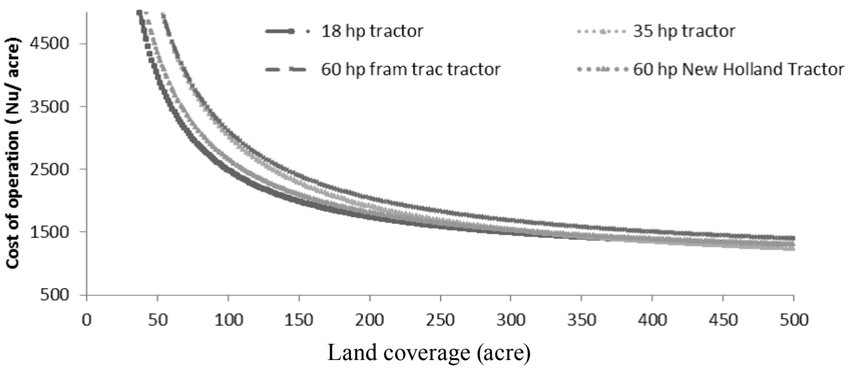

Fig. 8 Cost of operation for different tractors in Bhutan

profession. Efforts have been also to reduce the migration of agricultural population to towns through series of constructive efforts. Efforts like road, light, irrigation and farm shops connectivity are in full swing along with normal agricultural input supports.

Especially for the farm mechanization programme, now AMC has been separated into two new organizations. AMC shall concentrate more on innovative technology source, testing and certification centre and for imparting the training to all end users and also to collaborators for promoting and strengthening the farm mechanization programme. Farm Machinery Corporation limited has been instituted to work on commercial agriculture, sale of farm machinery and spare parts and back up services and also to fabricate farm machinery within the country to boost the private participation.

The private sector too needs to be supported and government or FMCL alone cannot fulfill the demand and requirement for the farm mechanization programme. Hence farm mechanization programme shall work into introducing safe and quality farm machinery and equipment from outside or within the country based on the need assessment from the farmers and the agricultural sector yearly involving all the sectors like FMCL, private and the end users. Already effort through JICA project had resulted in drafting standards for important machinery. This trend for other farm machinery shall continue so that farm machinery in the country are of safe and of quality. Quality trainings on the operation, maintenance and repair shall be carried out for the continuous and longer use of the machines purchased to get its return on time.

Land development and consolidation of the fragmented lands among relatives should be pursued by the government if the cost of agricultural work is to be reduced by use of machines. Also effective machines and its implements need to be evaluated and promoted to make the maximum use of the same machine which is not so as of now due to unavailability.

Hiring system should be promoted through FMCL and also eventually through private sector for optimum uses and discourages the individual owning and also self-use concept. Repair services and availability of spare parts need to be improved further to appreciate this programme.

Farm shops and post-harvest and processing units need to be established to encourage the production and reliable selling market connectivity.

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■■

Rice Mechanization in Laos and Its Current Issues

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Abstract

In Laos, traditional agricultural custom is established that has low productivity but relatively low labor requirement, and a sustainable livelihood with hunting and gathering wild plants, insects and animals. Since 1990's high production policy such as irrigation has been introduced in order to secure food sufficiency and promotion of commercial production. However, it has not been transformed well from conventional agriculture to intensive high productivity agricultural method due to short period of time. Utilization of agricultural machinery such as small tractors, threshers and rice mills has been increased, but important machines for rice production such as transplanters, seeders, and harvesters have rarely been utilized. It is considered that transformation from conventional agriculture to intensive agriculture is a precondition for entire rice mechanization and it is a critical issue in preventing from mechanization. In this paper, how to transform agricultural method is discussed by case studies.

Outlines of Agriculture in Laos

Land and Agriculture

Land area is 230 thousand km^2 and population is 6.809 million (Lao Statistics Bureau, 2014), and the population density of 29.6 persons/km^2 that is the lowest in Indo-China peninsula. Agricultural land area is 2.35 million km^2 and it is about 10% of total land area. The arable land area is 58% of the agricultural land. Agricultural household shares 79.2% and agricultural population is high. The GDP share of agriculture and forestry is becoming smaller due to recent economic development, but it still accounts for 31% (MAF, 2014a). Laos has a wide agricultural land and a rich water resources; therefore, it is expected that Laos agriculture has an important role in her economy. One of the examples is recent movement of massive rice exportation to neighboring countries (Vientiane Times, 2017).

Outline of Rice Production

Total harvested area of rice is 958,000 hectares that consists of 740,000 ha for wet season, 103,000 ha for dry season and 115,000 ha for upland rice cultivation as shown in **Fig. 1**. Basically wet season rice is for own consumption and dry season rice is for marketing. Paddy

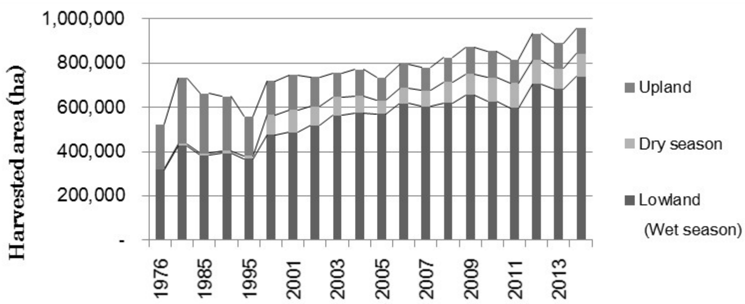

Fig. 1 Harvest area of rice by type

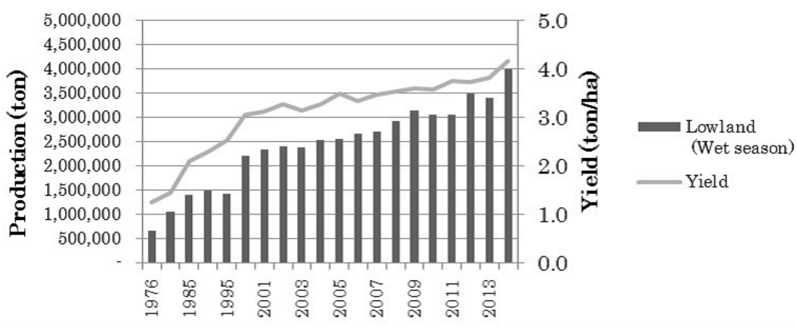

Fig. 2 Rice production and yield

Fig. 3 Traditional rice transplanting method (Agricultural faculty farm of National University of Laos)

rice shares 88% of total rice production. Since late 1990's irrigation was introduced, and rice has been self-sufficient after 2000. Recently the rate of dry season rice harvested area that requires irrigation has leveled off equivalent for approximately 10% of rice harvested area. Rice yield has been increased from 3.1 ton/ha in year 2000 to 4.2 ton/ha in year 2014 as shown in **Fig. 2** (MAF, 2014b).

Traditional Rainfed Rice Cultivation in Laos

Unique characteristics of traditional paddy production technology in lowland Laos are high density transplanting with large seedlings and all time flooding (**Fig. 3**). Large seedlings prevent damage from Golden apple snails. High density transplanting and flooding control weed growth and that gives less weeding operation after transplanting. Tillering of large seedlings is limited and the yield remains low, but production is stable. It is a low input rice cultivation and only manure is used for fertilization. Reduced farm work gives opportunities of income from hunting and gathering after transplanting, and this farming system perfectly fits for sustainable livelihood (Nonaka, 2008). It is, however, obsoleted after monetary economy and more cash income requires transformation of farming method.

Agricultural Machinery Distribution in Laos

Agricultural machinery is remarkably diffused in the last decade. According to the Laos agriculture census utilization rate of hand tractors has been tripled from 20% in 1998/99 to 61% in 2010/11 as given in **Table 1**. The regional rate is increased from 35% to 82% in central regions where center of rice production in Laos.

The most popular machines are rice mills and two wheeled tractors, followed by rice thresher as shown in **Table 2**. Other machines such as harvesters and planters/seeders are not diffused well. Two wheeled tractors are used for transportation in rural area especially it is necessary during wet season, and it is also used for water pumping. Therefore, the ownership of two wheel tractors was increased from 7% in 1998/99 to 34% in 2010/11. On the other hand, rice mills and threshers are less owned individually and they are hired (MOAF, 2014a).

Two wheel tractors diffused in Laos have no power-take-off system and it cannot be used for rotary tilling. They are used for plowing, harrowing and paddling in rice production. Four wheeled tractors are usually used for construction work other than farm work. There is a dryer manufacturer for special order in Vientiane, but no tractor manufacturers. Two wheeled tractors are imported from neighboring countries through machine dealers and repair shops are spread in local areas. Four wheeled tractors from Japan or Canada are imported through distributors in large cities.

Table 1 Increase of using and ownership of two wheeled tractors

Item		Census		Increase rate
		1998/1999	2010/2011	
Using	Whole country	20%	61%	3.1
	Northern regions	13%	47%	3.6
	Central regions	35%	82%	2.3
	Southern regions	5.4%	58%	10.7
Ownership in whole country		7%	34%	4.9

Table 2 Use and ownership of farm machinery by farm households, 2010/11

Machinery type	Percentage of farm HHs	
	Using	Ownership
Two wheeled tractor	61.3%	33.7%
Four-wheeled tractors	9.1%	2.1%
Rice miller	68.0%	9.6%
Rice thresher	43.0%	3.1%
Harvester	2.1%	1.1%
Planter/Seeder	0.3%	0.2%

Cases of Rice Mechanization in Laos

Water user organizations in Savannakhet Province

Savannakhet is the largest agricultural province located 500 km South of Vientiane. It has flat land scape and its paddy area share is 22% of total paddy production, and its dry season rice reaches 29% of national production. Most irrigation facilities are constructed after 1996. As shown in **Fig. 4**, in four years from 1996 to 1999, 37% of irrigation facilities were constructed and their total irrigated area shares 67% (Akutsu, 2014).

When irrigation facilities are constructed the farmer water user association are formed, and operation and management of irrigation facilities are obliged. It is, however, the first time for the farmers to use irrigated rice production, mainte-

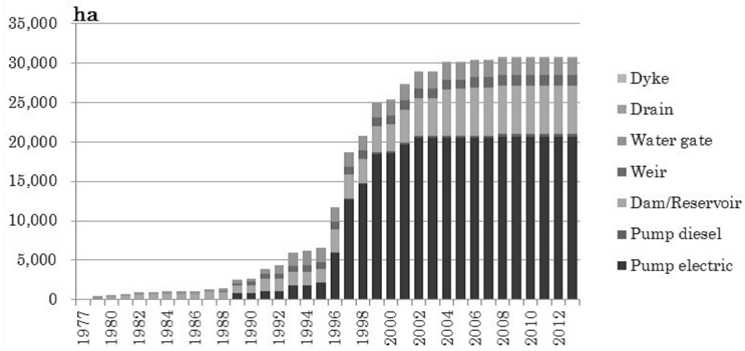

Fig. 4 Increase of Irrigation available area in Savannakhet Province

nance of facilities, water distribution control, and water user organization management. Moreover, technical staffs of the government to support farmers are not enough number and their capability is insufficient. Irrigated agriculture is not well established because of these poor supports from the government, and these remain in extensive conventional rice production.

Farmers' practices are not productive because they still use conventional cultivation method that cannot utilize merits of irrigated agriculture. For example, they don't use seed selection with salt solution, transplant randomly with aged seedlings, and remove only large weeds. Urea is applied for dry season cultivation, but mostly manure is used for set season. Water is always flooded and interval irrigation is not practiced. These methods don't increase yield, and there are less incentives to produce rice in dry season that requires more costs for labor, water fee and fertilizer. Many farmers find non-agriculture jobs, although paddy fields have enough water in dry season.

Recently, a project for promoting irrigated agriculture formed a group of farmers who achieved high yield using less density, checkrow transplanting with young seedlings (JICA, 2015). The new technologies are diffused to neighboring farmers, and transformation from conventional method to high yielding method is triggered. Most farmers own two wheeled tractors and farm operations are mechanized. Even threshing and milling operations are completely mechanized by own machines or service providers in villages.

For other farm operations it has not been mechanized. Recently labor shortage in rural area is remarkable, and some farmers use drum seeders as shown in **Fig. 5** to reduce labor requirement and to save cost. They estimate that the machine cost can be recovered in two years because yield is unchanged and they can get some service fees from neighboring farmers.

The direct seeded field showed healthy growth in leveled area, but it showed uneven growth and damages by Golden apple snails in unleveled field surface. It is important for direct seeding method to care for more precise levelling and puddling work and more strict water control with irrigation water distribution management. Farmers are required to learn necessary conditions for direct seeding method by seeing field practices.

Thangon rural development project

Fig. 5 Drum seeder

This area is located 25 km from Vientiane and was developed by Japan's grant aid and others from 1971 to 1977. This is a model of large paddy field for mechanized farming and it has a one hectare plot size of 50 m by 200 m with irrigation canals and drainage canals (**Fig. 6**).

All farmers own two wheel tractors and some use four wheel tractors. This area is very close to Vientiane and labor shortage is always observed. It is, therefore, farmers use several methods for seeding and transplanting work such as mechanical transplanting, broadcasting, drum seeding and broadcastable pot seedlings. However, productivity is not always high.

This area has not been mechanized with large machines and that caused difficulties in water management, and some farmers segmented a plot with levies. The merits of large plot have not been utilized.

It is worth mentioning that they have a management entity aiming for large size mechanization. The entity owns four wheel tractors, rice transplanters, combine harvesters and large rice milling system that can provide services to neighboring farm land dozens of hectares. The person is still using broadcastable pot seedlings, and it has not been fully mechanized. However, the farmers expects that he become a leader of modern rice mechanization in Laos.

Agricultural faculty farm of National University of Laos

The author conducted an experiment on System of Rice Intensification (SRI) cultivation technology. In

Fig. 6 Broadcasted paddy field in a large plot

this process the author observed the farm practice and university education on rice cultivation technology as well as interviewed teachers and students.

General rice technology is taught in classes, but cultivation practices are based on conventional method. Education on modern rice system and practical technology such as seed selection, checkrow transplanting and water management is not enough. There was an agricultural machinery course when the university was established, but it has been terminated due to too early to introduce in Laos. The Faculty farm owns only two units of two wheel tractors. Education is insufficient for young agriculturists who are most demanded in Laos.

Recently two deputy deans of agriculture are tackling on this problems. They conduct comparative experiments between conventional and modernized method in their paddy field, and the results are used in classes. Also they are developing a dry direct seeder as shown in **Fig. 7**. The modified direct seeder from upland seeder performed its yield as much as conventional method and it is continuously improved. Irrigation facilities in the farm were rehabilitated and up graded for large mechanization. Field practices were started using rice transplanters as shown in **Fig. 8**.

Fig. 7 Trial made seeder by the deputy dean of agriculture

Fig. 8 Field practice of transplanting

SRI extension project in Louangphabang province

Louangphabang is in northern Laos where rainfall is relatively little, therefore it is used that supplemental irrigation in wet season and full irrigation in dry season from river water. More than 500 households practice SRI in this area supported by Japanese NGO through JICA (Pronet-21, 2013a). Small paddy fields are located along small rivers in valley area, and many farmers could not achieve self-sufficiency of rice before introducing SRI. Yield level was increased to 4.5 tons/ha that is almost 60% increment from previous period, and farmers can sell surplus rice (Pronet-21, 2013b). Most farmers use two wheel tractors and rice threshers, but farm operations from seeding, transplanting, weeding to reaping are manually done.

Success in rice production using SRI brought changes in farmers' consciousness that farmers use their creativity and work together as an area movement. Spacing of transplanting is controlled according to varieties, soil fertility, age of seedlings and cropping seasons. During weeding operations they not only use rotary weeders provided by the project but also brushes and rakes are selectively used (**Figs. 9** and **10**). When they started market their rice products they unified rice variety. Through extension of SRI, farmers improved their technical level by exchanging information in villages. However, some villagers gave up using SRI due to more intensive farm operations than that of conventional method. The experience of the project suggests us what are important in order to transform from extensive conventional method to attentive high yielding technology.

Utilization of traditional farm tools

It was found that obsolete farm tools in Japan are introduced to familiarize checkrow transplanting in Laos. They received a favorable reputation among farmers who used them for the first time. Line markers are made by villagers by themselves for checkrow transplanting as shown in **Fig. 11**. In the beginning of introduction, farmers hesitated to use them because of cumbersome work. The method was spread after understanding easiness of weeding and harvesting operations. In addi-

Fig. 9 Rotary weeders (Japanese, Lao, Lao and Indonesian from the left)

Fig. 10 Rake for weeding

Fig. 11 Line marker

tion, Taisetsu Land Improvement District brought a rotary checkrow marker that is more efficient than line marker to Laos and it is popularizedi.

It is necessary to have weeding operations when less populated checkrow transplanting. There is no need to have weeding operation for farmers use conventional method in Laos, and they don't have special tools for weeding. That is why rotary weeders were introduced as described above. Several types were tested in addition to Japanese and Indonesian made tools. Farmers also modified and improved them. A domestic maker who asked trial production also advised for improvement and it is being localized. These are very simple tools but government is not conscious about checkrow transplanting and it is not wide spread to other places in Laos. People think these tools are innovative and it shows an issue that the level of rice technology is still primitive.

Conclusions

Rice cultivation is mechanized using small tractors for plowing, harrowing, puddling and threshing operations in Laos. However, important machines for rice production such as transplanters, and harvesters have rarely been utilized. Traditional society in Laos, it is not only depending on rice production but also on a sustainable livelihood with hunting and gathering wild plants, insects and animals. Under rainfed conditions, it is established that row productivity is relatively stable extensive rice cultivation method.

Fig. 12 Rotary checkrow marker in Thangon (Courtesy by Mr. Takayuki Hara)

As government promoted a policy in order to secure food sufficiency and promotion of commercial production and farmers needed cash income for rural livelihood improvement and education, rice production aimed marketing has been worked on by farmers in the last two decades. Most farmers still practice conventional agriculture, and transformation to intensive high productivity agricultural method has not been achieved due to short period of time.

The government is promoting rice transplanters as a symbol of agricultural mechanization, and farmers are interested in labor saving technology. Transplanter is one of the system components of rice transplanting system, and it cannot be effective using a single component. All technologies such as nursery for each variety, levelled paddy field, appropriate water management and early weeding should be integrated. Introduction of transplanters is not effective if farmers are not practicing checkrow transplanting. Pre-condition for using reapers or head-feeding type combine harvesters is checkrow transplanting, and harvesting operations will be mechanized if transplanters are introduced. Uses of large conventional combine harvesters are difficult because it requires large bearing power of soil and large plot sized other than high price for farmers.

It is necessary for farmers to change their perception and their fundamental technology from conventional extensive method to intensive high yielding method to promote rice mechanization. It is effective to introduce simple farm tools such as sleds for levelling, line markers, rotary checkrow markers, rakes and rotary weeders. Considering unstable rainfalls in Laos and farmers' capacity, direct seeding could be used with small inexpensive farm machines, although it requires careful levelling and precise water control.

Farmers' consciousness on agricultural mechanization can be changed by innovative and creative actions with attentive observation on rice and paddy field. Some project areas show emerging activities on intensive farming groups, large machine service providers, farm tool making and modification, and school education improvement. If they manage these activities, it starts to replace farm tools with machines. It is necessary to patiently progress these activities and it is expected that innovation of farmers would increase with successful experience, enhancement of farmer organization, capacity development of agricultural engineers and improvement of education and human resources.

