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Agricultural Mechanization in Latin America and the Caribbean

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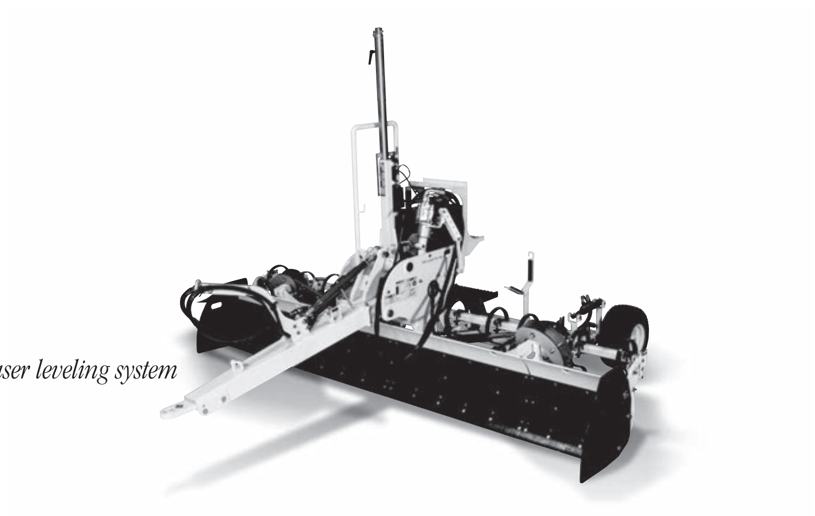

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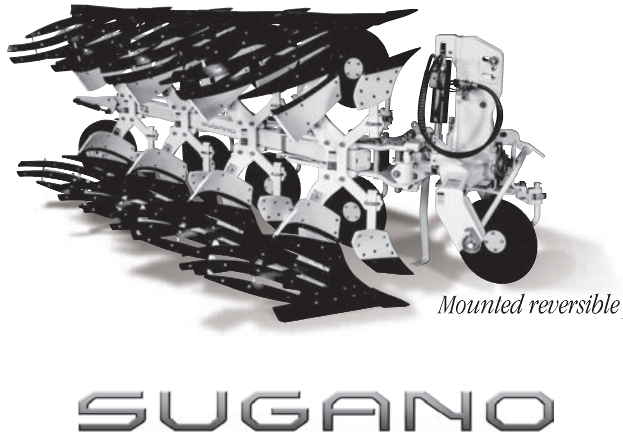

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EDITORIAL

The first issue of the AMA was published in April 1971 with the objectives to connect specialists in agricultural machinery all over the world for promoting agricultural mechanization in the developing countries. At that time, 80% of the global population was farmers in the developing countries. Their average income was low and a disparity in wages between theirs and urban people's was getting wider and wider. We wanted to support them to improve their life by using appropriate new technologies themselves. So we launched AMA to promote research and development on such new agricultural machinery and broadening its availability in various regions of the globe. Compared to that time, development of agricultural machinery seen at the present time in Asian region such as China, India, Korea etc. is striking. And at the same time, the global population has increased to over 7.3 billion. However, in contrast, the number of farmers has been decreasing. It's because the young people do not like to engage in farming and wants to go to cities. Increase in the number of urban people is a notable feature when you see the trend in global population. Excluding the developed countries, there are still many countries that have hardly achieved agricultural mechanization in the world. Even in a developed country, China has not experienced full agricultural mechanization. In addition to that, aging is causing a decrease in available agricultural labor force.

According to estimations, global population continues to increase and it will go beyond 9 billion by 2050. However, the volume of available farmland would not increase and natural resources for food production are limited. The United Nations holds "Sustainable Development Goals (SDGs)" and advocates sustainable agriculture. New agricultural mechanization techniques are needed so as to use the limited natural resources efficiently and to achieve the goals.

The level of agricultural mechanization greatly varies among countries in Latin America. There are countries that have difficult issues such as Venezuela which has suffered due to political and economic confusions. To improve agricultural mechanization in all the countries, we need to try earnestly and vigorously.

However, central and south Americas occupy a large area in the world and we need expansion of farmland there. To do so, we need to intensify efforts for promoting new agricultural mechanization techniques suitable for each region.

We hope to stimulate communications between specialists in agricultural machinery in Latin America and in the rest of the world through the special features in this issue of the AMA.

Yoshisuke Kishida
Chief Editor
April, 2019

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Current Situation of Agricultural Mechanization and Conservation Agriculture in Latin America

by

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Abstract

This article shows the behaviour of the distribution of agricultural machinery market in Latin America, the major manufacturing countries, main commercial flows, industry, exports and imports of agricultural machinery in the region. It also describes the competitive profile of the sector in Mexico, Brazil and Argentina, advances of no-tillage system, experiences of countries in the region and the conservation agriculture in the world. The objective of this paper is to present the current situation of agricultural mechanization in Latin America and the Caribbean, advances in conservation agriculture in this region and the world, its perspectives and possible alternatives to obtain what is desired.

Keywords: agricultural activity, machinery market, no-tillage, direct seeding

Introduction

The mechanization of agriculture in the world has allowed the increase of the capacity of work and production, to execute the operations with greater opportunity and quality, thus, reducing and dignifying the physical effort of man; however, tractors and agricultural machines have a high cost of acquisition and operation in monetary and energy terms (Paneque & Soto, 2007).

In order to optimize the exploitation of agricultural machinery in Latin America and the Caribbean and to establish organizational methods that ensure the correct use of mechanization means, it is necessary to make a detailed study of the current situation in the region, its behaviour and the possible alternatives to obtain what is desired. Such study is also essential for increasing production efficiency and to make machines work with high quality and energy efficiency, (Miranda *et al*., 2002, Fernandes & Souza, 2003 and Dirven, 2004).

In Latin America, more than 30 percent of the population is engaged in agricultural tasks with very small land areas. The fact that more than 85 percent of the peasants do not have more than 5 hectares of arable land and that 90 percent of them do not reach 3 hectares clearly indicates their great need to look for alternatives. Some of those alternatives are substituting the technology imported by local technology, prioritizing artisanal biotechnology to produce bio fertilizers and bio pesticides and using green fertilizers to replace herbicides. Others are the conversion of conventional agriculture to conservation agriculture, from heavy machinery to light machinery and the efficient use of human resources, land, energy, animal traction, among others. Moreover, other alternatives are crop diversification and animal integration, the preservation of the environment and conservation of natural resources, the active participation of rural communities, and cooperation among them for the generation and diffusion of technology (Altieri & Nicholls, 2013). All of the above should help in rethinking the public policies promoted in the region, which should encourage research, teaching and development of agricultural machinery congruent to the average size of the related agricultural properties and carry out an incentive program for mechanization similar to those from Brazil and Cuba. Those programs provide credits for the acquisition of agricultural machinery with very low interest rates, to farmers called "familiars", which are small rural producers (Cáceres & Soto, 1997; Araya & Quesada, 2000; Altieri & Nicholls, 2013; Friedrich, 2017).