Acknowledgements

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EVENT CALENDAR

◆ **CaspianAgro 2017 –11th Azerbaijan International AGRICULTURE EXHIBITION–**
May 25-27, Baku, AZERBAIJAN
http://caspianagro.az/2017/?p=index

◆ **20th FOODAGRO Africa 2017**
June 2-4, 2017, Nairobi, KENYA
http://www.expogr.com/kenyafood/

◆ **XXXVII CIOSTA & CIGR Section V Conference**
June 13-15, 2017, Palermo, ITALY
http://www.aidic.it/ciosta2017

◆ **2nd International Forum on Agri-Food Logistics**
June 22-23, Poznan, POLAND
http://www.agrifoodlogistics.eu/

◆ **ASABE 2017 Annual International Meeting**
July 16-19, Spokane, USA
http://www.asabemeetings.org/

◆ **AGM & Technical Conference (Joint Meeting with CIGR Section VI Bioprocesses)—FOOD, FUEL, AND FIBRE FOR A SUSTAINABLE FUTURE—**
August 6-10, Winnipeg, CANADA
www.csbe-scgab.ca/winnipeg2017

◆ **ASIA AGRI-TECH EXPO & FORUM 2017**
September 28-30, Taipei, TAIWAN
http://www.agritechtaiwan.com/en-us/

◆ **Agritechnica 2017**
November 12-18, Hanover, GERMAY
https://www.agritechnica.com/en/

◆ **AGROCIENCIAS 2017**
November 20-24, Havana, CUBA
Organizer: Agrarian University of Havana

◆ **KISAN 2017**
December 13-17, Pune, INDIA
http://pune.kisan.in/

◆ **XIX. World Congress of CIGR**
April 22-25, 2018, Antalya, TURKEY
http://www.cigr2018.org/

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Trends of Tractorization in Indian Agriculture

by

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Abstract

Farm mechanization in India is still in its early stages for the last two decades and only able to achieve a meagre growth rate of less than 5%. Tractors play an important role in mechanization of Indian agriculture. The status of tractorization and growth pattern in sale of tractors in India was studied in the paper. The tractor sale increased at a Compound Annual Growth Rate (CAGR) of 9.39% during the last 54 years and reached a level of 493,764 units in 2015-16. The trend of increasing sale of tractors over the years indicates a rising acceptance of tractor operated agricultural machines and equipment with the Indian farmers. The current trend in sale of tractors indicated the highest share of 43% for 31-37 kW category tractors. The requirement of high power category tractors in India increased for using high capacity farm machines on custom hiring basis. Haryana state of India has the highest tractor density of 96 tractors per thousand hectares of net cropped area and followed by 79 for Punjab. The lowest tractor density of 4 was in Kerala with all Indian average of 43. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, and Gujarat were the top five states in India in terms of higher sale of tractors from 1995-96 to 2004-05; however, Punjab and Haryana states were replaced by Andhra Pradesh and Maharashtra during the last decade. It was observed that there was a positive relationship between available tractor power and food grain productivity for all the major states except Assam and West Bengal. It was concluded that rainfall pattern, land holding size and government policies affected the sale of tractors in India.

Key words: Tractor Industry; Tractor density; Productivity; Land holding; Mechanization

Introduction

Indian agriculture employs over 50% of the domestic workforce and contributes to around 14% to gross domestic product (GDP) of country. In order to ensure self-sufficiency in food grain production in the backdrop of increasing population, state agencies have assumed a greater role as facilitators of technology adoption (Anonymous, 2013). Indian agriculture especially practiced on small farms, was seen as being traditional and low productive activity. The productivity of farms depends mainly on judicious use of available farm power by the farmers. Higher production and productivity, and reduced drudgery are major contributions of farm mechanization (Van den Berg, 2007). Economic growth in Indian agricultural sector lags behind growth in industry and services, creating an ever widening rural-urban income gap (Mandal and Maity, 2013). Agriculture was not considered central to economic growth and development that would instead be led by services (134 million enterprises) and manufacturing industry (92 million enterprises) in unorganized sectors. Indeed, the main role of unorganized agriculture's sector enterprises (224 million) is dual i.e. sector development and release of labour from low - marginal productivity in agriculture to industry (Anonymous, 2009).

The farm power availability and farm mechanization have a crucial role to play to enhance agricultural productivity. Agricultural implements and machinery enable the farmers to employ the available farm power judiciously for production purposes (Cavallo, 2014). The opportunities are still huge considering the low farm mechanisation levels in the country as compared to other developed economies across the world. Agricultural machinery increases productivity of land and labour by meeting timeliness in farm operations resulting in increase work output per unit time (Panin, 1995). Agricultural mechanization technology plays a key role in improving agricultural production and productivity in developing counties, and should be considered as an essential input to agriculture. The increased use of farm machines has led to increase in cropped area, cropping intensity and agricultural production of the country (Singh, 2000). Besides, its paramount contribution to the multiple cropping and diversification of agriculture, mechanization also enables efficient utilization of inputs such as seeds, fertilizers and irrigation water (Singh, 2006; Mehta *et al.*, 2014a). The shift has also helped in diversification of agriculture from conventional crops to commercial crops. The programmes of farm mechanization such as Sub-mission on Agricultural Mechanization (SAM) resulted in adoption of farm machinery such as tractors, power tillers, combine harvesters, irrigation pumps, plant protection equipment, threshers, improved implements and hand tools (Mehta *et al.*, 2014b).

Tractors are an integral part of Indian agricultural machinery industry. Tractor industry plays an important role in agriculture sector as major contributors to India's GDP. Tractor has a significant role in agricultural operations and remains the most important and extensive path-breaking machine in agricultural world (Iftikhar and Pedersen, 2011). The tractors in India are also used for transport and non-agricultural applications. The use of tractors in agriculture in India started during the 1950 with annual introduction of about 8,000 imported units. The tractor manufacturing process started in India during 1961-62 with the help of foreign collaborations (Jain, 2006). Presently, there are 21 tractor manufacturers producing tractors in India. The Indian tractor industry has developed over the years to become the largest in the world and accounts for one third of global production. By advancement in manufacturing of tractors, there is a possibility that could lead India to another green revolution (Mandal and Maity, 2013). Starting in 1960′s, it had reached about 50,000 units in the early 1980′s, but today the size of Indian tractor market has grown to over 600,000 units (Goel and Kumar, 2013; Sarkar, 2013). The Indian tractor industry is headed for a slowdown after a splendid performance during the last decade.

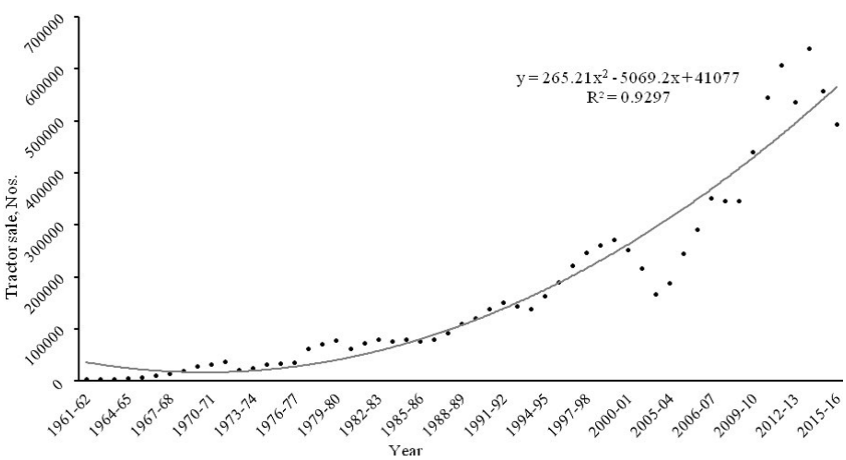

Fig. 1 Trend in sale of tractors in India

Rainfall, land holding size and food grain productivity are key drivers for sale of tractors in India. A series of good or bad monsoon affects the sale of tractors. The good growth in sale and exports of tractors also depend on the initiative of the government to boost up agriculture and agricultural machinery industry. The tractor penetration level in different parts of the country is also not uniform due to many reasons. It is observed that net sown area in the country is about 140 million ha for last many decades while gross cropped area increased from 132 million ha in 1950-51 to 198.9 million ha with a cropping intensity of 140.5% during 2010-11 (Anonymous, 2014a). Tractor played a significant contribution in increasing the gross cropped area. This paper gives an insight into the trend in tractorisation of Indian agriculture. The data on power-wise and state-wise sale of tractors over the years have been analysed in the paper.

Trend in Sale of Tractors in India

The use of different types of farm machinery including hand tools, animal-drawn implements, seed drills and planters, plant protection equipment, diesel/electric pump sets, combine harvesters, threshers etc. has been accelerating over the past several years in India. Due to use of these implements, the total power available per unit area on farms has also increased. The sale of tractors in India was only 3,877 units in 1961-62 and reached to all time high of 633,656 units (163 times) in 2013-14 (**Fig. 1**). The sale of tractors increased at a compound annual growth rate (CAGR) of 10.3% during the last 52 years. The sale of tractors in India increased at an annual growth rate of 4.97% from 1990-91 to 2015-16. The increasing trend in sale of tractors over the years indicated a rising ac-

Table 1 Trend in growth in domestic sale of tractors from 1961-62 to 2015-16

Period	Compound annual growth rate (CAGR), %
1961–62 to 1970–71	24.03
1971–72 to 1980–81	5.24
1981–82 to 1990–91	6.52
1991–92 to 2000–01	5.24
2001–02 to 2010–11	9.63
2011–12 to 2015–16	-4.06

ceptance of agricultural machines and equipment with the Indian farmers. However, there was a large year-to-year fluctuation in growth rate during the period. There were five instances where growth in sale of tractors was negative for two or more successive years. The first such instance was during 1972-74 and followed during 1983-86, 1992-94, 2001-03 and 2014-16. The slowdown in tractors sale began in 1997-98 with negative or low growth rate up to 2000-01 and was followed by negative growth rate during 2001-02 and 2002-03. The sale of tractors increased rapidly from 2004-05 onwards, with output crossing the 300,000 mark in 2006-07. There was another dip in sale of tractors in 2007-08 and 2008-09 and followed by a big rise in 2008-10. The domestic sale of tractors decreased during the last two years from 633,656 units in 2013-14 to 493,764 units in 2015-16 due to poor rainfall.

The trend in growth pattern in sale of tractors at an interval of 10 years during last 54 years (1961-62 to 2015-16) is reported in **Table 1**. It is indicated that the tractor sale in India increased at a CAGR of 9.63% from 2001-02 to 2010-11. The maximum CAGR growth in domestic sale of tractors was 24.03% from 1961-62 to 1970-71. The growth in tractor sale was negative (-4.06%) during the last four years (2011-12 to 2015-16).

The Indian tractor industry is the largest in the world and accounts for one third of global production. Mahindra & Mahindra Ltd., Mumbai is market leader with 41% share in sale of tractors in India. The population of tractors in India reached to 5.81 million in 2015-16 as compared to 3,877 units only during 1961-62. The net area sown by a tractor was 3,600 ha during 1961-62 and reduced to 24 ha by 2015-16. However, the country still lags behind the developed countries in terms of the net area sown by a tractor. India also lags behind in terms of availability of tractors not only to developed countries but also some of the developing countries of the world e.g. China.

Power-wise sale of tractors

The trend in power-wise sale of tractors in India during the last 16 years is shown in **Fig. 2**. The sale of tractors in India has grown at a CAGR of 5.62% during the last 16 years from 217,456 in 2001-02 to 493,764 in 2015-16. The domestic sale of tractors is the highest (43%) in 31-37 kW power range and followed by 36% in 23-30 kW power range during 2015-16. The percentage share in domestic sale of more than 37 kW tractors decreased from 7.3% to 6.6% and 31-37 kW tractors increased from 14% to 43% during the last sixteen years (2001-2016). It is indicated that requirement of high power category tractors in India increased for using high capacity farm machines on custom hiring basis. However, during the same period, the percentage share in sale of medium power tractors (23-30 kW) decreased from 55 to 36% and low power tractors (15-22 kW) from 23 to 6.2%. The sale of less than 15 kW tractors was only 4.7% during 2015-16. The industry is, however, witnessing polarization, with higher growth in the upper and lower power segments. The rate of growth in medium power segment (23-30 kW) is nearly constant.

A farmer's choice of tractor size is typically a trade-off between the utility of the tractor (which includes transport capacity requirement) and its price. Despite higher prices, several factors have led to a structural shift in the industry towards high power tractors. The factors for sharp increase in sale of high power tractors in India are increasing tractor penetration in southern India due to high power requirement in paddy fields, replacement demand for high power tractors from the northern region, increasing use of tractors for non-agricultural applications and growth in export of high power tractors. Nevertheless, the growth in

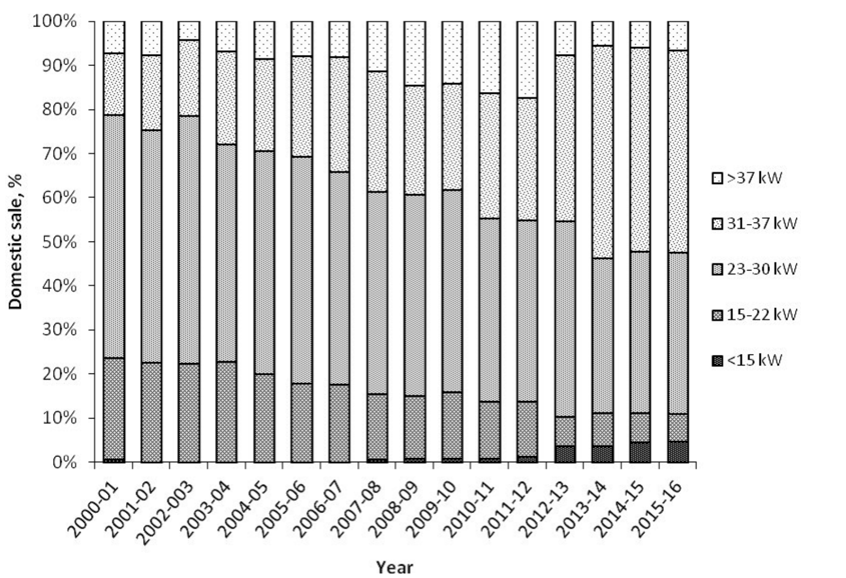

Fig. 2 Trend in power-wise sale of tractors in India

more than 31-37 kW tractors market is expected to remain strong.

The sale of less than 15 kW tractors indicated strong growth of 38.2% in 2012-13. The strong underlying demand in less than 15 kW tractor category has prompted the entry of organised players like Mahindra & Mahindra Ltd., VST Tillers Tractors Ltd., Escort Group and Kubota Agricultural Machinery India Pvt. Ltd. in Indian tractor market, a segment which is currently catered by un-organised players. With roughly 45% of the area under cultivation contributed by small and marginal farmers (less that 2 ha land holding), the opportunities in this area are plunged; more so in light of very low tractor penetration at present. Also with scarcity of farm labour and rising cost of animal power, the trend of ownership of small and less expensive tractors by small and marginal farmers is increasing. Apart from lower initial costs, these tractors deliver better fuel efficiency as compared to high power tractor, making it viable for small farmers to upgrade power sources from human, animal or power tiller to a tractor. While currently, Mahindra & Mahindra Ltd. and VST Tillers Tractors Ltd. are the only two large players that have presence in this under INR 0.2 million (US$ 3,000) tractor market. The other tractor manufacturers likes International Tractors Ltd. (ITL) and Escorts are expected to enter this segment soon. However, restricted application to soft soil conditions, competition from second hand market of high kW tractors, and limited credit worthiness of marginal farmers are some of the factors that are influencing the growth in the under 15 kW tractor market.

Region-wise sale of tractors

In recent years, the tractor industry has registered a good growth in sales, both domestic as well as exports. This is also partly because of the initiative of the government to boost up growth in agriculture and agricultural machinery industry. The tractor penetration level in India is very low as compared to the world standard and not uniform throughout the country.

The percentage contribution of different states in sale of tractors in India from 1995-96 to 2015-16 is reported in **Table 2**. The sale of tractors was more than 8% in the states of Uttar Pradesh, Madhya Pradesh, Rajasthan, and Maharashtra from 2010-11 to 2015-16. These four states together accounted for about 40% of the total tractors sale in the country during 2015-16. Tractors sale in Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh states have shown consistent growth during the last ten years. It is expected to increase at a faster rate due to growing of high value cash crops and adopting latest crop production/ management practices by farmers of Central and Southern regions of the country.

The differential pattern of growth in tractors sale, with faster growth in the initially laggard states, has reduced the regional concentration of tractors sale over time. The combine share of the top five states viz. Madhya Pradesh, Uttar Pradesh, Rajasthan, Punjab and Haryana in total tractors sale was 63.6% during the period from 1995-96 to 1999-00 and reduced to 41.7% from 2010-11 to 2015-16 (**Table 2**). Further,

Table 2 Percentage contribution of different states of India in sale of tractors from 1995-96 to 2015-16

State	Sale of tractors, %				CAGR
	1995–96 to 1999–2000	2000–01 to 2004–05	2005–06 to 2009–10	2010–11 to 2015–16	1995–96 to 2015–16
Andhra Pradesh (AP)	5.34	6.33	10.09	7.03	4.99
Assam (AS)	0.20	0.23	0.48	0.69	13.09
Bihar (BR)	4.18	6.66	4.84	5.23	9.45
Gujarat (GJ)	8.35	5.64	7.08	7.36	4.02
Haryana (HR)	8.97	6.12	6.32	4.39	0.86
Himachal Pradesh (HP)	0.18	0.26	0.28	0.23	9.86
Jammu and Kashmir (JK)	0.22	0.57	0.38	0.46	9.19
Karnataka (KA)	2.96	4.71	5.94	5.17	6.54
Kerala (KL)	0.32	0.14	0.22	0.08	-5.22
Maharashtra (MH)	11.91	12.70	7.06	10.03	3.59
Madhya Pradesh (MP)	6.75	4.21	7.71	7.97	6.10
Odisha (OD)	0.70	3.95	1.84	2.07	10.28
Punjab (PB)	11.82	7.52	5.48	4.34	-1.60
Rajasthan (RJ)	9.64	7.82	8.63	9.30	6.33
Tamil Nadu (TN)	4.24	3.68	5.05	2.66	1.22
Uttar Pradesh (UP)	21.26	22.23	14.92	13.66	3.75
West Bengal (WB)	1.03	1.23	1.76	2.10	11.01
Export & other states	1.93	6.02	11.93	17.22	18.17
Total India	100.00	100.00	100.00	100.00	

there is a change in the composition of the top five states with respect to tractors sale in India. Uttar Pradesh, Madhya Pradesh and Rajasthan states are among top five states in percentage sale of tractors in India during last 21 years (1995-96 to 2015-16). However, the states of Punjab and Haryana are replaced by Andhra Pradesh and Maharashtra during 2005-06 to 2009-10 and by Maharashtra and Gujarat during the last six years (2010-11 to 2015-16). The demand for tractors is also increasing due to an increase in use of tractors for construction work. Nearly, 70% increase in the demand for tractors during the last decade is from the infrastructure sector in the states of Assam, Odisha and Bihar. The tractors sale in Bihar tripled from 1995-96 to 2015-16 due to boom in infrastructure sector in the state.

Although huge regional disparities still exist in the level of tractorisation in the country, recent data on state-level tractors sale show that growth has been relatively high in states where tractor penetration in agriculture was low initially. Thus, over the last two decades, eastern India has emerged as the major market for tractors. In the highly mechanised regions of India, the annual growth rate in sale of tractors was (-) 5.22% and (-) 1.60% in the states of Kerala and Punjab, respectively during the period (**Table 2**).

Tractor density and food grain productivity

The state-wise tractor density per 1,000 ha of net sown area, power availability from tractor per unit area, food grain productivity and production per unit power are reported in **Table 3**. Overall tractor density per thousand hectare of net sown area in India is 43. It indicates that the tractor availability per 1,000 ha of net sown area is more than all India average of 43 tractors/1,000 ha in seven states viz. Haryana, Punjab, Uttar Pradesh, Bihar, Tamil Nadu, Andhra Pradesh and Gujarat. It ranges between 30-43 tractors per 1,000 ha in four states of Jammu and Kashmir, Rajasthan, Karnataka and Himachal Pradesh and less than 30 tractors per 1,000 ha area in six states of Madhya Pradesh, Maharashtra, Odisha, West Bengal, Assam and Kerala. Haryana state of India has the highest tractor density of 96 tractors per thousand hectares of net sown area and is followed by Punjab (79), Uttar Pradesh (58), Bihar (54), and Andhra Pradesh (48) states. The lowest tractor density is 4 in Kerala state and followed by Assam (14), and West Bengal (23) among the major states except north eastern states of India.

The relationship between tractor density and food grain productivity in major states of India is shown in **Fig. 3**. In general, the food grain productivity increases with increase in tractor density in a state. The states of India were divided into four categories based on average tractor density and food grain productivity in India. The average trac-

Table 3 State-wise tractor availability per 1,000 ha area, power availability from tractors and food grain productivity

State	Tractor density per 1,000 ha area	Power availability from tractors, kW/ha	Food grain productivity, t/ha	Power per unit production, kW/t
Andhra Pradesh	48	1.17	1.32	0.89
Assam	14	0.28	1.72	0.16
Bihar	54	1.34	2.10	0.64
Gujarat	44	1.07	1.96	0.55
Haryana	96	2.52	3.88	0.65
Himachal Pradesh	30	0.72	2.80	0.26
Jammu and Kashmir	40	0.92	2.03	0.45
Karnataka	32	0.73	1.64	0.45
Kerala	4	0.12	2.7	0.45
Madhya Pradesh	28	0.71	1.41	0.50
Maharashtra	28	0.64	1.15	0.56
Odisha	25	0.58	1.30	0.45
Punjab	79	2.29	4.34	0.53
Rajasthan	34	0.78	1.32	0.59
Tamil Nadu	46	1.29	2.69	0.48
Uttar Pradesh	58	1.55	2.50	0.62
West Bengal	23	0.51	2.68	0.19

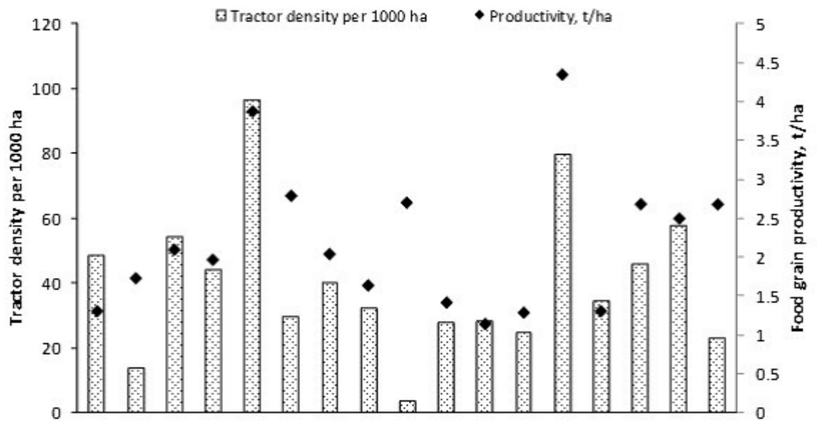

Fig. 3 Tractor density and food grain productivity in different states of India

tor density of 43 tractors per 1,000 ha and food grain productivity of 2.06 t/ha were taken as the base for categorizations of states. The first category was of high tractor density and high food-grain productivity in the states of Haryana, Punjab, Uttar Pradesh, Tamil Nadu and Bihar. These states utilized maximum tractor power for increasing food grain productivity on their farms. The food grain productivity is the highest in Punjab state and followed by Haryana state. It may be due to availability of more tractor power per unit area in these states. The second category is low tractor density and high yield in the states such as West Bengal, Himachal Pradesh and Kerala. It indicated that these states utilized more human and animal power sources than tractor power source to enhance productivity. The third category is high tractor density and low yield in states of Gujarat and Andhra Pradesh. This may be due to low rainfall and low land productivity of the states. The fourth category is of low tractor density and low yield in seven states of India.

Tractor power availability and food grain productivity

It was also observed that the highest power available from tractors was 2.52 kW/ha in Haryana and followed by states of Punjab (2.29 kW/ha), Uttar Pradesh (1.55 kW/ha), Bihar (1.34 kW/ha), Tamil Nadu (1.29 kW/ha), Andhra Pradesh (1.17 kW/ha), Gujarat (1.07 kW/ha), Jammu and Kashmir (0.92 kW/ha), Karnataka (0.73 kW/ha) and Himachal Pradesh (0.72 kW/ha). The lowest power available from tractors was in Kerala state (0.12 kW/ha) and followed by Assam (0.28 kW/ha), Odisha (0.58 kW/ha), Maharashtra (0.64 kW/ha), Madhya Pradesh (0.71 kW/ha) and Rajasthan (0.78 kW/ha) states. In case of power utilized for production of one tonne of food grain, the Assam state is leading with less power utilized (0.16 kW/t) and followed by West Bengal (0.19 kW/t), Himachal Pradesh (0.26 kW/t), Odisha (0.45 kW/t) and Kerala (0.45 kW/t) states. This may be due to highly fertile soil and good rainfall in the states of Assam, West Bengal and Kerala etc. The power utilized for production of one tonne of food grains was the highest in Andhra Pradesh (0.89 kW/t) state and followed by Haryana (0.65 kW/t) and Bihar (0.64 kW/t) states even though the total power availability was higher in other states. This may be due to over tractorization in these states. The increased use of tractors has resulted in increase in cropped area, cropping intensity and food grain production. The shift

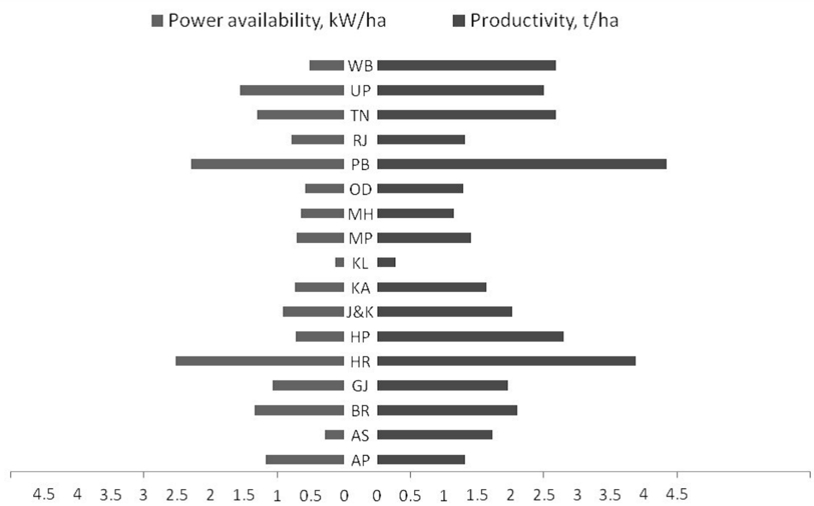

Fig. 4 Relationship between food grain productivity and available tractor power in different states of India

Table 4 Percent share of power wise distribution of sale of tractors in different states of India during 2015-16

States	Power category, kW				
	<15	15-22	23-30	31-37	>37
Andhra Pradesh	2.9	1.7	28.7	62.7	3.9
Assam	1.7	0.6	24.0	69.1	4.6
Bihar	1.6	11.2	59.7	26.2	1.3
Gujarat	20.7	2.5	45.1	28.2	3.5
Haryana	1.5	15.3	26.1	42.1	15.0
Himachal Pradesh	3.1	2.2	47.6	44.9	2.2
Jammu and Kashmir	2.5	12.9	11.1	55.0	18.5
Karnataka	4.4	8.4	28.1	53.6	5.5
Kerala	14.2	2.3	8.9	58.1	16.5
Maharashtra	18.4	17.0	8.6	49.8	6.2
Madhya Pradesh	1.3	1.4	38.0	53.4	5.8
Odisha	0.5	1.4	50.3	45.3	2.5
Punjab	0.3	6.6	7.6	54.6	30.9
Rajasthan	0.8	1.9	53.2	41.9	2.2
Tamil Nadu	4.7	1.2	7.8	77.1	9.3
Uttar Pradesh	1.5	7.8	41.6	42.6	6.4
West Bengal	2.1	3.5	18.0	62.6	13.9
Other states	1.8	3.2	37.3	45.2	12.5
Exports	0.9	1.2	5.7	25.3	66.9
Domestic sales	4.0	6.0	33.0	43.0	15.0

has also helped in diversification of agriculture from conventional crops to commercial crops.

The relationship between power availability from tractors and food-grain productivity per unit area for all major states in India is shown in **Fig. 4**. It was observed that there was positive direct correlation between available tractor power and food grain productivity for all the major states expect Assam and West Bengal. In Assam state, even though the available power is low (0.26 kW/ha), the food grain productivity is 1.73 t/ha. This may be because of good rainfall and climate and fertile soil type etc.

Power-wise regional distribution

The tractors sold in India are of different power range from less than 15 kW to more than 37 kW. The percentage share of sale of tractors during 2015-16 in different power ranges in different states of India is given in **Table 4**. From this Table, it is concluded that the sale of tractors was the highest in 31-37 kW power range in most of states of India except Bihar, Gujarat, Himachal Pradesh, Odisha and Rajasthan. The percentage share in sale of tractors in 31-37 kW power range was the highest (77.1%) in Tamil Nadu state and followed by Assam (69.1%) state. The percentage share in sale of tractors in 23-30 kW power range was the highest in Bihar (59.7%) state and followed in states of Rajasthan (53.2%), Odisha (50.3%), Himachal Pradesh (47.6%), Gujarat (45.1%), Uttar Pradesh (41.6%) and Madhya Pradesh (38%). The percentage sale in tractors of less than 15 kW power was the highest in Gujarat (20.7%) and followed in Maharashtra (18.4%) and Kerala (14.2%) states. These states used the tractors for intercultural and spraying operations in horticultural and cash crops.

Table 5 Major markets for tractors in India

Tractor power (kW)	Major markets
Less than 15 kW	Gujarat, Maharashtra and Kerala
15-22 kW	Maharashtra, Haryana, Jammu & Kashmir and Bihar
23-30 kW	Bihar, Rajasthan, Odisha, Himachal Pradesh and Gujarat
30-37 kW	Tamil Nadu, Assam, Andhra Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Punjab, Uttar Pradesh and West Bengal
More than 37 kW	Punjab, Haryana, Kerala, Jammu & Kashmir and West Bengal

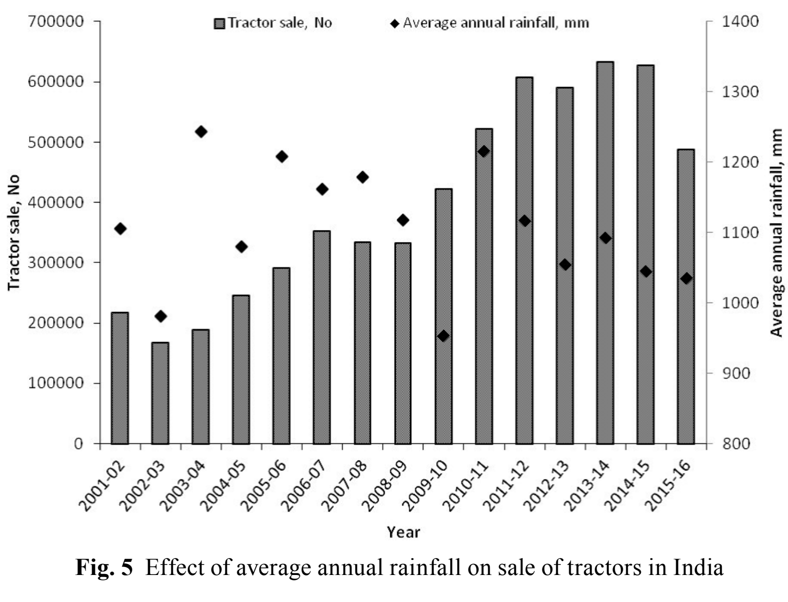

Fig. 5 Effect of average annual rainfall on sale of tractors in India

The major markets for power-wise sale of tractors in India are given in **Table 5**.

The percentage sale of tractors of more than 37 kW was the highest in Punjab (30.9%) and followed by Jammu and Kashmir (18.5%), Kerala (16.5%) and Haryana (15%) states. The farmers of Kerala state used these tractors with tractor mounted combine harvester. Moreover, a large size tractor is also considered as a status symbol in large parts of rural Punjab, Haryana and Jammu and Kashmir states. The high power tractors are not only used for custom hiring of farm machinery but also for transport of farm produce (sugarcane, potato), construction materials, and development of infrastructure activities. The sale of high power tractors in Northern states is due to high power requirement for paddy and straw management practices and in Southern states for cultivation in black cotton soil and for non-agricultural applications. In general, the margin money required for getting a loan for high-end tractors is obtained by selling the used tractor. It is estimated that replacement sale of tractors are currently around 40 to 45% of total sales. It was also observed that 66.9% of total tractors exported from India during 2015-16 are of more than 37 kW power as compared to 15% sale in domestic market.

Factors Affecting Sale of Tractors in India

Monsoon and rainfall pattern

The spatio-temporal distribution and magnitude of rainfall under the South-West monsoon in India influence the *Kharif (summer)* crop output, and in-turn has a bearing on the domestic sale of tractors in India. While it is intuitive to correlate a good monsoon year with strong tractors sale, the impact of monsoons on tractor industry is reducing with reducing dependence on rain-fed farming. Although the shift from rainfed agriculture to irrigated farming has been gradual (50% of cultivated area in India is still dependent on rains), the percentage of area under irrigation is particularly high in states such as Punjab (98%), Haryana (88.5%), Uttar Pradesh (74.9%) and Bihar (63.1%), which also have large population of tractors in the country (Anonymous, 2014a). The rainfall, below average usually leads to increase in the prices of food grains, thereby reducing the impact on the farmers. Further, in case of delayed monsoon, there is a shift towards other *Kharif* crops with smaller crop cultivation cycles. The ability of a farmer to invest in farm mechanisation is also contingent on the cash flows from the winter Rabi crop.

Fig. 5 shows that the growth in domestic sale of tractors has not exactly followed the performance of monsoons, as represented by all India area weighted rainfall. Notwithstanding, a weak (22% lower than long period average) and delayed monsoon in 2009-10, tractor sales were buoyant during the period; although after a period of subdued industry sales in 2008-09. Rainfall activity during the monsoon season and post-monsoon season over the country as a whole was recorded deficit during 2014-15 and 2015-16, the domestic sale of tractors dropped by 22% during 2015-16 from the peak of 634,151 units in 2013-14. The key reason behind this decline is, two successive years of deficient monsoon followed by unseasonal rains, which have impacted the crop production and rural sentiment at large (Anonymous, 2016).

Average land holding

The number of land holdings in India is increasing during the last 40 years; however, the average land holding size has declined from 2.30 ha in 1970-71 to 1.15 ha in 2010-2011. The marginal (below 1 ha) and small (1 to 2 ha) farms constitute 85% of the total number of holdings and cultivate only 44.6% of the total area; whereas 14.3% semi-medium and medium farms (2 to 10 ha) account for 44.9% of the cultivated area and 0.7% of large farms (above 10 ha) account for 10.6% of the cultivated area (Anonymous, 2011). The relationship between average land holding size and tractors sale for the years from 1970-71 to 2015-16 is shown in **Fig. 6**. It is observed that even though the average land holding size reduced from 2.30 to 1.15 ha, the domestic sale of tractors increased from 37,839 to 545,109 during the period. This is due to increase in farm mechanization in Indian agriculture during the period. This is contrary to the popular belief that the benefits of tractorization can be availed by large farmers only. It has been observed that small and marginal farmers are quite open to adopt equipment for tillage, sowing, plant protection, harvesting and threshing etc. on custom hiring basis.

The state-wise relationship between tractor density and average land holding size is shown in **Fig. 7**. It was observed that there was direct positive correlation between tractor density and average land holding size for all the major states

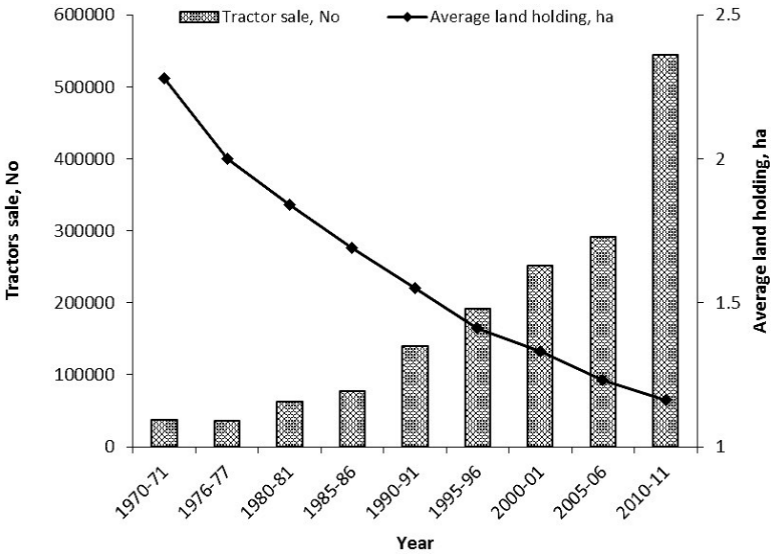

Fig. 6 Relationship between average land holding and domestic tractor sales

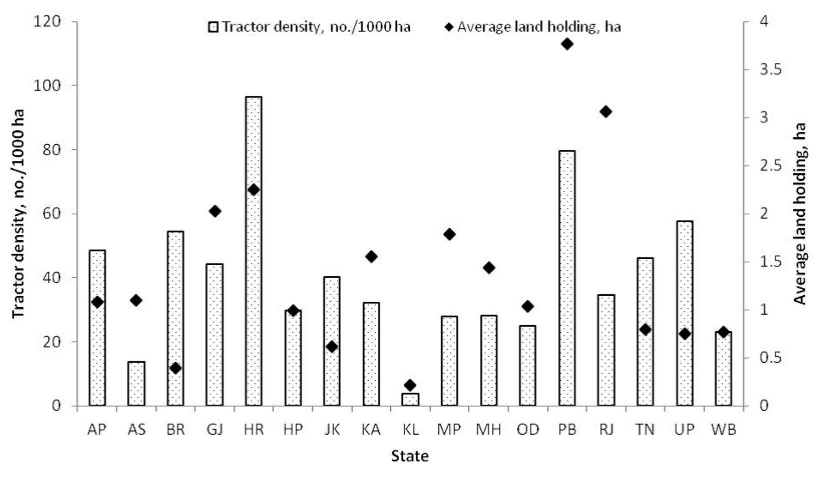

Fig. 7 Relation between tractor density and average land holding size in different states

expect Bihar, Jammu and Kashmir, Tamil Nadu and Uttar Pradesh. In these states, even though the average land holding size is small, the tractor density is high. This may be because of high tractor population density; use of tractors for non-agricultural purpose and increase in custom hiring of farm equipment etc.

Government intervention and policy

As the electricity to rural areas is subsidized for agricultural purpose in India, most farmers either individually or jointly have installed tube-wells wherever ground water is available. Exploitation of ground water and water from ponds and small reservoirs are the highest priority to increase agricultural productivity in rural areas. This is mainly done by farmers using supporting infrastructure made available by the government and necessary equipment, spare parts and maintenance provided by the private sector. With assured irrigation, farmers are able to plant high yielding variety (HYV) seeds and apply higher doses of fertilizers to get high yield. With the infrastructure assistance i.e. markets connected by rural roads and government procurement at minimum support price (MSP) of food grain, farmers are able to make reasonable profit and invest in mechanization to purchase tractors and other farm equipment. The mechanization in India was driven during initial years by assured price to farmers for their produce (wheat and rice). The rising wages of labors and maintenance cost of bullocks also contributed to higher viability of tractors and created the condition for diversification into high value crops. This helped in availability of mechanization services at competitive rates to small and marginal farmers. The benefits to smallholders could also be increased through tractor custom hiring services. There was a good growth in sale of tractors in India due to favorable government policies for promoting machinery manufacturing in private sector by de-reserving it for small scale industries. The programmes of farm mechanization have resulted in adoption of farm machinery such as tractors, power tillers, combine harvesters, irrigation equipment, plant protection equipment, threshers and improved implements and hand tools.

The Government of India has also initiated programme like Sub-mission on Agricultural Mechanization (SMAM) with an estimated outlay of US$ 350 million during XII plan. The objectives of SMAM are to increase the reach of farm mechanization to small and marginal farmers, promote custom hiring centres, create hi-tech, high value farm equipment hubs and create awareness among stakeholders (Anonymous, 2014b). Under mechanization component of the SMAM, there is a provision of subsidy of 40% for ownership of tractors restricted up to INR 75,000 (up to 20 PTO hp) and INR 0.10 million (above 20-70 PTO hp) for promoting agricultural mechanization. Different state governments of country offer top up subsidy for purchase of small tractors by farmers for use on their farm work.

The government's target to double farm income in five years will not only help in reducing volatility in sale of tractors, but also act as a catalyst to drive penetration of related implements.

Conclusions

The following conclusions can be drawn from the study.

i. The sale of tractors in India increased at a compound annual growth rate (CAGR) of 10.3% from 3,877 units in 1961-62 to 633,656 units in 2013-14.
ii. The domestic sale of tractors is the highest (43%) for the 31-37 kW power range and followed by 36% for the 23-30 kW power range during 2015-16. The requirement of high power category tractors in India increased for using high capacity farm machines on custom hiring basis.
iii. The states of Uttar Pradesh, Madhya Pradesh, Rajasthan, and Maharashtra together account for about 40% of the total tractors sale in India during 2015-16.
iv. The tractor availability per 1,000 ha of net sown area is more than all India average of 43 tractors/1,000 ha in seven states of Haryana, Punjab, Uttar Pradesh, Bihar, Tamil Nadu, Andhra Pradesh and Gujarat.
v. There was a positive direct correlation between available tractor power and food grain productivity for all the major states except Assam and West Bengal.
vi. There was direct positive correlation between tractor density and average land holding size for all the major states except Bihar, Jammu and Kashmir, Tamil Nadu and Uttar Pradesh.
vii. The percentage sale in tractors of less than 15 kW power was the highest in Gujarat (20.7%) and followed in Maharashtra (18.4%) and Kerala (14.2%) states. These states used the tractors for intercultural and spraying operations in horticultural and cash crops.