Thus, the objective of this paper is to present the current situation of agricultural mechanization in Latin America and the Caribbean, the advances of conservation agriculture in the region and in the world, their perspectives and possible alternatives to obtain what is desired.

Development of the Topic

Through the history of agriculture and humanity, man has manufactured a variety of utensils and hand tools; some of them coupled to animals, which have been used to facilitate agricultural work, seeking energy efficiency, efficiency and productivity. Today, these techniques still coexist, not without difficulties and confrontation, which in turn, with the development of technology are being displaced by machines and equipment of greater power and operating capacity (Crovetto, 2002; Fernandes, Silvera & Rinaldi, 2008; De las Cuevas *et al*., 2011).

Since last century, agricultural production systems have evolved rapidly with a significant increase in yields. But, unfortunately, they have sometimes had unwanted secondary environmental effects. Soil degradation and erosion, pollution caused by chemical fertilizers and the loss of biodiversity have all been emphasized. Furthermore, it was considered that certain agricultural production systems were unsustainable, not only environmentally, but also economically in certain places (Crovetto, 1988, Friedrich, Kassam & Shaxson, 2009; Almorox, López & Rafaelli, 2010; Bhatia *et al*., 2010).

There is a wide variety of tillage options for the formation of an adequate seedbed. However, what must be selected is a technically and economically viable method. Moreover, since there has been progressive deterioration of the soil, productivity, medium and long term profitability is affected (Derpsch, 2008, Kassam *et al*., 2009 and Cortés, Álvarez & González, 2010).

The agricultural technique includes all aspects of the application and manufacture of technical auxiliary means in the agricultural production, its precedent and postponed areas, as well as the generation and decentralized use of energy in the rural area. To that agricultural technique corresponds, with much greater importance, the vegetal production, but also, in increasing measurement, the animal production (intensive livestock, poultry, swine, etc.). The most frequent applications of mechanical means are in soil management and transport, to which threshing is added and, in the corresponding places, the transfer of water (Treto *et al*., 2001, Riechmann, 2003 and Triplett & Warren, 2008). The field of activity of agricultural technology must therefore be considered as an extension of the scope of plant production. Relations with animal production, irrigation and agroindustry are frequent. What has been said about objectives, effects and protection measures has also validity similarly in this area.

Most measures of mechanization in agriculture are produced for reasons of economy at work:

- To increase the productivity of work (performance per worker);
- To make the work physically easier and less fatiguing.

A key role corresponds to the correct selection and to the appropriate and timely use of machines and tools. This must be achieved essentially through the training and advice of the operating personnel (Cortés *et al*., 2010).

Economic growth allows the improvement in the quality of life and well-being of rural society, through the sustainable, environmentally clean, technically appropriate and socially acceptable use of renewable natural resources. And the fundamental objective of mechanization is to seek economic growth as a result of the development of agricultural, livestock, forestry and agro industrial activities. Mechanization is one of the essential factors that allow, ensure and maintain a sufficient level of agricultural production

(Lal, 1993; Cáceres & Soto, 1997; Bragachini *et al*., 2004; Paneque & Soto, 2007).

Fig. 1 and **Fig. 2** show the main activities in Latin America and the major agricultural machinery manufacturers (Donoso, 2007). Agricultural activity in Latin America is concentrated in Argentina, Brazil and, to a lesser extent, Mexico. These countries are the largest manufacturers of agricultural machinery in the region. In Latin America, large corporations have plants in Mexico and Brazil, from where they supply the region, according to a presentation by Donoso (2007) consulting, in Rosario, on December 6.

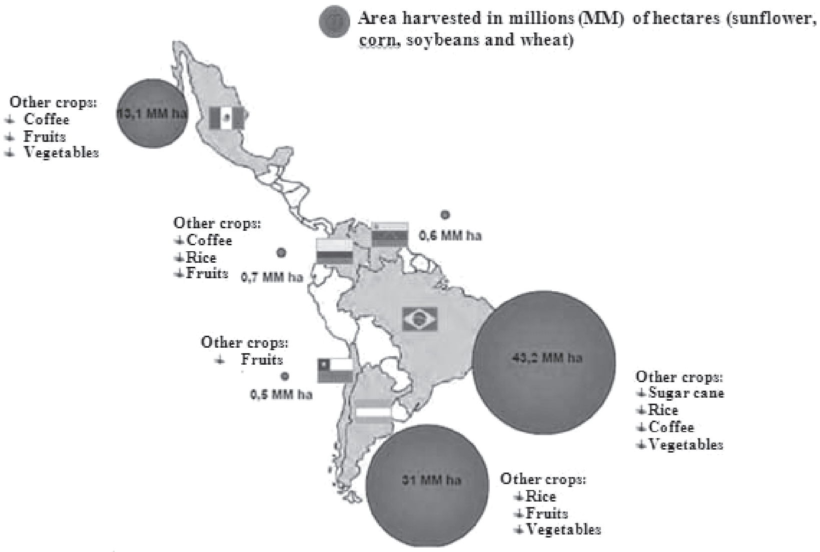

Fig. 1 Agricultural Activity in Latin America
Source: Donoso (2007)

Fig. 2 Largest manufacturers of agricultural machinery in Latin America
Source: Donoso (2007)
Note: the mention of commercial equipment marks, instruments or specific materials obeys identification purposes, there is not any promotional commitment related to them, neither for the authors nor for the editor

Competitive Profile of the Sector in the Latin America Region

Mexico's participation in international trade has been consolidated based on a specialization model in the middle range of products, particularly in tractors. The level of integration of the industry is intermediate (of the order of 50 percent), with own production of machined parts based on local inputs and import of the components of higher added value (engines, transmissions, drivelines), which are assembled directly (Ruiz, 2000; Sandoval *et al*., 2004; Sandoval *et al*., 2008).