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Present Status and Future Prospects of Agricultural Machinery Industry in Iran

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IRAN

Overview

Iran is a temperate zone with most arable land of 16,500,000 ha. Farming is mostly irrigated but in some northern parts cereals are grown as dry cultivation. **Fig. 1** shows land use and major crops cultivated in Iran (Source: Wikipedia)

Agricultural Machinery

Tractors

There is only one government factory that assembles MF285 in Tabriz city under English license. Some parts are made locally, some comes from Turkey. The production before Iran's world sanction was 14,000 per year but during the sanction period it dropped to as low as 4,000. There are private companies that import other tractors like Valtra from Finland, New Holland tractors, TYM tractors from South Korea and some from China. These tractors come as a complete set. The price of Valtra and New Holland are

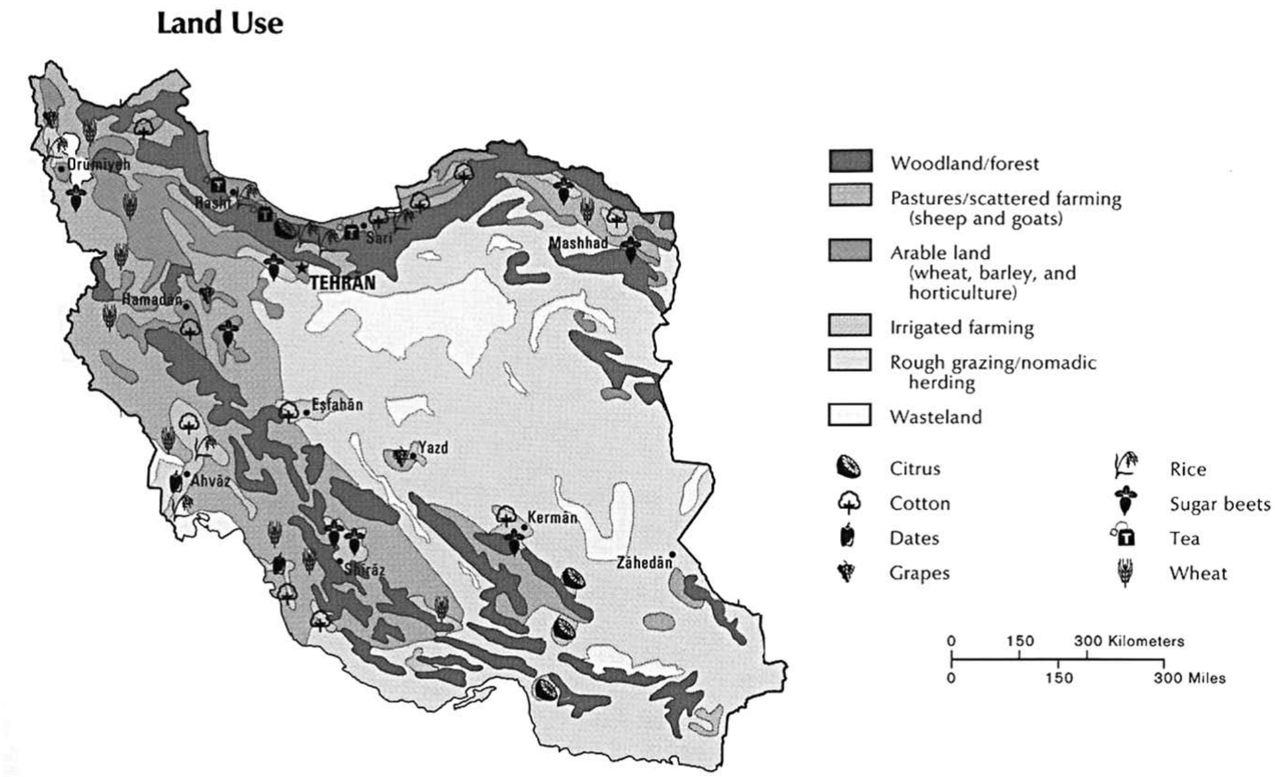


Fig. 1 A map of land use and major crops in Iran

as high as about 4 times more than the nationally assembled MF285 but yet some farmers prefer to pay the price because of the low quality of MF285. After sales service generally is very poor.

Grain Combines

There is only one factory shared with government that assembles the John Deere 995 and some John Deer 1165. Header is 16 feet long. The body parts are made locally but the engine comes from Germany and transmission parts from Brazil, China and or Turkey. A few other types of combines like Claas also imported as a complete set. The price of these machines may be as high as 10 times more than the Iranian combine; yet some farmers prefer to pay the price because of low quality of domestic machines. The Iran combine factory also produce some Baler some of which are exported to Russian Azerbayjan.

ICM (Iran Combine Manufacturing) products have been exported to China since 1984, and since then, the company's distribution network has expanded to include Kazakhstan, Tajikistan, Pakistan, Afghanistan, Iraq, Zimbabwe, Spain and Venezuela.

Other Machinery

Corn choppers are imported from Germany or other countries. Plows, Disks and Levelers are assembled with imported parts. Mechanical grain drills of 2.5 meter width are assembled in government owned factory but some Pneumatic ones are recently imported too. Rotary tillers and drum type harvesters are manufactured or assembled by private companies.

The future plan is unknown yet but hopefully joint venture companies either government or private companies may manufacture more and better quality machines. Manufacturing as many as national need and even exporting to the neighboring Middle East countries may be in sight.

The following two **Table 1** and **Table 2** give insight to the mechanization degree. The statistics is given by the Ministry of Agriculture. These are old values but may still be valid for present time. **Table 3** is a comparison for change in degree of mechanization between 1993 and 2005.

Future Expectations

Cited from Institute for Community Economics (ICE) tractor demand in the province is for units in the 150-200 HP category and that more powerful 200-300 HP tractors are not manufactured in the country. Regarding the other machinery, priority demand is for soil preparation machinery, technologies for seeding and fertilization and harvesting machinery. In this connection as the ICE report explained, this means that a large part of the country's farming enterprises are operating at below full capacity and at low levels of productivity. The question of the mechanization of the countryside and renewal of the machinery inventory, with the current crucial factor for purchasing being the quality/

Table 1 Degree of Mechanization in Iran for 1993*

Crop type	Tillage			Planting			Cultivation				Harvesting			Post harvest
	Plow	Disk	Leveler	Broadcast	Drill	Row	Fertilizer	Cultivator	Spray	Thinning	Binder	Rotary	Combine	
Wheat irrigated	100	86	22	61	10.3		77		26		9.5		65.6	
Wheat dry farming	80	65		50					30		8.6		63.4	
Barley irrigated														
Barley dry farming														
Maze	100	100	30				50	35	35	35			90	
Corn	100	100	30		100	6	50	35	35	35				
Rice	100	15	100		100		10		15			100		
Sugar beet	100	100	50				50	50		50		100	53	
Cotton	100	98	30		53		85	55		55			1	
Alfalfa														
Potato	95	65	10		15		20							
Onion														
Tomato														
Beans irrigated														
Beans dry farming														

*Blank means not applicable or non-exist data price ratio, looks certain to be raised in the not distant future. On the other hand, with consideration of the structural make-up, Iran appears strongly focused on tractors, 16% of the total, power ploughs, 14.1%, and trailers, 10.3%, whereas forage harvesting machinery with balers, mowers and rakes account for only 1.73% at the opposite end of inventories. In detail, the tractor market is clearly an oligopoly with some

Table 2 Degree of Mechanization in Iran for 2005

Crop type	Tillage			Planting			Cultivation				Harvesting			Post harvest
	Plow	Disk	Leveler	Broadcast	Drill	Row	Fertilizer	Cultivator	Spray	Thinning	Binder	Rotary	Combine	
Wheat irrigated	100	88	62	57	38.3		77		48		12		80	
Wheat dry farming	88	57	6	26	62		24		32		19		69	
Barley irrigated	78	68	49	52	25		49		22.5		15		70	
Barley dry farming	90	50	0.5	40	32.5		26		11		15		66	
Maze	98.5	93.5	70			88	91	48	64				98	3
Corn	96	95	76			90	83	50	70			99		1
Rice	78	78	69				23				11		20	
Sugar beet	100	89	67.5			83	71.5	55.5	71			80		
Cotton	98	90	53			42	56	35	43					4
Alfalfa	78	67.5	53	27	16		36		28			42	1.5	
Potato	96	85	51			61	68	36	37			70		
Onion	99	75	28		9		20		9.5					
Tomato	90	80	50				60	25	40					
Beans irrigated	92	39	38		32		46	2	26		5		1	
Beans dry farming	80	32	2		18		22		20					

Table 3 Comparison of changes of Degree of Mechanization in Iran from 1993 to 2005*

Crop type	Tillage			Planting			Cultivation				Harvesting			Post harvest
	Plow	Disk	Leveler	Broadcast	Drill	Row	Fertilizer	Cultivator	Spray	Thinning	Binder	Rotary	Combine	
Wheat irrigated		2	40	-4	28				22		2.5		15.6	
Wheat dry farming	8	-8	6	-24					2		10.4		5.6	
Barley irrigated														
Barley dry farming														
Maze	-1.5	-6.5	-40			-22	41	13	29				8	
Corn	-4	-5	46			-10	33	15	35			-1		
Rice	-22	53	-31				13							
Sugar beet		-11	12.5			30	21.5	5.5				27		
Cotton	-2	-8	23				21	20						
Alfalfa														
Potato	1	20	41			46	48							
Onion														
Tomato														
Beans irrigated														
Beans dry farming														

*Figures with positive sign means increase in degree mechanization and the one with negative sign means decrease. The blank means no change.

brand names strongly denominating the market followed by a few others in competition among themselves. According to Iranian Ministry for Agriculture data cited by ICE, the tractor inventory in 2013 consisted of slightly fewer than 390,000 units and 51% of them, more than 200,000 of them, were Massey Ferguson tractors and another 35% carried the Romanian brand Tractorul Brasov. Far below the standings were John Deere at 3.4% and Goldoni at 4.1%. This oligopolies arrangement is more visible in the sector of combine harvesters for cereals where it may be more appropriate to refer to a monopoly for John Deere, the supreme leader with 75% of the market with 10,911 harvesters out of a total of 14,608 units. The Claas, New Holland, Massey Ferguson and Belarus brands compete.

Marginally less than 12% and the remaining 13% is held by other brands. In this polarized setting, Made in Italy production played a marginal role up to 2013 with 4.6% of the tractor market and 3% for harvesters. Confirming this picture is the trend for 2011 to 2013 when Italian tractor exports to Iran came to the value of only € 780,000 per year for a total of € 2.3 million to indicate a degree of chill in these trade relations. This was especially true for 2013, when Italian exports went beyond the value of € 470,000 only with difficulty. The statistics on tractors for the first nine months of 2014, on the other hand, provide a glimpse of a decisive reversal of this trend with export value quadrupled over the previous year. It is difficult to say whether this recovery might be the beginning of a new course or is merely an episode in a sector in which the climate of caution and uncertainty will continue until the problem of the sanctions is solved.

A major crop is saffron in the Khorasan province for which Iran is the world's leading producer with 56 tons exported in 2011. The province is also home to agricultural machinery manufacturing with plants in Mashhad which turnout 55% of Iranian machinery. Iran's major crops are shown in **Fig. 2**.

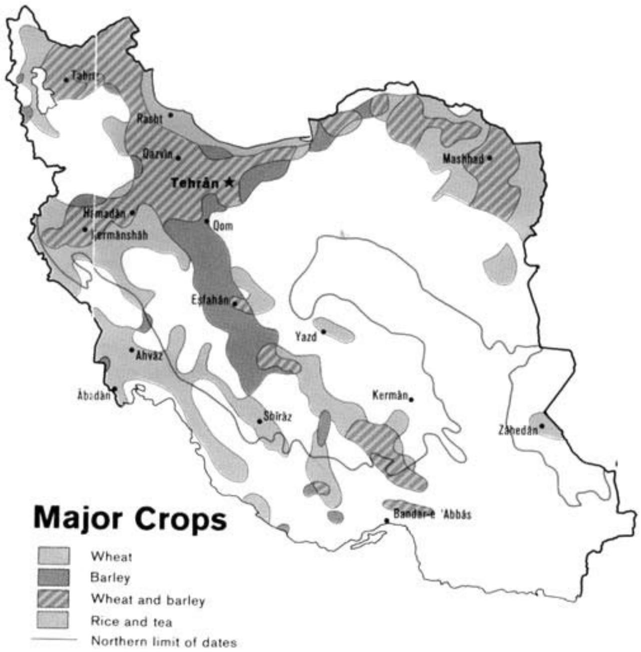


Fig. 2 Iran's major crops. (Source: Wikipedia)

Degree of Mechanization VS Level of Mechanization

Level of mechanization as defined the power/ha available nationwide is of no use in Iran and vaguely worldwide. In Iran specially, it is not a concern because accounts for tractor power only while the electric motor or diesel engine power, the pickup trucks engine power used for farm displacement mater and or back pack power sprayer is not accounted for. It does not account for human power used in the farms either. More than that, the power is not used economically and efficiently in Iran. It also does not exclude the depreciated and/or under repair machines. Mechanization level is not an indication of the progress or depression of mechanization but it

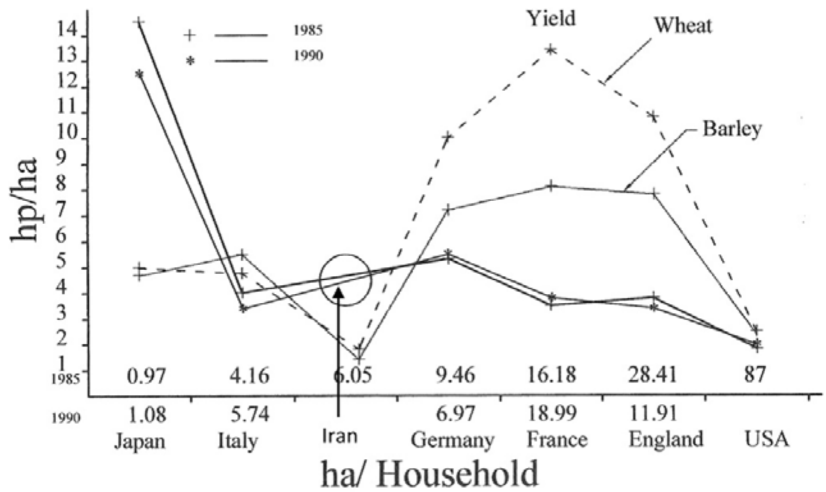


Fig. 3 Mechanization level in some countries and interpolated for Iran

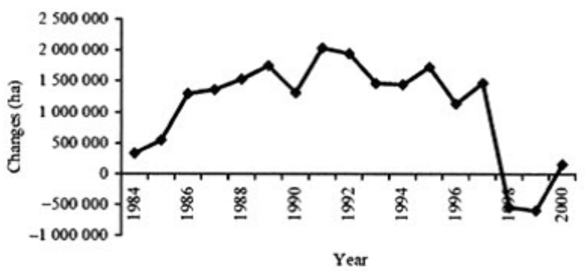


Fig. 4 Changes cultivated land through the years

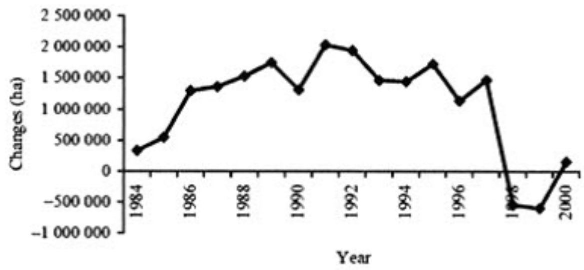


Fig. 5 Number of tractors supplied to agriculture sector through the years

is the degree of mechanization that does so as illustrated in **Tables 1-3** above.

Mechanization level although may be a good comparison between the first world like European, US and Canada where the power is economically and efficiently used but its shortcoming is that it does not explain that what kind power it shows; that is the indicated power, brake power or drawbar power.

Mechanization level depends on the average household farm area as shown in **Fig. 3**. The less the area the more power is needed. As such, the level of mechanization in Iran with about 6.5 ha/household by interpolation should go above 4.5 hp/ha while it is said that the present level is about 1 hp/ha and aimed to increase it to 1.7 hp/ha.

Iran's agriculture in general and mechanization specially not only improved but have declined since the start of global sanction against Iran from 1070 till now. The Ministry of agriculture was driven out of the big 20 stories by the government and placed in an old small four story building. Because of the sanction, thousands of companies closed down and many farmers left for nearby town to seek job. **Fig. 4** shows how many hectares were left uncultivated which runs to about 2,500,000 ha form the middle of 1907 to about 2000, So the number of tractors delivered to the farms followed as is shown in **Fig. 5**.

No data are available on mechanization degree other than the one given in **Table 2** for the year 2005. In the paper in the year 2009 use is made of the data for the year 1995 as shown in the **Table 4** which is almost similar to data for 2005.

After the implementation of the JCPOA in 2016 and lifting the sanctions it is been forecasted that agriculture sector in Iran will improve quickly. **Fig. 6** was obtained from internet about Iran's agriculture (sours: TRADING ECONOMICS).

Last: 30191 Irr Billion (Q1 2015)

Forecast: 100934 Irr Billion (Q2 2015)

Appendix

See next page.

■■

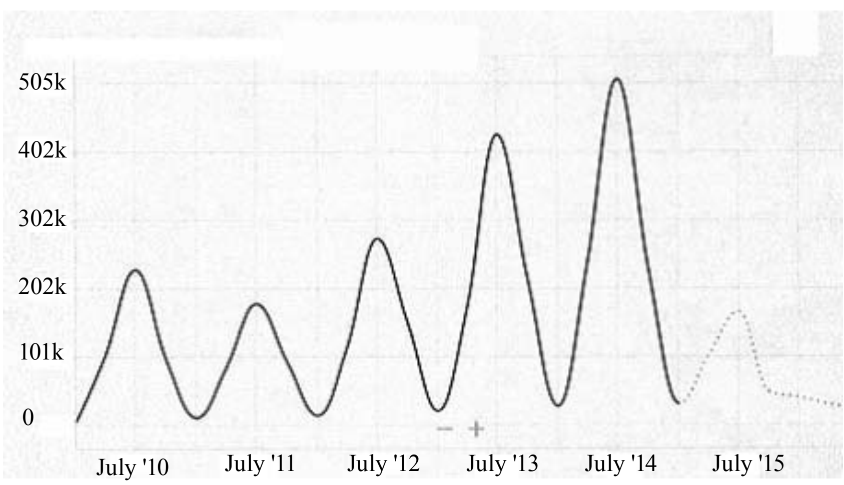
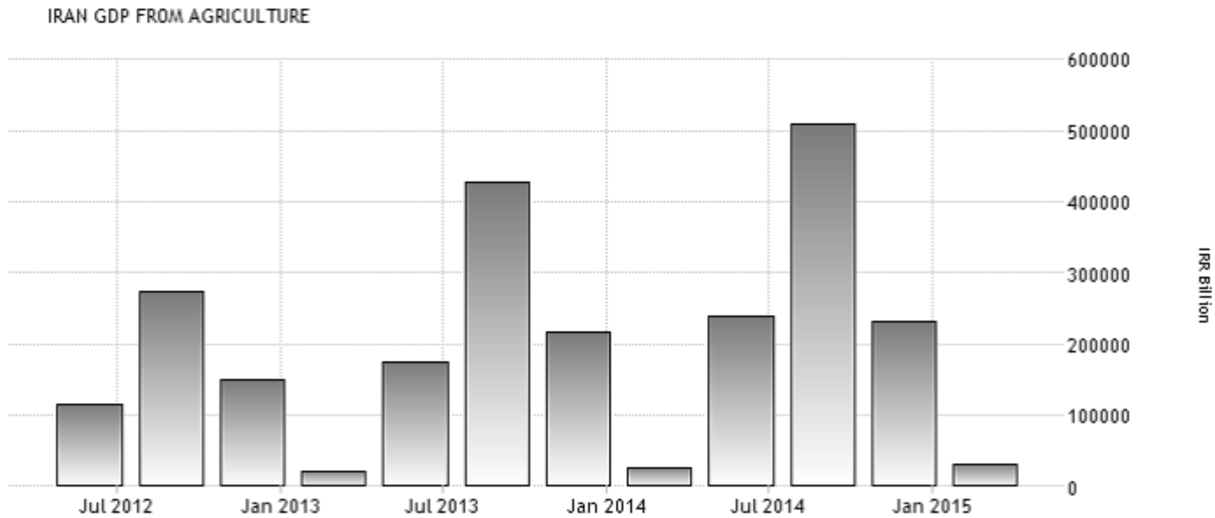


Fig. 6 IR GDP from Agriculture: 507973.00 (3Q 2014)

Forecast of Iran GDP from Agriculture
Iran GDP from Agriculture is forecast to go up to 100934 Irr (Iran Rial) Billion

Iran	Latest	Unit	T+1	T+2	T+3
GDP From Agriculture	30,191	Irr Billion	157,248	100,934	165,316
Government Debt To GDP	16.36	Percent	14.76	16.78	15.72
GDP Per Capita PPP	16,507	USD	15,701	15,508	15,499
GDP Annual Growth Rate	0.6	Percent	3.5	0.4	0.9
GDP	425.33	USD Billion	489.06	381.06	340.32
Current Account To GDP	0.41	Percent	3.39	4.41	3.59

Iran GDP from Agriculture 1988-2017
GDP from Agriculture in Iran decreased to 30,191 IRR (Iranian Rials) Billion in the first quarter of 2015 from 231,145 IRR Billion in the fourth quarter of 2014. GDP From Agriculture in Iran averaged 50,053.82 IRR Billion from 1988 until 2015, reaching an all-time high of 507,973.00 IRR Billion in the third quarter of 2014 and a record low of 142.44 IRR Billion in the first quarter of 1989.
1Y 5Y 10Y MAX



SOURCE: WWW. TRADINGECONOMICS. COM CENTRAL BANK OF IRAN

Iran GDP	Last	Previous	Highest	Lowest	Unit
GDP Annual Growth Rate	0.6	3.7	23.01	-12.54	percent
GDP	425.33	511.62	592.04	6.15	USD Billion
GDP Constant Prices	509,325.00	501,323.00	576,140.00	41,193.94	IRR Billion
Gross Fixed Capital Formation	755,886.00	803,515.00	815,867.00	928.35	IRR Billion
GDP per capita	5,936.54	5,762.52	8,372.61	2,511.00	USD
GDP per capita PPP	16,507.00	16,023.20	17,949.20	10,173.70	USD
GDP From Agriculture	30,191.00	231,145.00	507,973.00	142.44	IRR Billion
GDP From Mining	677,059.00	655,596.00	677,059.00	695.23	IRR Billion
GDP From Services	1,558,114.00	1,406,140.00	1,558,114.00	2,625.68	IRR Billion

Iran GDP from Agriculture
The following data provides - Iran GDP from Agriculture- actual values, historical data, forecast, chart, statistics, economic calendar and news. Iran GDP From Agriculture - actual data, historical chart and calendar of releases - was last updated on January of 2017.

Actual	Previous	Highest	Lowest	Dates	Unit	Frequency	
30,191.00	231,145.00	507,973.00	142.44	1988-2015	IRR Billion	Quarterly	Current Prices, NSA

M. Ghadiryanfar, A. Keyhani, A. Akram, S. Rafife, 2009. The effect of traaftor supply in Iran Agricture from a macro plan point of view. Res. Agr. Eng., 55, 2009 (3): 121-127

Farming Systems in Oman and Mechanization Potentials

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SULTANATE OF OMAN

Abstract

Arid climate and water scarcity are main hindering factors of crop cultivation in Oman. Arable land area is limited to 5.2% of total lands of 1.6 million ha, and which is fragmented to 150,000 land holdings and nearly 80% of them are small holdings limiting the efficient mechanization options. The 20% of large farms covers 29.4% of the arable land area, and thus possess the highest mechanization index. Nevertheless, Oman has shown potentials for agricultural crop production with the adoption of modern technologies. However, the medium and large farms although in numbers are small having good use of machinery and technology. There is an increasing trend of farmers moving to controlled environment agriculture in Oman including hydroponics and aquaponic systems with high value crops. Mechanization potentials in Oman is positive in a broader areas such as machinery and equipment needs for field crops and greenhouses, precision irrigation equipment, water treatment and desalination equipment and accessories etc. needing for higher efficiencies and capacities. Another important and priority requirement in the country is to develop the local skills in production, maintenance and service provisions of these machinery and equipment needs at appropriate costs. Government's investment on skills development at local universities, technical colleges and vocational training institutes is necessary.

Key words: Mechanization, Technology adoption, Potentials, Hindrances,

General Introduction

Oman possesses arid and semi-arid climates with 100 mm average annual precipitation and with summer temperature reaching over 45°C, thus considered not suitable for intensive agriculture. While being a major source of employment, the agriculture sector in Oman has recorded an absolute value added to the economy to be about US$ 930 million in 2010. About 13% of the country's population is considered to be actively engaged in agriculture related employment. However, a major limitation faced by Oman is its limited arable land, which amounts to only 7.07% of the total land area, and only about 10 percent of the total cultivable land is under productive agriculture. About 56% of the cultivated land is in coastal areas. Among these areas, the Al-Batinah region which possesses over 320 km of coastal belt can be considered as the area where cultivation is most intense. Most of these areas are irrigated by groundwater abstraction (MAF, 2013a; Zekri, 2008).

As a semi-arid region, Oman's agriculture relies mainly on ground water abstraction. There was about 315 million m^3 of water deficit to the water table in 2013 (Mott Macdonald, 2013). The deficit balance seems to be compensated by the seawater intrusion in the coastal belt. It is reported that agriculture uses 93% percent of the nation's renewable water, and the agricultural water use was 16% percent more than renewable supplies. In the recent years, Oman has experienced a reduction in agricultural productivity despite newly cultivated lands, especially because the loss due to salinization is higher than the added productivity through new lands (Alahkoon *et al.*, 2013). Reducing the groundwater use in agriculture, another are need to be developed and promoted is the conjunctive use of treated wastewater with groundwater. In Muscat governorate along, the waste water production in 2014 was 90,000 m^3/day and projected to be four-fold in 2025 (Haya, 2016; Jayasuriya *et al.*, 2016). There are sewage and wastewater treatment plants in many areas of the governorate, making tertiary treatments following international standard procedures. However, due to the distribution deficiencies and lack of farmer/consumer preferences, nearly 50% of the treated wastewater is dumped in the sea. This problem has to be rectified by providing necessary extensions services and the distribution network for farms which

Table 1 Trends in agriculture and land use in the Sultanate of Oman

Indicator	Decades				
	1961-1970	1971-1980	1981-1990	1991-2000	2001-2011
1. Economic contribution of agriculture					
Agriculture, value added (% of GDP)	46.29	5.49	3.02	2.52	2.00
Agriculture value added per worker (constant 2005 US$)	nd	nd	1,029.31	1,009.59	nd
2. Employment contribution of agriculture					
Employment in agriculture (% of total employment)	nd	nd	nd	7.67	5.20
Rural population	486,887	554,104	631,064	618,826	706,316
Rural population growth (annual %)	0.99	1.73	0.14	0.16	2.31
Rural population (% of total population)	76.65	60.69	42.12	29.47	27.67
3. Agricultural Land use					
Total Land area (sq. km) = 309500.00					
Agricultural land (hectares)	1,037,300	1,047,400	1,064,400	1,073,400	1,578,800
Agricultural land (% of land area)	3.35	3.38	3.44	3.47	5.10
Arable land (hectares)	20,600	22,900	29,700	30,600	30,473
Arable land (hectares per person)	0.03	0.03	0.02	0.01	0.01
Arable land (% of land area)	0.07	0.07	0.10	0.10	0.10
Land under cereal production (hectares)	2,900	3,162	1,647	3,103	4,084
Perennial cropland (% of land area)	0.05	0.08	0.11	0.14	0.13
4. Agricultural/land productivity					
Crop production index (2004-2006 = 100)	17.63	25.78	57.49	84.34	107.85
Food production index (2004-2006 = 100)	12.01	20.26	47.17	71.14	97.87
Livestock production index (2004-2006 = 100)	9.75	18.05	35.59	54.37	84.38
Cereal yield (kg per hectare)	1,144	1,131	1,738	2,647	5,823
5. Agricultural technology adoption					
Agricultural machinery, tractors per 100 sq. km of arable land	5.76	29.98	41.41	53.23	nd
Agricultural machinery, tractors	12.20	68.80	122.20	161.70	nd
Fertilizer consumption (% of fertilizer production)	nd	nd	nd	nd	3.01
Fertilizer consumption (kilograms per hectare of arable land)	nd	nd	nd	nd	613.14
6. Agricultural Trade					
Agricultural raw materials imports (% of merchandise imports)	nd	1.67	0.99	0.74	0.50
Agricultural raw materials exports (% of merchandise exports)	nd	0.00	0.02	0.02	0.01
Note: nd implies no data records.					

Source: ACoO (2014); World Bank (2013)

Table 2 Distribution of landholding in Oman

Range of farms (ha)	No of Land Holdings	Total Area (ha)	Cropped area (ha)	Land Holdings (%)	Total area (%)
0-0.42	110,233	10,448	8,747	71.58	7.0
0.42-0.84	12,596	7,314	5,032	8.18	4.9
0.84-2.1	14,371	18,863	9,896	9.33	12.7
2.1-4.2	9,046	26,325	11,974	5.87	17.7
4.2-8.4	5,501	30,308	13,491	3.57	20.3
8.4-12.6	1,210	11,938	4,907	0.79	8.0
12.6-16.8	409	5,783	2,202	0.27	3.9
16.8-21.0	174	3,197	1,156	0.11	2.1
21.0-42.0	273	7,746	2,924	0.18	5.2
42.0-84.0	120	6,697	1,701	0.08	4.5
84.0-more	75	20,487	9,469	0.05	13.7
Total	154,008	149,104	71,499	100.0	100.0

Source: ACoO (2004); AcoO (2014) in Kotagama (2014) will help significantly reducing the groundwater abstraction in this area (Al-Wahibi, 2017; Jayasuriya *et al.*, 2016).

There are two main agro-climatic zones can be recognized in Oman based on parameters which influence potential of land, water resources and cropping patterns. The first area is northern Oman including Batinah Coastal plain, Interior Oman and Dahira plains, Jebel Akhdar and Sharqiya plains. The second areas situated in the southern Oman, Dhofar including Salalah plain, Dhofar Jebel and Najd (MAF, 2008). Fruits are widely grown in the southern Dhofar region include bananas, mangoes, and coconuts, citrus fruits, nuts, melons, bananas, coconuts, alfalfa, and tobacco. Tomatoes, cabbages, eggplant, okra, and cucumbers are important winter crops. Frankincense is traditionally produced from about 8,000 trees growing wild in Dhofar. Along the northern Batinah coastal plain, addition to the above mentioned crops, a wide variety of produce is grown, including wheat, rice, and

Table 3 Total number of machinery by type in reporting farm holdings

Machinery Type	Number of Machinery	Subsidized	Total Area of Reporting Holdings (ha)	Total Number of Reporting Holdings
Tractor >40 HP	644	159	14,989	510
Tractor (25-40)	1,179	346	10,395	1,071
Power tiller	7,773	2,036	19,241	6,470
Combine harvester	202	34	9,492	146
Hay Baler	102	12	2,857	72
Greenhouse	3,590	1,681	139	-
Trailer	508	136	1,4072	424
Modern Irrigation pump	6,790	1,563	30,800	5,838
Agricultural residues thresher	1,158	410	6,950	1,108
Pesticides sprayers	10,717	2,743	48,822	9,185
Milking equipment	304	56	1,897	118
Hatching Chambers	532	102	3,984	323
Traditional Irrigation pumps	14,938	226	26,488	12,971
Cart	50,067	1,050	67,376	34,680
Cold Transport vehicle	333	2	5,038	257
Open Transport Vehicle	16,315	67	29,887	15,082
Dates pit remover	16	9	646	16
Sugar cane extractor	44	11	381	39
Irrigation water desalinization equipment	91	5	1,089	79
Dates pressing	29	13	480	25
Dates packaging	31	15	724	28
Dates grinding	49	16	719	40
Dates pollination	6	2	258	6
Dates moisturizing and disinfection	18	6	99	10
Dates washing and drying	14	8	663	14
Agricultural residues shredder	367	100	3,183	349
Dates fumigation	49	1	408	44
Dates pit crusher	9	3	32	6
Milk pasteurizer	88	25	879	80
Green forage shredder	1,153	118	8,579	1,096
Poultry slaughter unit	185	22	3,566	171
Honey extractor	434	119	412	280
Dates residues pressing and manufacturing	18	5	412	18
Butter extractor	167	22	980	153
Rose juice boiler	12	2	3	9
Banana ripening	5	0	19	5
Honey ripening	269	123	617	117
Rose juice extractor	4	0	0	2
Traditional products equipment	656	1	109	228
Others	11,267	43	5,150	4,001

Source: MAF, (2013b)

sorghum (Al-Yahyai *et al.*, Nations Encyclopedia, 2014 retrieved; 2014; Kotagama *et al.*, 2013).

Tables 1 and **2** shows the decade-based averaged summarized statistics of changes in the agricultural and land use in Oman. The agricultural land area of the total land area (309500 sq.km) has been 3.35% in the 1960s which has increased to 5.10% by years 2000s. From 1961 to 2012 there has been 71% increase in the agricultural land area i.e. from 10,350 to 17,705 sq.km. Seven type of farm enterprise combinations of land use have been identified in Oman. These are: crops only, livestock only, poultry only, crops and livestock, crops and poultry, livestock and poultry, crops, livestock and poultry. The solely cropped area in farming systems have remained the same at about 39% of farmed area, the balance being diversified of combinations of crop and livestock or livestock only, between 2004 and 2013 (ACoC, 2004; ACoO 2014; Kotagama, 2014). Kotagama (2014) reported that the small farms are using land (% cropped area) more intensively than large farms, while small farms are cultivating more than 50% of farm area, whilst large farms are cultivating less than 50% of the farm area.

Tractors and field machinery and other technological tools are essential in productive agriculture and makes profits for farmers and growers. With regards to the mechanization, the governmental inputs of tractors and field machinery to promote mechanization in the Sultanate of Oman began in the mid-1970s. Under agricultural technology adoption, the decade average of tractors/sq.km significantly increased from 5.76 in 1961-70 to 53.23 in 1991-2000 (**Table 1**). Promoting mechanization (**Table 3**), during the inception between 1976 and 2002 the government of Oman distributed 1,803 double axel tractors to farmers at 50% subsidized price. At the end of 2002, the usage of equipment as indicated by mechanization index and power input were 75% and 1.10 kW/ha, respectively.

According to the latest census that was held by the Ministry of agriculture and Fisheries, the total number of double-axle tractors and power tillers in reporting farm holdings were, 1,823 and 7,773, respectively (MAF, 2013b). While the number of double-axle tractors remained relatively the same compared to 2002, the number of power tillers has increased approximately by 8.5 folds.

a. Traditional farming with aflage/ spring irrigation

b. Wadi (low-land) farming of vegetables and forage

c. Terrace intercropping of dates, banana and vegetables

d. Irrigation with Aflaj/spring water in mixed farming

Fig. 1 Small and traditional farming systems in Oman

Although the climatic conditions does not help much in agricultural production due to water scarcity, all types of farming systems can be seen in Oman in the northern coastal belt (Al-Batinah region), North-Central (Nizwa, Bahla regions) and in the South (Salalah region) and can be classified as small, medium and large farms. Arable land area in Oman is mere 5.1% (157.9 Sq km) of the total land area of the country. Majority of the production is for local consumption and small volumes are produced for export; 66% family consumption, 28.4% trade within Oman, 3.9% export (ACoO, 2014, Kotagama, 2014)

Farming Systems in Oman

Small and Traditional Farming in Oman

Small farms (0-0.84 ha) covers nearly 79.8% of the farmland holdings, but only 11.9% of the total arable lands (ACoO 2014, Kotagama, 2014). **Fig. 1** shows some pictorials of small and traditional farming systems in Oman. Technology adoption is minimal, however in the plain and Wadi low-land) farming can be improved with adoption of appropriate technology. Along with the crop production, animal husbandry activities (Cattle, Goats, Camels, and Sheep etc.) are taking place, for which some of the small farms are used for forage crops (Kotagama, 2014).

Medium Scale Farming in Oman

Medium farms (0.84-12.6 ha) covers 19.6% of the farmland holdings and 58.7% of the total arable land area (ACoO, 2014, Kotagama, 2014). **Fig. 2** shows some pictorials of medium farming systems and activities in Oman. Moderate technology adoption and mechanization can be seen in these farms. Mechanization is limited to small and medium tractors and associated implements, irrigation pumps and equipment, sprayers, and other crop protection devices. Medium scale farmers face the challenge when concerned with marketing. Under open trade policy, agricultural products are imported with taxation and local farmers have to compete with imported products and fluctuating prices.

Large Scale Farming in Oman

Large farms (12.6-more ha) cov-


a. Planting machinery


b. Baling machinery


c. Medium farm growing open-field tomatoes


d. Medium farm growing coriander/ parsley


e. Irrigation with groundwater in mixed farming


f. Produced sold at local markets, compete with imported products

Fig. 2 Medium farming systems and activities in Oman


a. Beans fields


b. Carrot fields


c. Radish fields


d. Cherry tomatoes in large greenhouses


e. Bell pepper in large greenhouses


f. Water melon as a summer crop

Fig. 3 Crops grown in large farms in Oman. (TAS LLC., 2017) ers 0.69% of the farmland holdings and 29.4% of the total arable land area (ACoO, 2014, Kotagama, 2014). The limited number of holdings of 29.4% of the arable land area means there are large farms. There are large farms adopted with cutting-edge technology in Oman. Some farms even hold the Global GAP licenses and exporting their products overseas including North American and European markets. **Figs. 3** and **4** show some pictorials of large agricultural farms in Oman and activities with technology adoption.

Conventional Practices, Tools and Agricultural Machinery Used in Oman

Since ancient ages, the Omani farmer has been interested in the cultivation of various kinds of crops, but mostly dates palm, mango and lemon, as well as crops for cattle feed such as, alfalfa, grass, etc. As it was the case with most ancient agricultural civilizations, farmers used simple and conventional machinery for accomplishing the various field operations, such as, plowing, seeding, harvesting, irrigation, etc. However, the common element on performing these operations was the use of human and animal muscles (Ampratwum *et al.*, 2004).

Examples of tools used for tillage were, axes, and grub hoeses (**Fig. 5a** and **b**). Those implements were used to dig into the soil to open holes for planting trees, or for plowing agricultural fields. Similarly, for harvesting, farmers used sickle knifes (**Fig. 5c**). For transporting harvested crops and products, containers that are were made from date palms fronds, locally called “qafeer” (**Fig. 5d)**.

Those were used to harvest crops and to cut dead or unwanted

a. Fleet of machinery in a large farm in Oman

b. Equipment yard ina large farm in Oman

c. Planting

d. Irrigation

e. Crop protection - spraying

f. Automated drip irrigation systems

g. Moisture conservation in summer

h. Carrot combine

i. Cleaning and sorting of carrots

j. Packaging for marketing

Fig. 4 Farm activities with technology adoption in large farms in Oman. (TAS LLC., 2017)

a. Grub hoe plowing b. Axe for plowing c. Sickle knife for harvesting d. Container made of date palms fronds (Qafeer)

e. Plowing with bullocks f. Traditional groundwater lift g. Aflage water channels

Fig. 5 Examples of tools and methods in traditional agriculture in Oman

branches of plants. **Fig. 5e** shows a traditional tillage implement

Table 4 Development of Greenhouse cultivation in Oman

Year	Subsidized	Without subsidized	Total
2001	80	702	782
2002	81	835	916
2003	100	915	1,015
2004	164	1,094	1,258
2005	198	1,139	1,337
2006	256	1,393	1,649
2007	341	1,557	1,898
2008	917	1,574	2,491
2009	1,274	1,774	3,048
2010	1,692	3,048	4,740
2011	N/A	N/A	N/A
2012	2,975	2,244	5,219
2013	2,790	2,259	5,049
2014	2,949	2,526	5,475
2015	2,900	2,663	5,563

N/A – Not available. ICARDA, (2011), MAF, (2014)

Fig. 6 Detached Quonset-type greenhouse commonly used in Oman

dragged by bullocks. Most of water used for irrigation was provided from wells. Water was lifted from these wells using novel machinery locally named "Al-mangoor" (**Fig. 5f**). Bullocks were used to provide physical power to lift the water from the wells to the surface. Water channels "Aflaj" (**Fig. 5f**) were used to transport water to the anticipated agricultural lands.