In Brazil, domestic demand, coupled with a consistent industrial policy, availability of inputs and abundant labour, have allowed a vigorous development of industry, reaching a high level of international competitiveness. Brazil currently exports 50 percent of the tractors and 75 percent of the harvesters it manufactures, to a great diversity of destinations, including countries of Europe and the USA, which demonstrates the high degree of competitiveness of its industry in terms of quality and price. The large transnationals of agricultural machinery have installed high-tech plants in Brazil, with capabilities that far exceed the needs of the domestic market (Donoso, 2007). The sowing and implements segment follow the regional logic characterized by the leadership of medium-sized local manufacturers that specialize in the characteristics of the soils in their areas of influence. The advancement of conservation agriculture, which reaches 80 percent of the planted area, accentuates the dominance of local developments, which have also reached good competitiveness standards but are mainly oriented towards the domestic market (Riechmann, 2003).

In Argentina, the development of agricultural machinery industry is moderate, with the country being a net importer of machinery. The offer is composed of several manufacturers of seeders and few producers of tractors and harvesters. Large transnationals do not produce in Argentina, which have modern and large-scale plants in Brazil, from where they supply the markets of South America (García, 1988; Kjöllerström, 2004; García *et al*., 2010).

The industrial plants of agricultural machinery in Argentina are small and with scales that make it difficult to achieve international competitiveness in terms of costs and technologies. There, exports are small and occasional, having recently started some more solid attempts in the field of sowing machines, in which Argentina has developed a leadership in the application of the technique of conservation agriculture.

With the exception of Brazil, the rest of the countries in Latin America and the Caribbean are net importers of agricultural machinery.

So, in general, the main global trends in the agriculture sector are associated with high concentration, intensive use of technology and change towards Conservation Agriculture (Derpsch, 2003; Friedrich *et al*., 2009 and Derpsch *et al*. 2010).

Progress of Conservation Agriculture

Of the main trends shown above, the conservation agriculture can be analyzed:

- Because of its advances in the agricultural sector in recent decades.
- Because of the lower use of tractors, which reduces fuel consumption.
- Because it includes the three fundamental axes of Sustainable Agriculture.
- Because it is considered to be the best alternative for small farmers in the region.
- Because conservation agriculture is living in harmony with nature.

Conservation Agriculture

The three fundamental axes of conservation agriculture are listed as the following:

- It provides economic support to those who practice it. It also constitutes a way to obtain income for family sustenance.
- It integrates and respects the environment, conserves and, if possible, improves the rest of its biotic and abiotic components (human or not).
- It respects and enriches the social development of the human groups directly and indirectly involved.

Conservation Agriculture. No-Tillage System

The no-tillage system (as it is called in this work) is targeted as a proposal and reality of conservation agriculture, which fulfills the three requirements of a sustainable agriculture (Crovetto, 1988; Friedrich *et al*., 2009; Derpsch *et al*., 2010 and Derpsch *et al*., 2014). It does so based on its three fundamental principles:

- Do not remove the soil, avoiding mechanical disturbances.
- Maintain crop residues, favouring permanent soil cover.
- Make use of crop rotation.

No-tillage system

- The no-tillage system is not intended to be presented as a finished proposal. In fact, its development is nourished by permanent contributions and adaptations to local conditions, thus, respecting its three fundamental principles.
- University institutions and public and private entities dedicated to research, will find in the no-tillage system a valuable motivation in recovering the soil and helping the conservation of the environment. Topics such as cation exchange, the retention capacity of elements such as calcium, magnesium, potassium, sodium and ammonium occupy a space to be investigated in improving acidity or phosphate formation.
- The look at nature in the no-tillage system does not mean the rejection of technologies that facilitate man´s work, give him advantages over it, and benefit him economically. An important part of these technologies, that are incorporated, is aimed at achieving less human effort and lower costs, using agricultural mechanization mainly in the sowing and harvesting stages. The most important challenge in this aspect is the sustainability of the environment.

Experiences of Countries in the Region in Conservation Agriculture

- Taking advantage of the advances in other countries in Conservation Agriculture, it is convenient to know them and decide their applicability in each situation.
- There are useful developments for small agriculture, especially in implements for planting.
- It will be necessary to contrast them with the ergonomic convenience and the safety requirements in relation to the presence of animals in the field.

In **Fig. 3**, **4** and **5**, some equipment and tools for the no-tillage system are shown, which are manufactured and used in the Latin American region.

Dissemination of Conservation Agriculture

Conservation agriculture has experienced the greatest diffusion in the United States, where in 2018, it has been carried out on41.7 million ha(Araujo 2018). The second country of greatest diffusion of no-tillage is Brazil, where the technique is practiced on approximately 33,550,000 hectares, followed by Argentina with nearly 31,450,000 hectares (Araujo 2018). The interest in this system is constantly increasing in Argentina, because in the Pampa region there is a strong erosion and degradation of soils under conventional agriculture. In Paraguay, the no-tillage system was

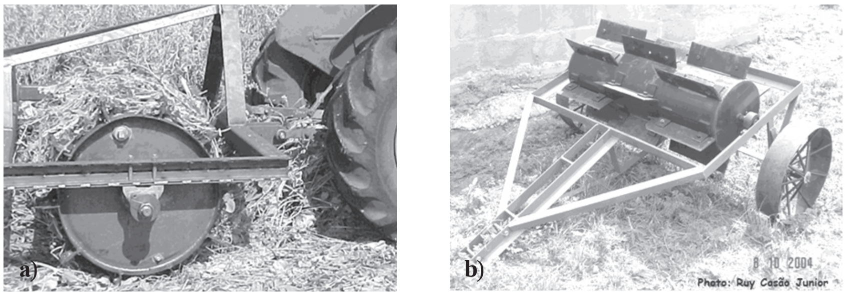

Fig. 3 Stubble and crop management with knife rollers
Source: Friedrich *et al.* (2009)

Fig. 4 **a**) Manual seeding (with rattle) **b**) Animal traction (with oxen)
Source: Friedrich *et al.* (2009)

Fig. 5 **a**) Seeder (no-tillage, new). **b**) Seed drill (no-tillage, adapted in Cuba)
Source: De las Cuevas *et al.* (2013)

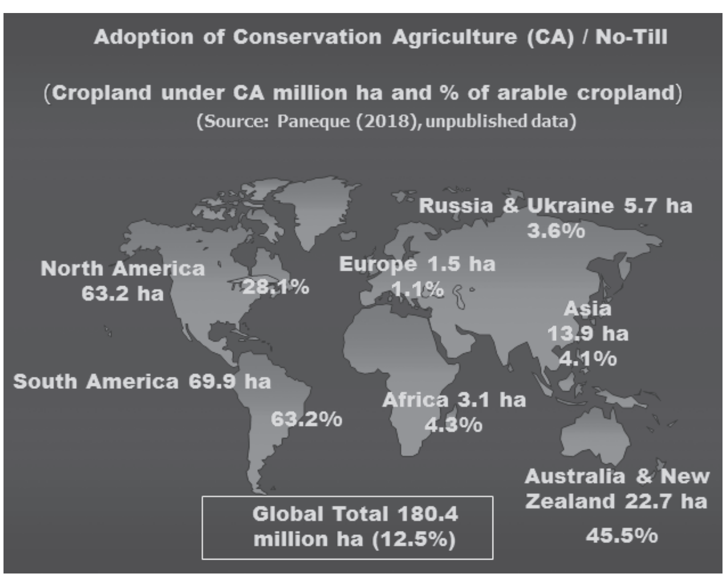

Fig. 6 Development and Current Status of No-Till Adoption in the World

adopted on approximately 2,796,000 hectares (Araujo 2018). The system is awakening interest of farmers in Chile, Bolivia, Uruguay and in other countries of Latin America. Due to the advantages of the system, no-tillage is also spreading more and more among small farmers with animal or manual traction.

The Conservation Agriculture in the World

According to Araujo (2018), conservation agriculture was practiced on more than 180,000,000 hectares in 2018. Particularly in South America, both smallholders and large farmers are rapidly adopting this technology. In some states of Brazil, it is an official policy. In Central America, Costa Rica has a Directorate of Conservation Agriculture in its Ministry of Agriculture. The available figures show that no-till or no-tillage agriculture is used in 63.2 percent of agricultural land in South America. Although in absolute terms the largest area applied with no-tillage is in North America, which corresponds to just over 28 percent of its cultivated areas (Araujo 2018).

Fig. 6 shows a map with the areas (million hectares) under conservation agriculture (year 2018) in different regions of the world.

Conclusions

- Most of the mechanization measures in agriculture are produced for reasons of economy at work: to increase the productivity of work (yield per worker) and to make the work physically easier and less fatiguing.
- Except for Brazil, the rest of the countries of Latin America and the Caribbean are net importers of agricultural machinery.
- Brazil currently exports 50 percent of the tractors and 75 percent of the harvesters that it manufactures, to European countries and

the USA.

- The main global trends in the sector are associated with high concentration, intensive use of technology and change towards conservation agriculture.
- The no-tillage system is based on three fundamental principles: (1) no removing the soil, avoiding mechanical disturbances, (2) maintaining crop residues, favoring permanent soil cover and (3) using crop rotation.
- Conservation agriculture is practiced on more than 180 million ha worldwide, especially in Latin America with 69.2 million ha.

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■■

Current Status and Future Prospect of the Agricultural Mechanization in Brazil

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Abstract

Brazil is known worldwide as one of the major producers of grain, meat, sugar, coffee and other products. Agribusiness is one of the main activities in Brazil and contributes significantly to the Brazilian economy. This fact led to even greater investments and developments in the market of agricultural machinery and implements in the country. From the 1960s to the end of 2018, land areas with agricultural potential increased substantially, while the total number of wheel tractor fleets increased six-fold; in other words, the mechanized area in hectares per tractor decreased from 410 to 65 ha/tractor. The machinery and equipment manufactures in the country today is sufficient to support a high-level mechanization process and to decrease the number of tractors/seed planters/combines and other types of equipment per hectare. The acquisition and modernization of tractors, harvesters and other equipment types depend on the income of farmers and governmental and private credit policies. The sales of agricultural machinery in Brazil are strongly influenced by the prices of international commodities such as soybean, maize, citrus and coffee. With excessive urbanization and fewer labor resources available, extensive and highly mechanized crop systems, such as soybean, sugar cane, rice and corn, have been established to attend to farm chronograms at different levels of technology. In addition to a large machinery production capacity, the Brazilian industry has also invested in advanced technology, mainly in tractors and combines, to save time and fuel, lower the level of fatigue and reduce cost.

Introduction

Brazilian agricultural production has exhibited several important achievements during the last four decades, which is reflected by the large increase in the agricultural GNP over the years. The 5.3 million farms cover an area of 350 million hectares and house a population of 207.6 million inhabitants, with almost 85% of the Brazilian population living in cities (IBGE, 2017).

The agriculture and agro-processing sectors in Brazil have shown impressive growth over the past three decades. This growth has been driven by productivity improvements and structural adjustments, as well as new technologies. The growth in an area with agricultural potential is related to the growth in productivity indices due to the more intensive use of mechanization (FAO, 1994). From the 1960s to the end of 2018, the land area with agricultural potential increased substantially, from 19 to 60 million hectares, while the total number of wheel tractor fleets increased only by six-fold; in other words, the ratio of mechanized areas to tractors decreased from 410 to 65 ha/tractor. However, according to the Brazilian Automotive Industry Association (ANFAVEA, 2018), the machinery industry in Brazil today is prepared to support a high-level mechanization process and to decrease the number of tractors/seed planters/combines and other types of equipment per hectare.

The Brazilian agricultural machinery scenario is characterized by an active local manufacturing and trading industry. The agricultural machinery industry of Brazil is dominated mainly by local machinery manufacturers, and Brazil is the sixth largest exporter of machinery units. The Brazilian agricultural machinery market is expected to grow at a compound annual growth rate, CAGR, of 6.68% in 2018-2023.

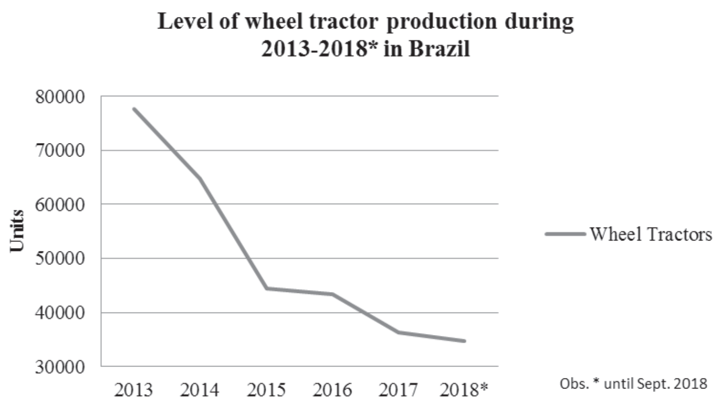


Fig. 1 Wheel tractor production levels of Brazilian manufactures, period from 2013 to 2018*. (Source: ANFAVEA, 2018.)