Potentials of Control Environment Agriculture in Oman

In Oman, crop cultivation in controlled environment agriculture (CEA) systems is developing very rapidly (**Table 4**). The number of greenhouse units leaped from 782 in 2001 to 5,058 in 2014 (MAF, 2009 and 2014). Annual greenhouse growth rate was reported to be around 40% [Al-Kiyumi, 2006; and Al-Sa'di *et al.*, 2007]. However, this rapid increase was not accompanied with the adoption of agricultural machinery due to two main reasons. The first reason is the small scale greenhouse farming where 89% of farmers grow in single detached greenhouses having an individual area of 350 m^2. The second reason was that most farmers have a Quonset-type (semi-circular tunnel) greenhouse structure (**Fig. 6**) which is not spacious enough to allow heavy machinery to operate. Nevertheless, many famers started embracing light-weight, small-size machinery inside greenhouses. For instance, besides manual tillage, the use of mini-tillers was practiced in many greenhouse units. **Fig. 7** presents three types of mini-tillers available for greenhouse uses.

High-tech greenhouse farms are very scarce in Oman, yet they started increasing. **Fig. 8** illustrates the largest greenhouse company where barrel-vault connected greenhouses are used. In this farm, the area under plastic is around 9.6 ha divided into 8 greenhouse units. There is a very high potential to use heavy machinery in this type of farms due to the large greenhouse structures which allow access and operation of different types and sizes of machinery.

Constraints for Production Agriculture and Mechanization Potentials in Oman

When concerned with the constraints, and hindrances holding the agricultural productivity improvement through technology adoption following areas have the potentials once the withholding bottlenecks are removed.

For solving most of the issues below needs a strong extension services through the Ministry of Agriculture and Fisheries of Oman. Training of such extension officers is one of the main requirement and a challenge for the tertiary educational institutions in Oman and elsewhere.

1. For solving domestic/irrigation water requirements of farming community in seawater intruded areas; solar-powered stand-alone desalination technology can be promoted for rural farms.
2. For solving large and increasingly deficit in groundwater aquifers along the coastal plains and reducing over pumping of ground water;
   a. adopt and promote precision irrigation technology with sensor-based, stand-alone systems among farmers (Jayasuriya *et al.*, 2014a). Government subsidiary programs may assist in this issue as the water table deficit and salinity in arable lands along the coastal plain is an alarming issue in Oman.
   b. promote the use of treated wastewater conjunctively with ground water. This approach can be fulfilled by providing more treatment plants and transportation networks in planned manner. Technology and machinery for filtering, pumping etc. will be necessary (Jayasuriya *et al.*, 2016).
3. For improving the irrigation water use efficiency and reducing the consumption; technology for better tillage management (precision tillage) to improve the water holding capacity (Jayasuriya *et al.*, 2014b).
4. For solving the issues with high percentage of small land holding still growing traditional and open-field agriculture (**Tables 1** and **2**);
   a. promote the use of small, appropriate size machinery and tools to improve land and labor productivities.
   b. promote technology adoption in Controlled Environment Agriculture (**Table 4**) with greenhouses, hydroponics and aquaponics etc., appropriate technology and services providers are need to be made available.
5. Local machinery and equipment industry and service providers should be made available.
6. Better distribution of machinery and equipment dealers and service providers at local levels, within reach of farmers. Also small scale machinery and equipment availability for small farmers should be worked out.
7. For handling all above all above requirements, local skilled manpower will be necessary. Government investment and support will be necessary for capacity building and technology transfer through universities, technical colleges and vocational institutions. Training programs of specific needs are to be given priority.

Conclusions

Agricultural mechanization in Oman is spread in a broader spectrum. Small farms with low level of mechanization and largest farms adopted with best technologies and highest level mechanization and even holding Global GAP certification for product exports. Potential sectors which are to be given emphasis on improvement are;

- Better machinery, equipment and services distribution throughout the agricultural areas.
- Small capacity machinery and equipment availability for small farmers.
- Better availability of precision irrigation equipment and technology, which can improve the water use efficiency.
- Better availability of low-cost technology and equipment for desalination and wastewater reclamation.
- Better availability of technology and equipment for controlled environment agriculture such

a. Medium-scale tiller
b. small-scale cultivator
c. small-scale cultivator tiller

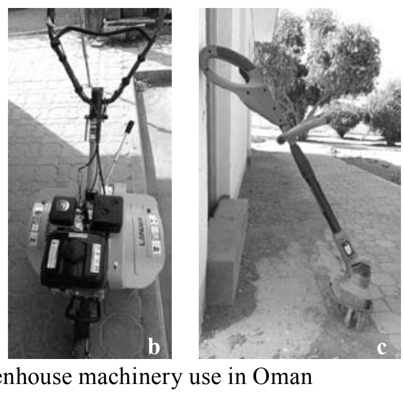

Fig. 7 Small- to medium-scale greenhouse machinery use in Oman

Fig. 8 Large-scale high-tech greenhouse enterprise found in Oman

as greenhouse, hydroponic and aquaponic systems.

- Uplift of local skilled manpower through better educational and training facilities.
- More investment for local Universities, technical colleges and vocational training institutes to conduct specific programs for capacity building and technology transfer.

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Controlled Environment Agriculture in Oman: Facts and Mechanization Potentials

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Abstract

Harsh weather conditions in Oman curbs open-field cultivation of high-value vegetable crops. Greenhouse cultivation presents a promising solution to overcome these conditions. This paper presents the status of controlled-environment agriculture in Oman and highlights the associated mechanization potentials. It was reported that greenhouse population increases swiftly due to the subsidy program implemented by the government. Greenhouse cultivation increased water and land productivity by 2 and 12 times, respectively. The dominant crop cultivated in greenhouses is cucumber (90%) followed by tomatoes (5-9%). Other crops such as beans, capsicums, strawberry, raspberry and melons are also cultivated. Although the main purpose of greenhouses is crop cultivation, other applications such as poultry production, growth chambers, solar drying and saline water desalination are also practiced. Single-span Quonset-type greenhouses are the most popular greenhouses (89%) while double- and multi-span greenhouses are less popular (11%). The majority of greenhouses are covered with polyethylene films but some farmers started shifting to polycarbonate cladding due to its long-lasting and thermal insulation properties. For environmental control, fan-pad evaporative coolers are used to reduce ambient temperatures. Natural ventilation is only practiced in high tech-greenhouses. Other mechanisms such as shading and painting with reflective materials are implemented to reduce light transmission. Soil-based cultivation practice is more popular (97%) as compared with hydroponic systems (3%). The seasonal profitability of cucumber and tomato crops is USD 744 and 369 per greenhouse, respectively. The use of machinery in greenhouses is very weak due to the limited access inside Quonset greenhouses. However, small-size machinery such as mini- and medium-size tillers are used.

Keywords: Quonset-type, multi-span, productivity, profitability.

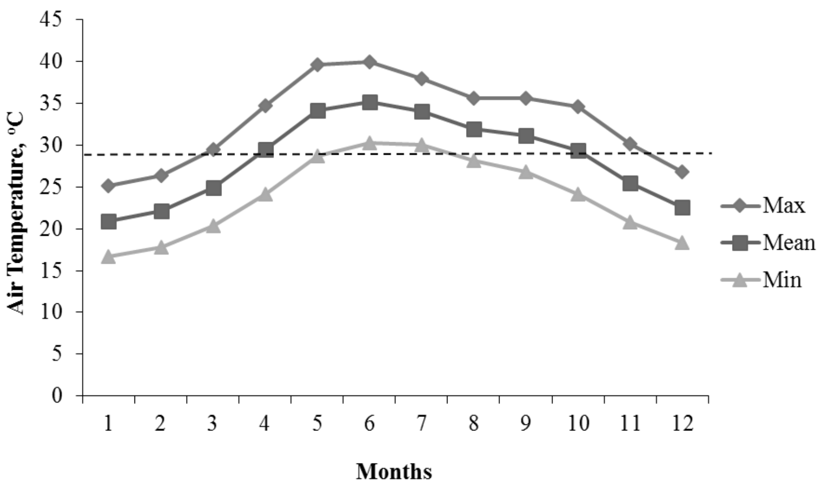


Fig. 1 Monthly averages of minimum, mean and maximum air temperatures for the period 1986-2009 in Oman (DGM, 2017).

Background

In Oman, ambient weather conditions are not conducive for open-field cultivation of most vegetable crops. Using a dataset of 24-year period (1986-2009), it was found that the average monthly air temperature was ranging from 20.9 to 35.15°C whereas the maximum values were between 25.1 and 40°C (DGM, 2017). In several places, the average temperatures can go beyond 45°C during the summer months (Al-Ismaili and Jayasuriya, 2016). Many vegetable crops have a decline in their growth and production as the temperature exceeds their optimal temperature range. For tomato, cucumber, pepper and lettuce, this happens if temperature exceeds the range 29-30°C (Hochmuth, 1990; Fath and Abdelrahman, 2005). Thus, it is clear from **Fig. 1** that open-field cultivation of these vegetables in Oman will be less-efficient or impractical for 9 months of the year when air temperature exceeds 29°C.

Another challenge facing open-field cultivation is water scarcity due to low precipitation. The annual precipitation in Oman is only around 100 mm while the potential evapotranspiration is 20 folds higher (Stanger, 1985). This scarcity coupled with aggressive groundwater over-pumping resulted in a severe seawater-intrusion problem in coastal areas (Ahmed *et al.*, 2001; Al-Ajmi and Rahman, 2001). As a result, more than 50% of the agricultural land of Al-Batinah coastal plains, most agricultural area in the Northern of Oman, has been abandoned (AlKhamisi *et al.*, 2013). Therefore, to tackle these challenges, technology and proper management of agricultural practices could be the key solution. The adoption of controlled environment agriculture (CEA) was one of the practiced solutions.

Facts on CEA in Oman

Commencement

The term Controlled Environment Agriculture (CEA) refers to a variety of agricultural systems including greenhouses, shade-houses, screen-houses and aquaponics. However, this term is mostly used to mean solely greenhouses because the latter is the dominant form of CEA. In Oman, greenhouses represent 92% of total CEA systems (MAF, 2014). The Ministry of Agriculture and Fisheries in Oman played an important role to spread greenhouse technology across the country via awareness campaigns and subsidy programs. First greenhouses were constructed in the 1990s and since then their numbers keep growing rapidly at a rate of 40% (Al-Kiyumi, 2006; AL-Sa'di *et al.*, 2007). **Fig. 2** illustrates the rapid increase of CEA systems (greenhouses and shade-houses) in Oman. This figure also depicts that the greenhouse subsidy programs achieved the pre-set objectives as many farmers were motivated to build new greenhouses on their own expenses.

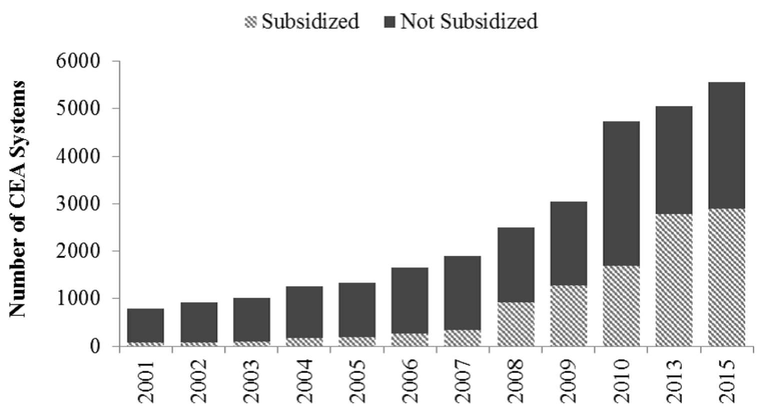


Fig. 2 Number of subsidized and non-subsidized CEA systems in Oman for the period 1986-2009 (MAF, 2009; MAF and ICARDA, 2011).

Purposes

The main purpose of greenhouses in Oman is crop cultivation where more than 90% of greenhouses are cultivated with high-value vegetable crops (MAF and ICARDA, 2011). Yet, some new applications started emerging. Greenhouses are also widely used for poultry production (**Fig. 3**). For a vegetable greenhouse to be transformed into a poultry greenhouse, the only necessary modification is to add a thermal insulation layer under the cladding material. Greenhouses are also used as growth chambers for certain types of functional and medical herbs and algae. **Fig. 4** illustrates one greenhouse used to grow spirulina algae which is used as a nutrient supplement. Another application of greenhouses is for drying different varieties of food products such as fish, dates and limes as in **Fig. 4** (Basunia *et al.*, 2011, 2012; Basunia *et al.*, 2013).

One more unique and advanced application of greenhouses is to use them for water desalination in conjunction with crop cultivation. This is clearly manifested in the seawater greenhouse (SWGH) located in Muscat (Al-Ismaili, 2014; Al-Ismaili and Jayasuriya, 2016). The SWGH (**Fig. 5**) is an ordinary-design

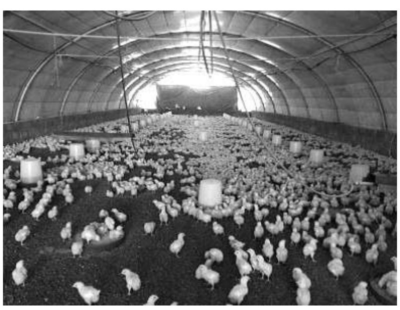


Fig. 3 Poultry greenhouse (left) and spirulina-cultivated greenhouse (right).

Fig. 4 (a) Small-scale solar-powered greenhouse, **(b)** greenhouse drying of dates, and **(c)** greenhouse drying of sardine fish

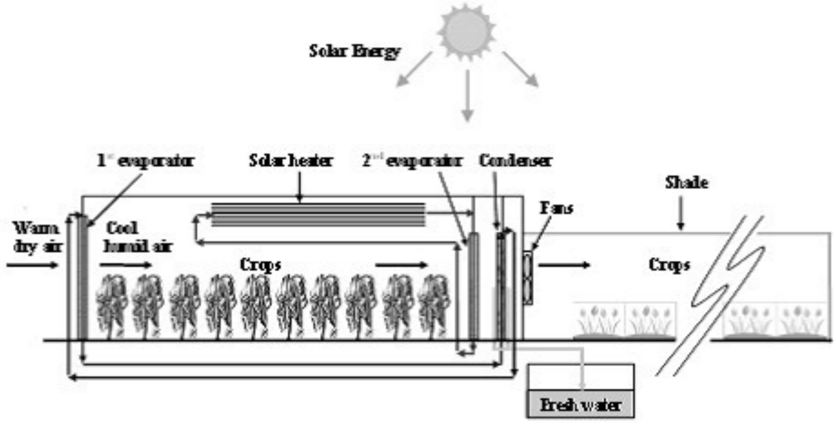


Fig. 5 Schematic of the SWGH in Oman (Al-Ismaili and Jayasuriya, 2016)

a. without side walls

b. with side walls

Fig. 6 Detached Quonset greenhouses at the agricultural experiment station of Sultan Qaboos University

greenhouse which has a condensation unit to dehumidify water vapor. Saline groundwater or seawater is used to wet the evaporative cooler at one end of the greenhouse. Temperature of water and air stream is reduced as they leave the cooler due to evaporative cooling. The cooled water is pumped to the condensation unit as a coolant. After air flows through the cropping area of the greenhouse, it passes through another evaporative cooler. Saline water in the second cooler is preheated via a solar heater in order to saturate and increase the temperature of the air. Eventually, the air stream passes through the plastic tubes of the condensation unit where air is dehumidified due to temperature differential. Produced freshwater is then used for irrigation.

Structural Design

The vast majority of greenhouses in Oman are non-connected (detached) single-span Quonset-type greenhouses, similar to **Fig. 6**. The detached greenhouses in Oman represent 89% of the total number of greenhouses (MAF, 2014). The standard dimensions of this type are 39 × 9 × 3 m (L × W × H). However, this is not the best design for vertically-growing vegetables due to the curvature of this design which causes wastage of space at both sides of greenhouse. To overcome this problem, Quonset greenhouses with side walls are nowadays built (**Fig. 6**). On the other hand, double- and multi-span greenhouses represent only 11% of greenhouses in Oman (**Fig. 7**). However, the number of farmers opting for double- and multi-span greenhouses keeps on growing. This type of greenhouses increased from 169 in 2008 to 388 in 2015 (MAF, 2009, 2014).

High-tech greenhouse farming is very rare in Oman due to the high investment cost which is not affordable by common farmers. The largest greenhouse farm is the Life and Water Co. where 8 multi-span Barrel-vault greenhouse units have been constructed where the area of each unit is 1.2 ha (**Fig. 8**).

The most popular cladding material for greenhouses in Oman is

Fig. 7 Double-span (left) and multi-span (right) greenhouses in Oman

Fig. 8 High-tech greenhouse series.

polyethylene films (**Fig. 6a**) due to their low costs, ease of installation and flexibility. However, double-layer polycarbonate cladding is getting a wide acceptance by the farmers' community due to its long-lasting and thermal insulation properties (**Fig. 6b**).

Crop Types

Cucumber is the most dominant cultivated crop in greenhouses. Nearly 90% of cultivated greenhouses grow cucumber and 5-9% grow tomatoes (MAF and ICARDA, 2011). Other vegetable crops such as capsicums and beans are also grown but at a small scale. Because most greenhouse farmers grow cucumber, the production of cucumber in 2010 increased by 24 times as compared with the production in 2009 from open-filed cultivation (MAF and ICARDA, 2011). Consequently, many farmers started exporting cucumber to regional and international markets. The reason for the widespread of greenhouse cucumber is its superior attributes such as simplicity of cultivation, salt tolerance and stability in market prices. Greenhouses are also cultivated with a limited number of fruits such as strawberry and melon. **Fig. 9** illustrates a variety of vegetables and fruits cultivated in greenhouses.

Environmental Control

As stated in section 1, temperature is a major constraint for open-field agriculture. Therefore, fan-pad evaporatively-cooled greenhouses are adopted by farmers. The fans, located at one end of the greenhouse, exert a negative pressure inside the greenhouse, causing ambient warm air to pass through the wet cooling pads at the opposite end (**Fig. 10**). Normally, ventilation and cooling systems are operated using two thermostats; one thermostat is connected with one fan and the other is connected with the second fan and the water pump associated with the cooling pads. When air temperature reaches the set-point of the first thermostat, one fan is operated (i.e. ventilation without cooling). When the temperature reaches the temperature set-point of the second thermostat, the second fan and the water pump operate (i.e. evaporative cooling). However, this cooling method sometimes needs to be accompanied with other mechanism to maintain temperature at acceptable levels. Some farmers tend to put a shading

a. cucumber crop　　b. cucumber yield

c. yellow and green capsicums　　d. red capsicums　　e. black tomato　　f. cherry tomato

g. strawberry　　h. raspberry　　i. honey melon　　j. rock melon harvesting

Fig. 9 Greenhouse crops

material over the polyethylene sheet to reduce light penetration (**Fig. 11**). Others spray reflective paints on the covering material or even they apply white cement powder (**Fig. 12**). On the other hand, natural ventilation is not practiced in most greenhouses because the design of the detached Quonset greenhouses does not allow. Some computer-controlled high-tech greenhouses adopt natural ventilation as well as thermal screens and fogging systems (**Fig. 13**).

Cultivation Practices

Cultivation of greenhouse crops is either soil-based or soil-less (hydroponic). The former represents 97% and the latter represents 3% of the total cultivated greenhouses (MAF, 2014). In soil-based cultivation, drip irrigation is always employed (**Fig. 14**). For hydroponics, several techniques have been practiced. These techniques include nutrient-film techniques (NFT), and drip irrigation with substrate growing media in vertical columns as well as in horizontal rows. The growing media could be rock wool, coconut coir, saw wood, perlite alone, perlite and peat moss mix. **Fig. 15** depict some of the hydroponic techniques practiced using different growing media.