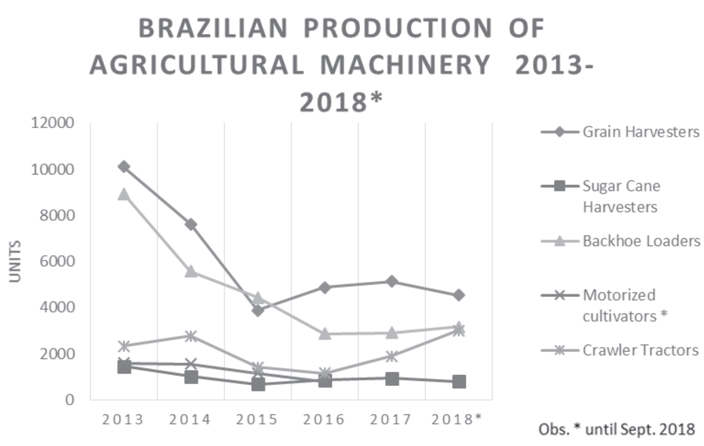


Fig. 2 Agricultural machinery production levels of Brazilian manufactures, period from 2013 to 2018*. (Source: ANFAVEA 2018.)

Fig. 1 shows the wheel tractor production levels of Brazilian manufacturers have been decreasing from 2013 to 2018, due to the economics problems in our country, but indicating a high capacity of almost 80.000 tractors/year.

Fig. 2 describes the total numbers and production levels of machine segments in Brazil from 2013 to 2018 based on the statistics provided by the National Association of Automobile Manufacturers (ANFAVEA, 2018). Similar to wheel tractors, most of the agricultural machinery production has decreased during the period 2013-2018.

Well-trained professionals in the national research system, both in Embrapa and in universities, have formed groups that have reached a high level of scientific knowledge in their respective fields. As a result, their efforts induced a new cycle of tropical agricultural processes, optimizing the use of Brazilian agricultural lands (Barros *et al*., 2002).

Fig. 3 shows the performance of tropical agricultural methods for 18 years (2000-2018) to produce new cultivars of rice, bean, maize, soybean, and wheat adapted to different regions with high soil management technology, which has increased grain production from 81million t, in 1980, to 219 million t, in 2018, a gain of 170%, while the planted area has increased from 34.6 million of ha, in 1980, to 58.4 million ha, in 2018, representing only an area extension of 68.8%.

The growing urbanization in developing countries tends to reduce the labor supply in rural areas and to increase the demand for food supplies in the urban population. An increased demand for food supplies while having reduced levels in labor resources poses as a challenge and may only be solved using biological, mechanical and organizational technology through developing an efficient research systems integrated with private companies.

Data from the census of agriculture of the IBGE (Brazilian Institute of Geography and Statistics) have indicated that in 2017, out of a total area of 220 million hectares, pastures occupied nearly 75% of lands (160 million hectares), while crops occupied the remaining 25% of lands (approximately 60 million hectares).

Because of the factors mentioned (high food demand, land availability, agronomic technology, population change, excessive urbanization level and lower labor resource availability), extensive and highly mechanized crop systems, such as soybean and corn, have been established to attend to the farm chronogram at different levels of technology. In addition to a large machinery production capacity, the Brazilian industry has also invested in advanced technology, mainly in tractors and combines, to save time and fuel, lower the level of fatigue and reduce cost. Also, GNSS (Global Navigation Satellite Systems) has been intensively used to determine the direction and navigation of agricultural vehicles for the application of chemicals, fertilizers and seeds with a high level of precision. Using the precision agriculture concept, equipment with satellite technology allows farmers to map fields and identify where fertilizers are needed, and exactly which part of a field needs spraying.

Currently, agriculture 4.0 (Adam, 2016) is being presented to Brazilian farmers and involves the integration of digital technology, by which farm machines can communicate with each other and related farm management systems.

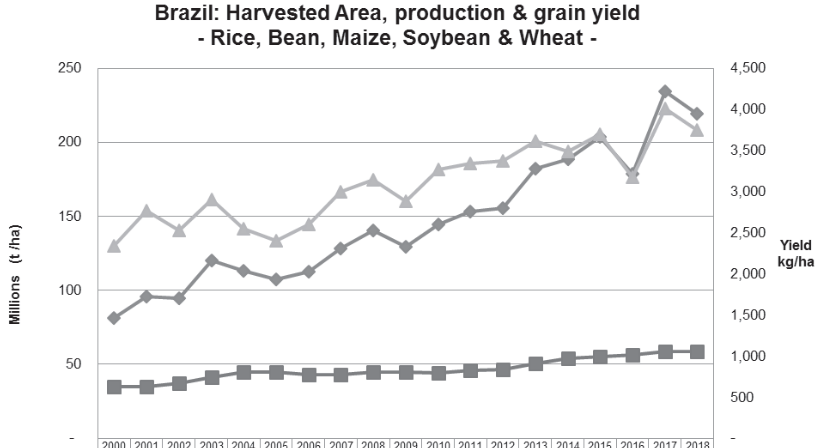
Present Status and Prospects of the Agricultural Machinery Industry

The established agricultural machinery industry in Brazil is quite diversified; the CSMIA (Sector Chamber of Agricultural Machinery and Implements) of ABIMAQ has 382 associates, and the main global players have factories in Brazil. Government policies have aimed for agriculture to have fleet modernization programs that require a national content of 30%, an accreditation index of 50% and the remaining 20% with qualitative items (i.e. the technological content of the product, innovation effort, level of exports and technical qualification of the employees and added value). The accreditation system inhibits the import of ready-made products but does not limit the import of parts and components, which can account for up to 70% of the total cost of the product. Moreover, this policy allows high-tech components, pieces and parts of the world's major players to be imported but requires that part of the manufacturing and assembly be done in Brazil. The incentive programs for mechanization rely on subsidies from the National Treasury, and the purpose of this government policy is to maintain the competitive characters of the national industry by discouraging the import of ready-made products. The import rate of agricultural machinery is 14%; however, unique products without Brazilian counterparts may require an aliquot of 2% to the government, a mechanism called extra tariff in Brazil.

In 2017, the total disbursement of government incentive programs for agricultural machinery totaled R$ 12.8 billion (equivalent to approximately US$ 4 billion); for 2018, a growth of 15% over 2017 is expected.

The import of agricultural machinery is very small due to the public policies described above and the variety of products offered by the industry. In the government program for small farmers called PRONAF, there are 3,428 products registered in the category of planting, crop treating and harvesting, and imports are restricted to machineries that have no significant sales volume or, as a rule, have very specific features that are not offered by the industry.

Machines used in Brazil tend to have differences in relation to the machines used in temperate climates. A good example is the no-tillage system, due the characteristics of tropical region, where the intensive use of soil is whole year, with two or three crops / year,



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Area (ha)	34,6	34,6	37,5	41,3	44,4	44,5	43,2	42,8	44,6	44,8	44,3	45,7	46,2	50,4	54,0	55,0	56,3	58,4	58,4
Production(t)	81,0	95,8	94,6	120,	113,	107,	112,	128,	140,	129,	144,	153,	155,	182,	188,	203,	178,	234,	219,
Yield (Kg/ha)	2,33	2,76	2,52	2,90	2,55	2,40	2,60	2,99	3,14	2,88	3,26	3,34	3,36	3,61	3,48	3,69	3,17	4,01	3,75

Fig. 3 Grain production and cultivated area, millions of ha and tons - 2000-2018. Source: IBGE - Produção Agrícola Municipal (PAM) e Levantamento Sistemático da Produção Agrícola (LSPA). 2017 = preview of september-2017

and the soil management is one of the main points to establish the best conditions with the agricultural equipment's for crop growth. Besides the use of crop cultivars of short cycle, there are many other factors and activities, that need to be considered for the production system, like: soil improvement with the increase of organic matter level, using previous crop residue covering the surface, to preserve soil/water and to modify soil temperature, establishing an intensive biology of soil, promoted by a large population of insects and fungi. To control weeds and plant disease, in this intensive crop system, the use of herbicides and other chemicals is important, demanding equipment of different size, with of soil and crop management, of specific solutions of farm machinery.

The development of products is preponderantly a task of engineering and marketing teams in the industry but in many cases, like the No till in Brazil, the project needed to be developed integrated with agronomists, from the National research system, to attend to the production systems of soybean and corn for new products or product developments are well known in the national industry.

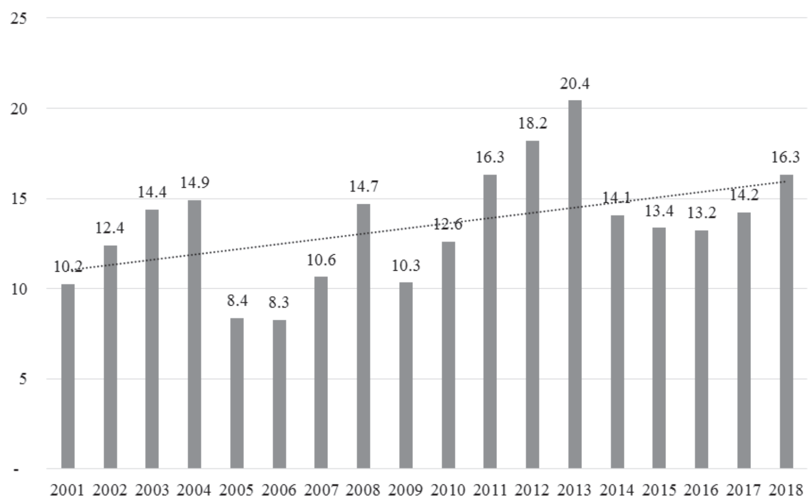


Fig. 4 Agricultural Purchasing Power Parity(PPP)- ABIMAQ - in billions of R$ in 2018

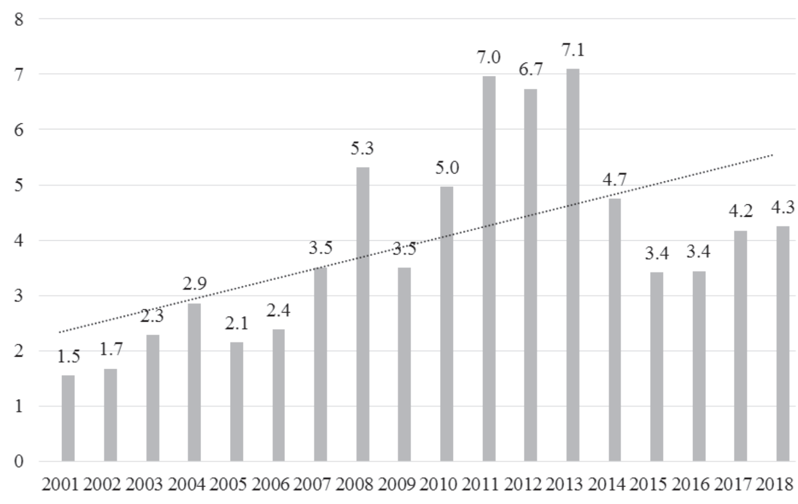


Fig. 5 Agricultural Purchasing Power Parity (PPP) - ABIMAQ - in billions of US$

The marketing of products is carried out through resellers, which may be authorized to sell only the brand of a manufacturer, or multibrand resellers, which sell more than one brand. Along with the traditional resale of machinery and implements, there are also sales inputs from commercial machine merchants, small farming houses and repair workshops that usually sell parts. The after-sales service is an essential condition to compete in the market because the machines are intensely used over short periods, and immediate repair in case of breakdown is an imperative necessity. The brands administer the level of coverage in detail, which the resellers can guarantee in the after-sales service. Thus, stocks of spare parts and trained personnel to maintain the machinery are necessary.

The sale of agricultural machinery in Brazil is strongly influenced by the prices of international commodities such as soybean, maize, citrus and coffee. In **Fig. 4**, the sales history of agricultural machinery of ABIMAQ associates clearly shows high sales cycles and low cycles that coincide with the high prices of soybeans and maize. The high sales cycles in 2002 to 2004 and in 2011 to 2013 coincided with high production levels of soybean and maize in the international market.