Water, Energy and Economics

Performance evaluation of greenhouse cropping systems in Oman showed a significant increase in land and water productivity. For tomato crop, water productivity increased from 2.083 kg/m^3 in the open field to 4.635 kg/m^3 in greenhouses and similarly for cucumber, it increased from 5.955 to 9.846 kg/m^3 (MAF and ICARDA, 2011). This could be attributed to the reduction in crop water demand inside greenhouses by almost 67% compared with open-field cultivation (Al-Mulla, 2006). Land productivity, on the other hand, increased by 12 times due to the increased crop density inside greenhouses (Tawfiq and Al-Kaefi, 2009). Tabook and Al-Ismaili (2016) found that land use efficiency ranged from 142450 to 181405 kg/ha for cucumber crop. In the economic side, the seasonal net return for tomato and cucumber crops cultivated in standard Quonset greenhouses is USD 369 and 744, respectively after taking into consideration all factors of cost and revenue. The increased net return of cucumber could be an-

Fig. 10 Fan-pad evaporatively cooled greenhouse (Al-Ismaili, 2003)

Fig. 11 Shaded greenhouses with (Left) black and (Right) green nylon mesh

Fig. 12 White cement poweder applied on the plastic cover of a greenhouse

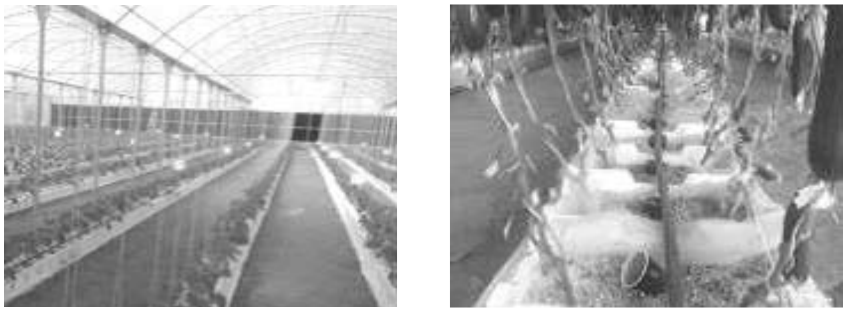
Fig. 13 Computer-controlled greenhouses with (Left) ridge vents for ventilation and (Right) fogging nozzles for cooling and thermal screens to reduce sun light (currently, they are wide-open)

Fig. 14 Drip irrigation used to irrigate greenhouse cucumber (Left) and rock melon (Right)

a. NFT

b. Drip irrigation with coconut coir

c. horizontal columns with drip irrigation and perlite



d. and e. horizontal rows with drip irrigation and perlite

Fig. 15 Hydroponic techniques

other attributable reason for the wide spread of greenhouse cucumber.

Mechanization Potential of CEA in Oman

The level of mechanization in greenhouses in Oman is still very low. This is because the widespread design of greenhouses (Quonset-type) has limited access of medium- to large-size machinery. Consequently, greenhouse farmers only use small-size machinery such as mini- and medium-size tillers (**Fig. 16**). However, in mega-size greenhouses, the level of automation and mechanization is very high. Tractors and other machinery can have an access easily inside these greenhouses (see **Fig. 8**). Other machines such as automatic vacuum seeders and produce washing, waxing, grading and sorting machines are also available (**Fig. 17**).

Conclusions

Greenhouse agribusiness in Oman is growing at a very rapid rate. Many farmers shifted from open-field cultivation to controlled-environment agriculture mainly to overcome the ambient harsh temperature conditions. The subsidy program implemented by the Ministry of Agriculture and Fisheries was a major driving force of the widespread of greenhouses. The main purpose of greenhouses is high-value crop cultivation yet, other application such as; poultry production, growth chambers, drying of food products and desalination of saline water are also practiced. The common greenhouse design is the single-span Quonset-type walls but double-span and multi-span greenhouses are also increasing. Cucumber is the most popular greenhouse crop followed by tomato. Most greenhouses are evaporatively-cooled and several mechanisms are implemented to reduce heat build-up inside greenhouses. Drip irrigation is the common method of water application in soil-based as well as soil-less (hydroponic) cultivation practices. Greenhouse cultivation has the advantage of elevated water and land productivity as compared with open-field cultivation. Finally, the mechanization level in greenhouses

Fig. 16 Greenhouses machinery; (a) medium-size, (b), (c) and (d) small-size

Fig. 17 High-tech greenhouse machinery; (Right) vacuum seeder and (Left) produce washing, waxing, grading and sorting machine

is still very low due to the small-scale greenhouse structures that are adopted in Oman. Yet, mechanization level can be escalated once mega-scale greenhouse farming is implemented.

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■■

Agricultural Mechanization in Jordan

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Introduction

Jordan is relatively small country with limited natural resources. Unlike most of the neighboring oil rich countries, Jordan has no oil. Most of its land is classified as Semi-Arid and Arid with very small arable land. Water is very scarce commodity and mainly is dependent on the rain fall during the 5 to 7 months of fall, winter and spring (October to April) with average annual rain fall of 450 mm, 350 mm and 280 mm in northern, middle and southern of the west strip of Jordan, respectively. However, in the Eastern part of Jordan which represent about 90% of the total area of Jordan (semi-arid and arid), the rain fall duration is shorter with less than 100 mm.

There are no lakes in Jordan. The only surface water is the River Jordan which flows from the North to end at the Dead Sea in the South (a distance of about 250 km) and few dams with a maximum capacity of 1,100 million cubic meters (MCM). The River Jordan for the last few decades is getting drier as result of building the dams up of its streams. Thus it is no more usable for irrigation and the flow to the Dead Sea was significantly reduced resulting into one meter annual drop of the sea level threatening its existence in few decades if no substitute was found. The dams never filled per any given year more than 70% of its capacity. The renewable ground water, estimated at 370 MCM per year, is very important source for irrigation. Despite the relatively high unemployment rate in Jordan, Jordanian workers shy away from working in the agriculture sector for social reason but not wage reason. The large labor shortage in the agricultural sector forced the sector to contract foreign labors in very large numbers. In normal cases, the sector that suffers from shortage of labor would resort to mechanization as the case in construction, transportation and industrial sectors in Jordan. However, the small holding of the

Fig. 1 View of the Jordan Valley showing the plastic houses located at an elevation of about 300 meters below sea level (photo was taken from an elevation of 100 meters below sea level)

Table 1 Some statistical data for Jordan

Item	1990	2000	2014
Population (mln)	3.4	4.8	7.5
Rural (mln)	0.9	1.0	1.2
Area Harvested (mln ha)	1.0	1.0	Na
Area equipped for irrigation (1000 ha)	na	na	96
Area irrigated (% of equipped)	na	na	91.3
Employment in agriculture (%)	na	4.9	2.0
Energy consumed to power irrigation (mln kWh)	29	106	157
Agriculture value added/worker (constant US$)	2,540	1,858	4,848
GDP per Capita (US$,PPP)	7,058	7,695	11,405
Cereal import dependency ratio (%)	92.2	97.4	96.2
Food production value (2004-2006 mln $)	557	777	1315
Agriculture value added (% GDP)	8	2	4
Food exports (mln US$)	98	164	1217
Food imports (mln US$)	635	676	3016
Net trade (mln US$)			
Cereals	-253	-245	-961
Fruit & vegetables	12	15	306
Meat	-58	-48	-279
Dairy products	-62	-60	-203
Fish	-10	-20	-105
Forest area (%)	1	1	1
Water withdrawal by agriculture (%)	na	na	65

FAO, 2015 Statistical Pocketbook, World Food and Agriculture, 2015.

Table 2 Population growth and annual rate of growth in Jordan for selected periods

Year	Population	Period	Annual growth %
1952	586,200	1952-1961	4.8
1961	900,800	1961-1979	4.8
1979	2,133,000	1979-1994	4.4
1994	4,139,400	1994-2004	2.6
2004	5,350,000	2004-2013	2.2
2013	6,530,000		
2015	9,500,000		

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

Table 3 Employees in the public and private sectors by nationality

Nationality	2010			2012		
	Male	Female	Total	Male	Female	Total
Jordanians	550,177	205,812	855,989	699,609	232,623	932,232
Syrians	3,804	534	4,338	7,210	165	7,375
Egyptians	74,876	487	75,363	68,370	353	68,723
Other Arabs	5,105	714	5,819	9,050	785	9,815
Non-Arabs	18,161	18,047	36,208	11,884	11,189	23,073
Total	652,123	225,598	88,721	796,123	245,115	1,034,218

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

agricultural land is limiting the use of farm machinery to perform the agricultural operations. The mechanized farm operation, mainly land preparation, is provided mainly through private individual contractors.

The agricultural sector in Jordan is an important sector although its contribution to the GDP may not exceed 4-5%. Its importance stems from the fact that the majority of the irrigated areas are located in the Jordan Valley (known under the name Al-Ghor) (**Fig. 1**) which is 200 meters below sea level in the north to 400 meters below the sea level in the south, a unique area suitable for off season production of vegetables and fruits that can be exported for high prices. In addition, agriculture is main source of income for the rural population.

Table 1 shows some statistical date for Jordan that will be discussed in details later.

Details

Population

Population in Jordan increased significantly in the last 6 decades (1952-2015) (**Table 2**). This rate of increase was mainly due to flux of refugees coming from different neighboring countries. Palestinians refugee crossed the west side of river Jordan in large numbers during the 1967 war, Iraqis refugees fled to Jordan as a result of the war and armed conflicts since 2003, Syrian refugees fled and still fleeing to Jordan during the last 6 years of armed conflicts and unrest in Syria in addition to some refugees from Libya and Yemen. Latest census of 2015 showed that the population of Jordan jumped from 6.53 million (excluding Syrian refugees) in 2013 to 9.5 million (including Syrian and other nation's refugees) in 2015. Normal annual population growth rate for the period 1994-2013 in Jordan dropped significantly as compared to 1952-1994 period (**Table 2**). Rural population dropped from 26.5% of total population in 1990 to 16.0% of total population in 2014 (**Table 1**).

Table 4 Non-Jordanian workers holding work permits in 2013

Nationality	Numbers
Egyptian	186,629
Syrian	4,069
Iraqi	1,019
Other Arab Nationalities	3,414
Non-Arab Nationalities *	91,066
Total	286,197

*Mostly house helpers

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

Labor Force

The estimated labor force in Jordan was little over one million in 2012 out of which about 90% Jordanian and 10% are non-Jordanian(**Table 3**). However, the non-Jordanian labor force showed significant increase in 2013 (from about 107,000 to about 286,000) (**Table 4**).

The agricultural labor represented 2% of the total labor force in 2014 down from 4.9% in 2000 (**Table 1**).

Land

The total area of Jordan is 89,858

Table 5 Size of different zones of Jordan

Zone	Size (Km^2)	% of Total Land
Total Land	88,778	99.4
Heights	550	0.6
Plains	10,000	11.2
Rift Valley*	8,228	9.2
Semi-Desert (Badia)	70,000	78.4
Territorial Waters	540	0.6
Dead Sea	446	
Red Sea	94	

Jordan in Figures 2015

Table 6 Rainfall Volume (RV), Evaporation Volume (EV) and Evaporation as % of Rainfall (EV % R), Floods Volume(FV) and Flood as % of Rainfall (F% R) and Infiltration Volume (IV) and Infiltration as % of Rainfall (I%R) for 2011/2012 season and the long term average 1937-2012

Period	RV(mcm)	EV(mcm)	EV% R	FV(mcm)	F%R	IV(mcm)	I%R
2011/2012	5,943	5,535	93.1	139.2	2.3	269.2	4.5
Long Term 1937-2012	8,195	7,581	92.5	194.4	2.4	420.0	5.1

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015 km^2, out of which 88,778 km^2 is land. Most of the land area (78.4%) is semi-desert (Badia) with a rain fall less than 100 mm (**Table 5**).

Water

Water resources are very scarce in Jordan. The reliable water resource is the rain fall which is decreasing from decade to decade (**Table 6**). The table shows the significant reduction in the annual volume of rain fall when comparing the 2011/2012 season with the long term annual average for the period from 1937 to 2012.

Table 7 Water Sources in Jordan

Water Sources	Quantity (mcm)
Surface water	300
Renewable ground water	370
Treated water	180
Peace treaty water	90
Al Disi Basin	100
Desalination of ground water	60
Total	1,100

Source: European Union, GOPA Consultant. 2014

Table 8 Major users of water in Jordan (as per 2007 year)

User	Quantity/ year (mcm)	% of Total
Agriculture	590.6	63
Domestic	301.5	32
Industry	48.0	5

Source: Nidal, H. 2015

Table 9 Dams in Jordan

Name	Catchment area (Km^2)	Total Capacity (mcm)
King Talal	3,700.0	86.0
Wadi Arab	262.0	20.0
Kafrein	163.0	8.2
Shuaib	178.0	2.8
Ziglab	106.0	4.3
Karameh	61.2	52.0
Tannur	2,160.0	16.8
Mujib	4,380.0	31.2
Wala	1,770.0	9.3
Al Wehdah	*6,200.0	110.0

*Out of which 5000 km^2 in Jordan

Source: Nidal, H. 2015

Table 7 shows that most of the annual average of 1,100 MCM volume of water resources in Jordan is generated from the rain fall.

Major user of water is the agricultural sector (**Table 8**). Due to that the main source of water is the rain fall, it is obvious that Jordan has to relay on the dams, whenever possible, for sustainable delivery of water for all purposes around the year. **Table 9** shows all the dams existed in Jordan. In addition, several water harvesting earth dams with capacity of one million cubic meters or less are being built by the public and private sector in the Badia areas mainly for animal drinking purposes.

Agriculture

The Jordanian agricultural sector is least contributor to the Gross Domestic Products (GDP) (3.1%) compared to the other sectors which contribute much higher percentage (**Table 10**). However, the agricultural sector in Jordan is very important because it is the main source of income for the rural population using available and renewable natural resource, although limited, and create other small businesses and relatively provide self-sufficiency for several essential food commodities (**Table 11**).

Agriculture in Jordan is practiced in two main agro-climatic regions, namely; a) rain fed highlands and b) intensive irrigated. Type of crops and size of areas under each region is shown in **Table 12**.

Rain fed highlands produce cereal crops (wheat and barley), legume crops (lentil and chickpea) and some fruit trees (olive and stone fruits). **Table 13** shows planted and harvested areas and production of selected field crops grown in the rain fed (highland) areas of Jordan in 2013.

Intensive irrigated areas, located mainly in the Jordan Valley, produce all kind of vegetables, fruit trees (citrus, banana and date palm), strawberry and seedless grapes. **Table 14** shows area and production of most important crops grown in the irrigated areas (mainly Jordan Valley).

Agricultural Mechanization

The use of farm mechanization in the agricultural production regions is limited and differs between the two main climatic regions.

In the rain fed region, the dominant farm machinery and equipment are; chisel plow and disc harrows for land preparation, seed drill for seeding, trailed sprayer for weed control,

Table 10 Percentage contribution Gross Domestic Product (GDP) by the agricultural sector compared to most important sectors at constant 1994 prices for some selected years

Sector	2006	2008	2010	2013
Agriculture	3.5	3.3	3.7	3.1
Manufacturing	17.7	17.6	16.9	17.0
Wholesale and Retail Trade, Restaurants & Hotels	9.9	10.0	9.5	10.0
Transport, Storage & Communications	14.8	14.3	14.2	14.7
Finance, Insurance, Real-estate and Business Services	17.9	19.0	19.2	20.1
Real-estate	11.1	10.3	10.5	10.4

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

Table 11 Self-Sufficiency Ratio for some selected agricultural products

Product	Wheat	Barley	Potatoes	Olives	Tomatoes	Fish	Beef	Chicken	Egg
Ratio	2.1	3.8	82.7	101.4	327.4	4.0	13.5	76.4	99.7

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

Table 12 Irrigated and non-irrigated areas under different crops

Crops	Total area (ha)	Irrigated (ha)	Non-Irrigated (ha)
Fruit trees	86,417	47,654	38,763
Field crops	131,407	9,682	121,725
Vegetables	48,773	46,143	2,630

Source: Jordan in Figures 2015

Table 13 Planted Area and Harvested area (ha) and production (ton) of selected field grown in the rain fed (highland) areas of Jordan in 2013

Crop	Planted	Harvested	Production
Wheat	26,240	21,380	28,500
Barley	89,560	38,380	40,900
Lentils	2,801	260	200
Chick-peas	990	800	700
Clover Trefoil	4,960	4,960	232,400
Common Vetch	1,400	1,300	19,200

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

combine harvester for harvesting wheat and barley, mower for cutting feed crops, rake for collection of feed crops and straw of wheat and barley and baler.

Records show that the use of combine harvester started in the mid 1930's when Jordan was cultivating large areas of the rain fed region and was producing enough field crops not only for domestic use but also for export to neighboring countries. At that period labor force needed for the agricultural activities were not available, until the refugees started coming from Palestine in the 1948 provided sufficient manual labor force.

Table 14 Area (ha) and production (ton) of most important crops grown in the irrigated areas (mainly Jordan Valley)

Crop	Area	Production
Tomatoes	154,300	869,100
Eggplants	3,770	109,400
Potatoes	3,400	103,200
Cucumber	2,900	172,300
Cauliflower	2,890	66,200
Water Melon	2,780	87,700
Broad beans	1,650	23,200

Source: Jordan Statistical Yearbook 2013 and Jordan in Figures 2015

Now a day the rain fed areas under cultivation is insignificant, thus resulting into stagnation or reduction in the number of farm machinery and equipment used in such areas (**Table 15**).

It should be noted that the jump in the number of boom sprayers and seed drill was due to the acceptance and adaption of recommended package by the Jordanian researchers as a result of several years of research that led into doubling and tripling the yields of field crops grown in the rain fed region. The recommended package included the use of chisel for land preparation instead of moldboard and disk plows and seed drill for seeding and fertilizing instead of hand broadcasting and boom sprayer for weed control instead of no weed control. Collection and bailing of resulted high yield of straw, very important feed for sheep, was possible with the recommended package which brought an additional income to the farmer.

All tractors, combines and other machinery are imported (**Fig. 2**). Most of the implements shown in **Table 15** are imported in full or in parts to be assembled in Jordan on a locally manufactured frame (**Table 16**). The assembly or the manufacturing is done in a small machine shops located in the rural areas or in the only one relatively medium manufacturer located in the free zone area near the capitol city Amman for the local market and for export to few Arab countries.

In the irrigated areas, where land holding is small and cultivation is mainly under plastic houses with standard size of 500 m^2, the use of farm machinery is limited to land preparation using harrows, rotary plow, plastic mulch spreader and sprayer. In the open fields where the palm tree and citrus orchards are established, moldboard and disc plows are used for land preparation and posthole digger for making holes and cultivator for once or twice inter-row cultivation.

The drip irrigation system is most dominant in all methods of cultivation which include the open field, covered tunnels and plastic houses. Water, provided by Jordan Valley Water Authority, flows to the farms under pressure, therefore in most

Table 15 Number of farm machines and equipment in Jordan for some selected years

Type	1992	1998	2004	2010
Tractors	3,442	5,212	5,583	5,674
Boom Sprayer	83	362	417	639
Combine Harvester	66	54	61	71
Seed Drill	80	98	111	200
Trailed Harvester	14	37	58	61
Thresher	502	695	609	545
Binder	44	97	64	62

Source: Taha A. Al-Issa. 2015

Fig. 2 Farm Machinery Dealer in Karameh village, Jordan Valley

Fig. 3 One of several Drip Irrigation System distributors in Karameh village, Jordan Valley

Fig. 4-1 Yard of one of several farm machinery contractors in the Jordan Valley

Fig. 4-2 One of many repair and farm implements machine shops in the Jordan Valley

cases the pumping units usually used in the drip irrigation systems will not be needed in most cases. Except for the pumps if needed, most the irrigation system components (all sizes of plastic pipes and tubes, fittings and filters) are manufactured in Jordan (**Fig. 3**).

The spread of use of drip irrigation system to cover all the irrigated areas in the Jordan Valley since early 1980's enabled to more than double the area originally intended to be irrigated with the amount of water made available from different sources.

Most, if not all, the farm machinery services needed for the rain fed and irrigated areas are provided by private contractors or small size co-operatives or enterprises (**Fig. 4**).

Fig. 5 Laser guided special plow (Delfino 3s) attached to specially equipped sizable tractor (This photo was provided by Issa Gammoh, Associate Professor at the Faculty of Agriculture, University of Jordan, Amman, Jordan).

Fig. 6 Micro-catchment created by the Vallirany Plow (This photo was provided by Issa Gammoh, Associate Professor at the Faculty of Agriculture, University of Jordan, Amman, Jordan)

As for the Badia area, mechanizing the water harvesting technique, using the Vallerani micro-catchment System (VS), at much lower cost than the traditional way, will restore the vast Badia region for grazing (3, 6 & 7). Use of VS allows the rehabilitation of 2,500 ha/year for up to 10 years at a cost 35 US$/ha compared to 190 US$/ha if done manually (traditional). The VS is laser guided special plow (Delfino 3s) attached to specially equipped sizable tractor (**Fig. 5**). The plow creates micro-catchment (basins or continuous furrows) (**Fig. 6**).