Fig. 5 shows the same data expressed in US$ for comparison. Although this figure provides an interesting perspective, the exchange rate in Brazil is subject to internal shocks, which always distorts the actual sales figures since the domestic prices of agricultural machinery are little influenced by the exchange rate.

Present Status and Prospects of Agricultural Machinery Research Activity

Brazilian universities had an important role in the development of agricultural mechanization. Agricultural mechanization started being taught in agronomy courses at the beginning of 20th century. The first departments in agricultural engineering were established to offer classes for agronomy courses.

The first graduate program in agricultural engineering in Brazil was set up in 1970 at the Federal University of Viçosa. Since the beginning, this graduate program has provided an opportunity for students to conduct work in the area of agricultural mechanization. From 2000 to 2018, a number of graduate programs were started in agricultural engineering. In 2018, 18 graduate programs in agricultural engineering are being offered in Brazil.

The first Brazilian undergraduate program in agricultural engineering was established in 1972 at the Federal University of Pelotas, located in southern region of Brazil. In 2018, there are 24 undergraduate programs in agricultural engineering among them 15 in Agricultural and Environmental Engineering and 6 in Biosystems Engineering.

Rio Grande do Sul is the southernmost state in Brazil and is one of the most important states in terms of agricultural machinery production. The Universidade Federal de Santa Maria (Federal University of Santa Maria) is located in this state and has been active in agricultural machinery research. In 1986, the Laboratory for Testing Agricultural Machinery, NEMA, was set up at this university. The Federal University of Pelotas, in the same state, set up the Nucleus for Innovation in Agricultural Machinery or NIMEq. In Rio Grande do Sul, a research center dedicated to developing the technology for wheat crops, Embrapa Wheat or the Brazilian Research Center for Wheat crops, is located. The Embrapa center has maintained a group of researchers dedicated to the technological development of agricultural machinery.

The state of Paraná greatly contributed to the development of agriculture in Brazil. It was in this state that the development of no-tillage techniques for grain production was started (**Fig. 6**). In this state, the University of Western of Paraná, UNIOESTE, is located. This university offers undergraduate and graduate programs in agricultural engineering. A group of researchers in agricultural machinery has concentrated their efforts to develop projects in precision agriculture. Additionally, Embrapa Soybean, the Brazilian research center for soybean crops, and the Paraná Research Institute IAPAR, a state institute, are located in Paraná state. These two institutions have a group of researchers working in the field of agricultural machinery. Their research is concentrated on the development of no-tillage systems and the development of agricultural machinery for small holder farms.

São Paulo is the state that has more groups of researchers working on agricultural machinery than any other state in Brazil. The ESALQ was the first institution to have a group working on power and machinery. More recently, they have concentrated their work on precision agriculture and on the mechanization of sugarcane crops, as shown in **Fig. 7**.

Campinas State University (UNICAMP) has maintained a group of researchers in the area of power and machinery since 1975. Most of their research works have concentrated on agricultural machine design, soil-machinery interaction and precision agriculture.

Another university that has strong programs in agricultural machinery is São Paulo State University. Most of the works at this university contributed towards the development of agricultural mechanization at the campuses located in Botucatu and Jaboticabal. They devote themselves practically to all areas of investigation of agricultural machines. Additionally, Embrapa Instrumentation, a Brazilian research center for instrumentation in agriculture, is located in São Paulo. This center has developed sensors for agricultural machines and has a laboratory dedicated to the development of research in precision agriculture. The Embrapa center has developed research linked to the analysis of seeding systems and precision agriculture of Maize and Sorghum, which is located in Minas Gerais state, Brazil.

Minas Gerais state has three universities that have developed research in agricultural machinery. The Federal University of Lavras has developed research in different

Fig. 6 Harvesting and sowing by taking advantage of the soil moisture and the coverage of newly harvested waste.
(Source: Gessi Ceccon; http://www.agencia.cnptia.embrapa.br/).

Fig. 7 Sugarcane crop harvest.
Source: 2013 Portal Agronegócio; https://www.portaldoagronegocio.com.br

areas of agricultural machinery, especially in coffee harvesting. The Federal University of Vicosa has also worked on different areas of agricultural machinery, including machine design, precision agriculture and soil-machinery interaction. The third university that has a group working in agricultural machinery is the Federal University of Uberlandia. The research group of this university is concentrating their works on precision agriculture. Both the University of Lavras and Viçosa have graduate programs at the MSc and DSc levels in agricultural engineering covering farm power, and machinery.

The Brazilian National Center for Research and Development or CNPq has a database called the Lattes Platform. Most Brazilian researchers have curriculum vitae registered in this platform. In the Lattes platform, it is possible to search for researchers from undergraduate level to Doctoral and even those developed recent inventions. Searching by main key words related to agricultural machinery, the following results are found presented in **Table 1**. More than one thousand researchers at the doctoral level are registered as working in agricultural machinery, more than four thousands of them are working on no-tillage systems and almost two thousands are working in precision agriculture. No-tillage systems are very popular in Brazil, and more than 30 million hectares are cultivated using this system. The adoption of precision agriculture is increasing rapidly in Brazil. Brazilian researchers are showing interest in these two areas of work.

Table 1 Number of researchers working in topics related to agricultural machinery in Brazil according to the Lattes Platform of the Brazilian National Center for Research Development (CNPq)

	Number of Researchers	
Key-Words	At the Doctoral Level	At All Academic Levels
Agricultural Machinery	1127	2383
Agricultural Tractors	382	776
Harvesters	272	508
Seeders and Planters	304	539
Tillers	7	7
Soil Tillage	567	924
No-Tillage Systems	4380	8965
Technology for Pesticide Application	199	366
Agricultural Machine Design	42	57
Mechanized Harvesting	733	1427
Soil-Machinery Interaction	5	9
Precision Agriculture	1725	3590
Yield Mapping	17	27
Variable Rate Application	14	19

Brazilian Society of Agricultural Engineering and Its Activities, Members and Magazine Publications

The Brazilian Society of Agricultural Engineering (SBEA) was established in 1965 by professors, engineers and technicians engaged in activities related to agricultural engineering. For more than half a century, it has been an important link and promoter of excellence of research in agricultural engineering-related areas in Brazil. The mission of the SBEA is to stimulate the growth and promotion of scientific and technological development in agricultural engineering through congresses, meetings and publications of a technical-scientific journal. In addition, the SBEA promotes exchanges among higher-level professionals in the search for solutions to challenges in the field of agricultural engineering. The vision of SBEA is to establish itself as a scientific association capable of representing agricultural engineering and holding general and sectorial technical-scientific events. In addition to bringing together professionals engaged in agricultural engineering activities, the creation of the SBEA aims to establish links with other similar entities established in other countries, especially its affiliation with the International Society of Agricultural Engineering (CIGR), based in Paris, and participates in the following technical sessions: i. Agricultural engineering. ii. Rural buildings and related equipment. iii. Agricultural machinery. iv. Rural electrification and agricultural applications of electricity. v. Scientific organization of work in agriculture.