Table 16 Average annual farm implements assembled or manufactured and sold in Jordan

Type of Implement	Medium Scale Enterprise		Small Scale Enterprise	
	Produced	Sold	Produced	Sold
Moldboard	80	75	35	35
Disk Plow	60	45	45	35
Chisel Plow	20	15	8	8
Rotary Plow	15	1	8	8
Cultivator	70	70	30	30
Disk Harrow	8	8	5	3
Seed Drill	5	3	-	-
Sprayer (Trailed)	115	100	20	20
Sprayer (Mounted)	125	130	-	-
Post Hole Digger	15	15	-	-
Rigger	30	30	20	20
Potato Planter	16	10	3	2
Trailers	70	65	65	55
Water Tanks	180	120	45	40

Source: Taha A. Al-Issa. 2015.

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Japanese Agricultural Machinery Situation and the Role of Institute of Agricultural Machinery

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Outline

The Institute of Agricultural Machinery (IAM) was established as a prioritized research center on April 1, 2016, within the National Agriculture and Food Research Organization (NARO) which was enormously reorganized and expanded as a result of the merger of the independent administrative agencies, to promote interplay between farm work and advanced technologies by placing special emphasis on incorporating interdisciplinary technologies such as robotics and ICT within agriculture.

The aim of IAM is to contribute to further development of Japanese and Asian agriculture based on wet paddy rice fields, by incorporating cutting edge agricultural technologies such as robotics, ICT and AI to agricultural machinery, as the national R&D Institution for agricultural machinery and facilities. At the same time, there are great expectation to contribute to Asia, African and other regions where agricultural mechanization is still in progress. The IAM has contributed greatly towards the advancement of Japanese farm machinery performance and safety with testing and evaluation technologies, which is applicable to cutting edge farm machinery development as well as human resources cultivation in order to support agricultural mechanization in Asia and Africa which is still in progress. It is expected to further advance interplay with R&D and testing/evaluation institutions of the world committed to agricultural machinery. In order for IAM to fulfil this role, understanding and support from all reagions would be greatly valued.

Japanese Agriculture and Agricultural Policy

Japanese agriculture has been on the wane such as weakening of production base, due to aging of the farmers and manpower shortage (**Fig. 1**). Under these circumstances, there appeared a new type of agribusiness such as large-scale farming with an area exceeding 100 ha, and innovative protected horticulture. These new types of agribusinesses where agriculture, commerce and industry cooperate together with the export of domestic agricultural product are coming into play and are attracting attention (**Fig. 2**).

Regarding the Japanese agricultural policy, the cabinet approved The Basic Law on Food, Agriculture and Rural Areas in March

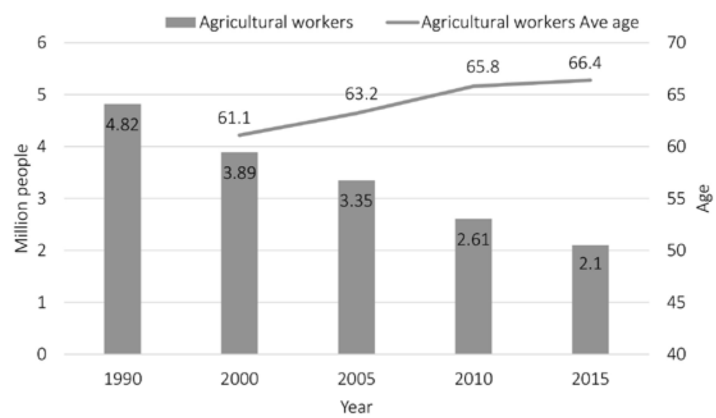

Fig. 1 Rapid aging and decrease of agricultural workers
(Sorce: Ministry of Agriculture, Forestry and Fisheries Statistics Department
Agricultural workers is defined as household membership whom are over 15 years old and been working only as a farmer or whom is a part-time farmer but actual farm workdays is greater, for the last year before survey)

2015, with the purpose of administrative innovation of agriculture and farming villages, and at the same time orienting Japanese agriculture towards “strong agriculture”, and “beautiful and active Rural Areas” where the youth can believe in their future. Together with this, the cabinet approved the Agriculture, Forestry and Fisheries Research Basic Plan, and the roadmap towards structural innovation of agriculture was established. The aim of the plan was to support actualization of the Basic Law with technology development.

The new Agriculture Forestry and Fisheries Research Basic Plan points to the R&D goal for the next decade, and the guideline for policy promotion has been established. Now it is required to specify technical needs of the production site by promoting collaboration between farmers and agricultural extension workers for the development of useful machinery.

In the newly developing Smart Agriculture incorporating the use of rapidly evolving ICT, robotics and other interdisciplinary R&D, extreme labor saving and high quality production is becoming feasible. This cutting edge technology is practiced not only in laboratory but also in the fields to verify the research, and our agricultural technology is rapidly evolving. To introduce leading technology, condition preparation is under way.

Regarding robotics, the Headquarters for Japan’s Economic Revitalization decided on the following three new robotics tactics: 1) Auto operation by GPS automatic traveling system, 2) mechanization and automation of heavy manual labor tasks and 3) labor saving and high quality production with advanced sensing technology. At the same time, Prime Minister Abe instructed the following two goals in the Public-Private Dialogue towards Investment for the Future: 1) selling agricultural machinery with autopilot in the market by 2018, and 2) development of institutions for remote monitoring autopilot system by 2020.

On March 2016, regarding ICT, the Ministry of Agriculture, Forestry and Fisheries created a guideline concerning farm work terms used in agricultural ICT system as well as the data items regarding environmental information, as part of a process of standardizing agricultural information. The Cabinet Secretariat created “Agricultural IT service utilization guideline” in corporation with the relevant ministries, to use and protect agricultural database cumulated by using ICT. The MAFF set another guideline for safe and proper chemical spraying with small autopilot aircraft such as the drone.

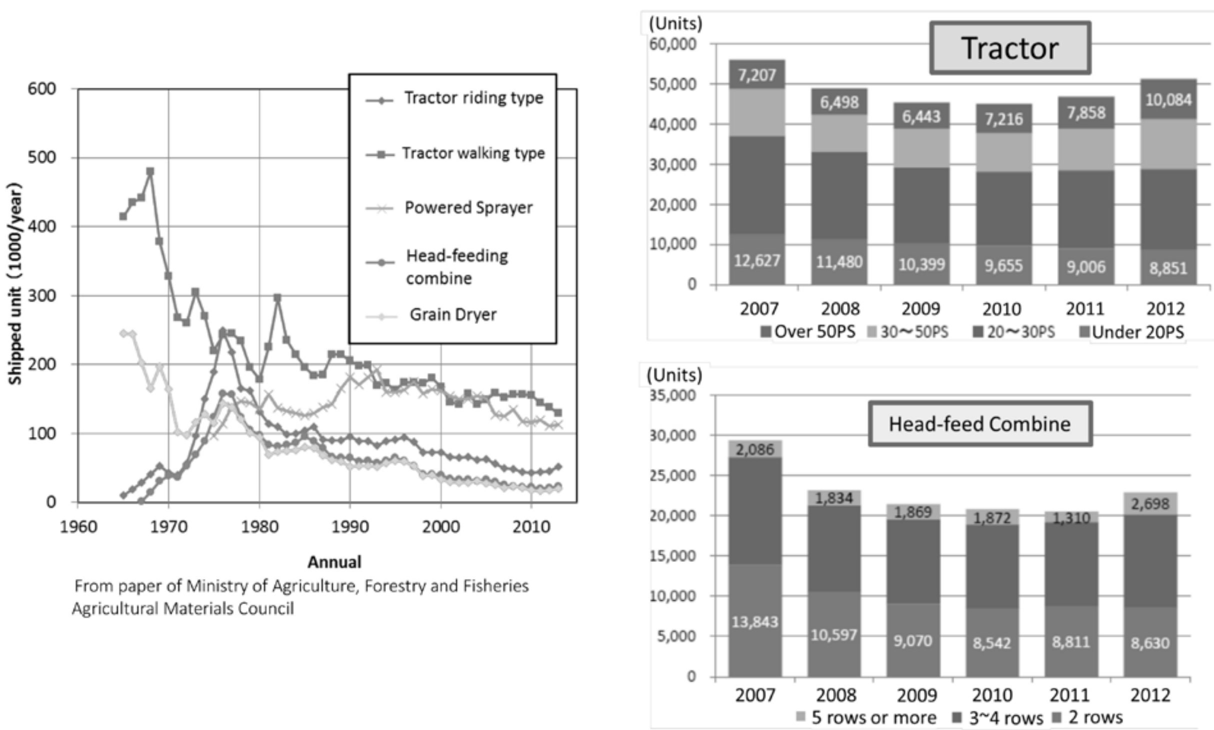

Fig. 2 Production and shipping of Agricultural machinery decrease of total numbers though increase of percentage of large size machinery
(Source: Ministry of Agriculture, Forestry and Fisheries Statistics Department; Japan Agricultural Mechanization Association (JAMA): Main Agricultural Machinery Shipment)

Future of Smart Agriculture in Japan

In Japan the vision of Smart Agriculture (**Fig. 3**), propelled by the policy situation of agriculture and science and technology, is divided into five directions by the interim report from the Study Group for the Realization of Smart Agriculture in March 2015.

i) Braking ceiling by auto pilot for agricultural machinery such as tractors to accomplish ultra-labor saving and mass production.
ii) To accomplish mass-crop and high quality production by (precision farming)
iii) Freeing from hard and dangerous manual labor, assist suit for moving harvested crop and automating slope grass cutting
iv) Assisting system for agricultural machinery, building cultivation database for unexperienced workers to start agricultural production.
v) Provide production information using cloud system and connecting production region and consumers to provide comfort and earn trust from consumers.

To accomplish these ASAP, related research institutions funded by the government, universities and private sectors are cooperating.

Founding and Role of Institution of Agricultural Machinery

The Institute of Agricultural Machinery at NARO was established for promoting agriculture mechanization by R&D and testing & evaluation of agricultural machinery, advanced and innovative mechanization technology and work system, development of efficient gathering and usage of agricultural information. The goal is to solve problems that the field faces such as vegetable crop production and orchard mechanization, high performance low cost commodification paddy rice and rice production, precision animal farming, low environment burden agricultural machinery, efficient agriculture safety measures. Also to become the core role to solve challenges by collaborating with other business and agricultural work such as ICT technologies and robotics.

On developing agriculture machinery with cutting edge technology such as robotics ICT in agricultural production, there is a drive for building an innovative agricultural production system by numerous agricultural robots running with autopilot as interacting with each other with data communication, safety technology, development of farm management technology with robotized farm vehicles and remote monitoring systems.

As for greenhouse horticulture,

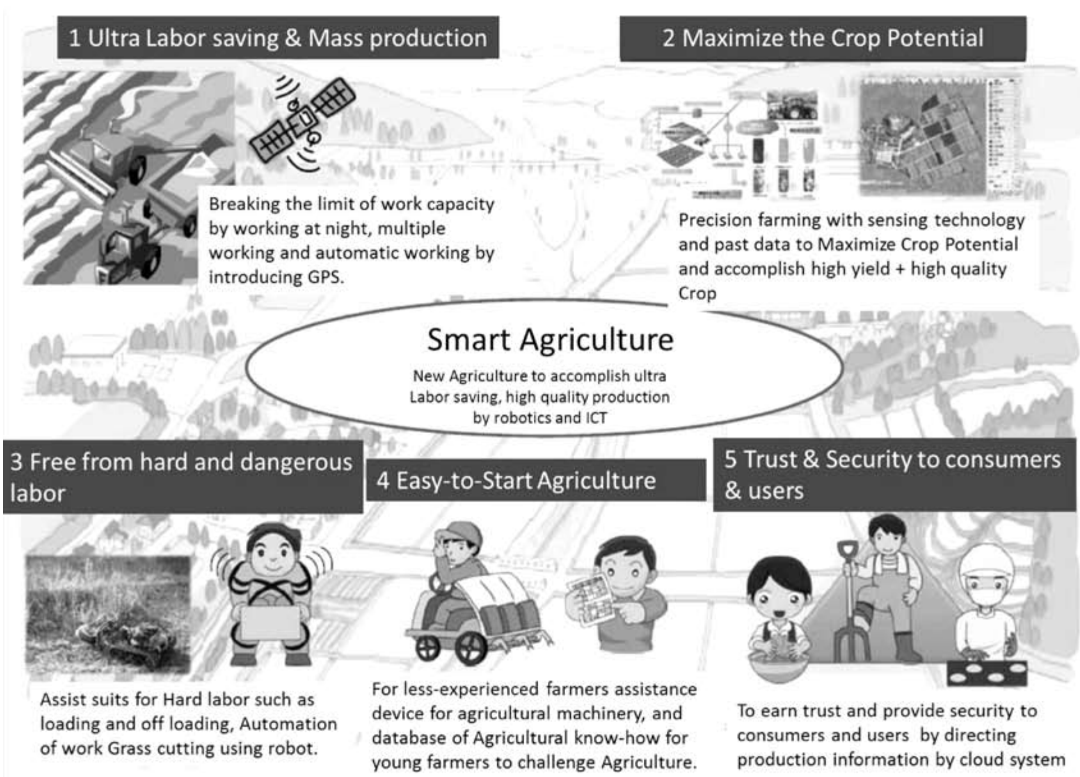

Fig. 3 Smart Agriculture
(Source: Ministry of Agriculture, Forestry and Fisheries Statistics Department; Work shop for implementing Smart Agriculture middle report 2014.3.28)

the process is in progress for building a Japanese greenhouse infrastructure using fine production technology such as production robot, high sensitive growing managements.

Furthermore, in order to accomplish more efficient farm management and high-quality high-yield production, multiple means of support for farming using informatics, big-data and IT information will be necessary, as well as building a unified infrastructure and model prediction. It is considered that this will contribute to the new agricultural technology innovation.

In order to address the problems faced by the production fields, the following measures are advisable: the development of machinery for large farmland in mountainous areas using crop rotation, producing a multi-high speed seeder, and riding type machine for paddy fields, combines with high performance and duration. The development of mechanizations which was delayed by size of market such as orchard and horticulture, increase of productivity and adding high values and stabilize productivity and saving labor for Livestock Industry, in new growing districts there been systems of mechanization is in progress. Even in growing districts today workers are aging and agricultural mechanization is expected. Our institution receives high hopes from farmers, agricultural machinery manufactures and government on development of safe and environmental friendly agricultural tools and machinery. Theme are endless such as safety, energy consumption, gas exhaustion, automation and robotics of sold machinery and safety of new agricultural machinery. In this field the research outcome will give the farmers a guideline to choose safe machinery and to producers to develop and sell safe agricultural machinery. On the other hand, it is inevitable to collaborate with about the standards. Now there is a movement to build an agricultural machine standard and test codes in the Asia region, as the agricultural mechanization is trying to leap. It is anticipated that as the institutions in Japan which have been leading the technology of agricultural machinery on high performance, safety, environmental friendly and be in position to contribute as training center of Asia for engineers and institution employs of testing and evaluation. Though not only the standards but also level of agricultural mechanization is diverse in Asia, there is available experience in both pros and cons.

Conclusions

The expectation for the Japanese agricultural mechanization is increasing to take the place of the aging and decreasing farming work force. This can be accomplished by introducing robotics and ICT and propelling the intellect of agriculture machine. For intellectual agricultural machinery it is mandatory to have not only engineering point of view but also agricultural production (breeding, growth, soil fertilization. Agricultural managing and value chain for including logistics processing) point of view. The Institute of Agricultural Machinery will act not only being just a research institution but also a match maker for companies, universities, regional institution, and other field. Finally, it is highly anticipated to encourage relations with institutions in Asia to support proper agricultural mechanization in each country.

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E J Hetz


M A L Roudergue


R Aguirre


O Ulloa-Torres


Y M Mesa


P P Rondon


S G C Magaña


H Ortiz-Laurel


G C Bora


M R Goyal


A K Mahapatra


S M Farouk


Daulat Hussain


M A Mazed


Chetem Wangchen


M A Basunia


Li Shujun


S M Ilyas


Surya Nath


Indra Mani

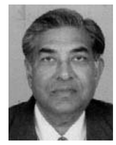

C R Mehta


A M Michael


B S Pathak


V M Salokhe


G Singh


S R Verma


Kamaruddin Abdullah


M Behroozi-Lar


Saeid Minaei


A M Abdul-Munaim


K Tokida


B A Snobar


J H Chung


In-Bok Lee


M Z Bardaie


Enkhbayar Gonchigdorj


M P Pariyar


H P W Jayasuriya


Alamgir A Khan


A Q A Mughal


M S Mirjat

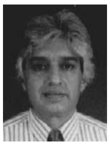

N A Abu-Khalaf


R M Lantin


R P Venturina


S A Al-Suhaibani


A M S Al-Amri


S G Illangantileke


S F Chang


Suming Chen


S Krishnasreni


S Phong-supasamit


A Senanarong


P Soni


C Ertekin


I Haffar


N Hay


P V Lang


T H Katardjiev


P Kic


J Müller


K P Ferentinos


E Gasparetto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e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
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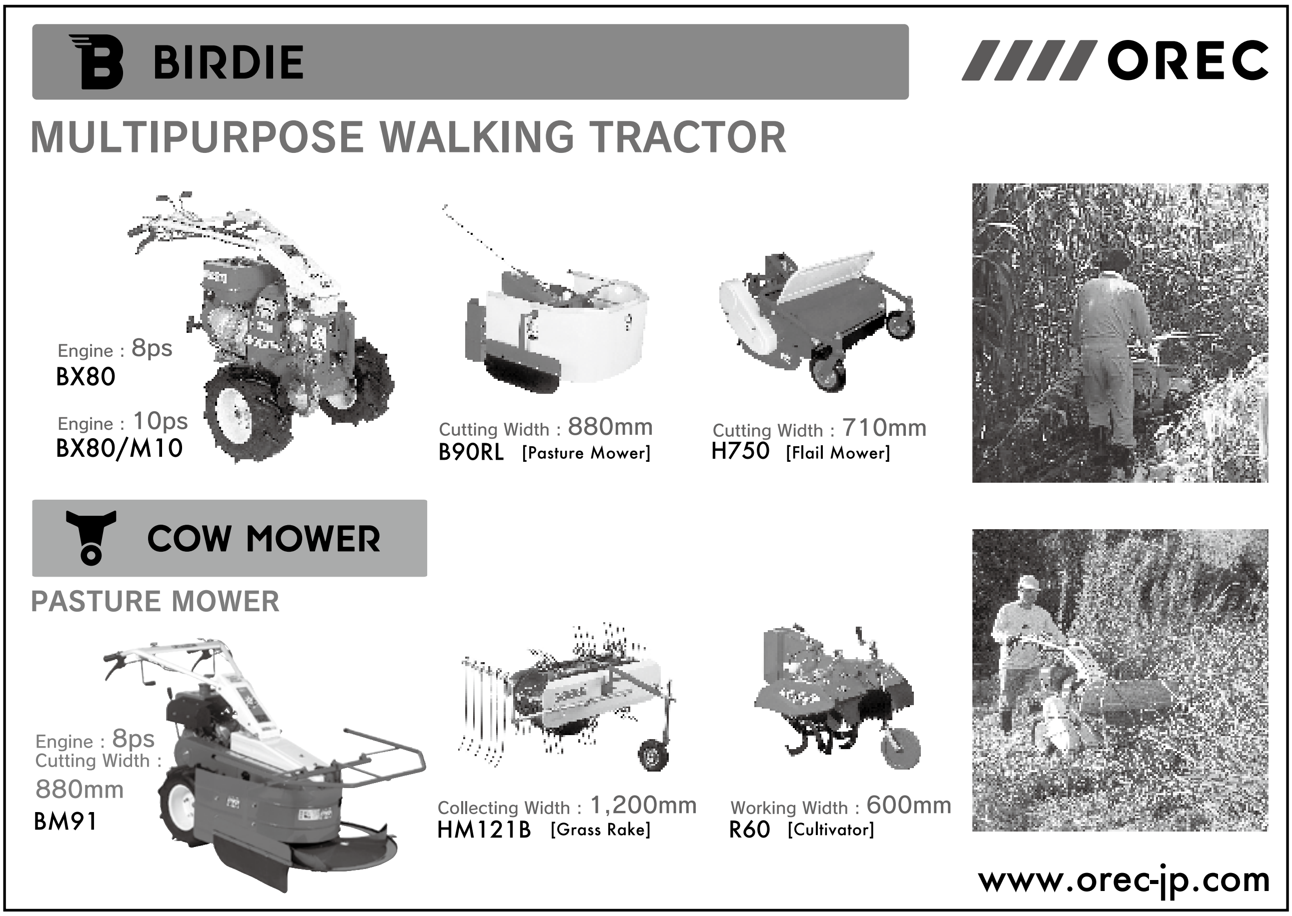
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram 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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