Similar to other societies, the statutes of the SBEA define the general and specific guidelines regarding the functioning of an entity during its establishment. The actual seat of the SBEA has been located in the Faculty of Agrarian and Veterinary Sciences, UNESP, on the Jaboticabal Campus, in São Paulo (www.sbea.org.br) (**Fig. 8**) and the SBEA has 532 active members active in teaching, research and extension institutions in all Brazilian regions.

Another highlight is the hosting of the annual National Congress of Agricultural Engineering, CONBEA, in a place and date to be

Fig. 8 The headquarters of the Brazilian Society of Agricultural Engineering (SBEA), UNESP, on the Jaboticabal Campus in São Paulo.

defined by the assembly, with the publication of annals containing the papers presented and approved in the congresses or the abstracts referring to such works.

Over the course of five decades (from 1965 to 2018), 47 CONBEAs have been held at different teaching and research institutions established in different parts of the country. The most recent edition was held in August 2018 in Brasília, DF (**Fig. 9**), where the site of the 2019 edition is also announced, namely, Campinas, SP, with the Faculty of Agricultural Engineering of UNICAMP as the host institution.

The event had already hosted 800 congressmen (**Fig. 9**), with the average number of participants in the last 15 years being 450 professionals

Fig. 9 National Congress of Agricultural Engineering, CONBEA, 2018, Brasília, DF

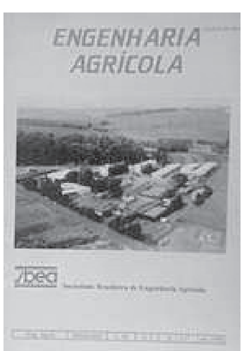


Fig. 10 The SBEA scientific journal

Fig. 11 Event highlight of CONBEA

and students in the area. In addition to the publication of the annals of the various Brazilian Congresses of Agricultural Engineering or CONBEAs, the society publishes its own magazine, with associates as the collaborators, as shown in **Fig. 10**.

During its 50 years of existence, the headquarters of the SBEA has remained for 15 years at ESALQ-USP, Piracicaba (from 1965 to 1980). From 1980 to 1987, Sorocaba hosted the office of the SBEA at CENEA/MA. For 31 uninterrupted years (1987 to the present), the seat of the SBEA has been located in the Faculty of Agrarian and Veterinary Sciences (UNESP) on the Jaboticabal Campus.

Advanced Technology in Agricultural Machinery

Agribusiness is one of the main activities of Brazil and contributes significantly to the Brazilian economy. In addition to its economic importance, agribusiness has a strong social impact on the country due to the generation of employment opportunities and impact on the supply of food, fiber and energy. In the same way, agribusiness also contributes significantly to the international scenario, i.e., as a commodity and food supplier to numerous foreign countries. In Brazil, the recent recovery of the national economy occurred along with a record harvest reached; there is a new impulse in the year 2018. This fact led to greater investments and development in the market of agricultural machinery and implements in the country. In the analysis presented by the Chamber of Machinery and Agricultural Implements (CSMIA) of the Brazilian Association of Machinery and Equipment Industry (ABIMAQ), the current balance is highly positive, and due to another record crop in the grain sector, there is a great performance in the sale of machinery and implements.

In addition, the extension of financing and additional lines of credit have become a reality to farmers, who have found an opportunity to improve their infrastructures, acquire innovations in the machinery sector and market their products in a favorable and competitive climate. The Program for the Modernization of the Fleet of Agricultural Tractors and Associated Implements and Harvesters (Moderfrota), the National Support Program for the Medium Rural Producer (Pronamp) and the National Program for Strengthening of Smallholders Farmers (Pronaf) found adequate financial support and the flow was uninterrupted during the second half of 2017 and in the subsequent months of 2018.

Included in this scenario of realities, in Brazil, the machinery and agricultural implement industries have started to offer both traditional machinery and intelligent machineries that has incorporated knowledge and innovation, such as embedded electronics for intelligent automation aimed at agricultural risk management and harvest forecast. In addition to that, precision agriculture for the characterization via prescription maps or real-time operation focused on soil fertilization and planting, pest control with intelligent sprayers, rational use of agricultural inputs, including the application at varied rates, and machines with sensors and artificial intelligence technology to infer the quality of products and levels of productivity. In this context, it could be observed that there was a greater interest of the machine-producing companies in prioritizing the supply of innovative machines for productivity gains and reduction in the operational and administrative costs.

Thus, by automating production based on management actions and considering a virtuous cycle that includes the preparation of the land and the selection of agricultural inputs and their management, including associated logistic aspects, Brazil was able to demonstrate its competitiveness and strategy to the world. In this context, the agribusiness sector has been generating commodities, food, fibers and energy, both for consumption by the Brazilian people and for export and trade.

Faced with a globalized planet, the machinery industry has relied on devices, methods and techniques that are often the result of integration processes that can occur in different parts of the planet.

To illustrate the actual situation in Brazil, a few examples regarding machinery industries and the adoption of their products by the production sector are considered as follows:

- First, Embrapa in 2017 delivered a smart sensor to the production sector to help control the application of herbicides. The sensor was organized and developed on the basis of direct injection systems, where the spraying response time plays an important role in the quality of spraying, particularly when operating in real time.
- Second, the Smart Sensing Brasil company has brought to the market, directly from the Netherlands, a precision spraying system in which the main focus is to avoid the waste of phytosanitary products. It works by emitting a beam of light, capable of recognizing whether the weed is alive or not and carrying out a chemical herbicide application to combat weeds.
- Third, meetings were held in Brazil such as the initiatives promoted by the Agrihub connection, which was organized by the Federation of Agriculture and Livestock of the state of Mato Grosso (Famato), in partnership with the National Rural Apprenticeship Service (Senar), and the Mato Grosso Institute of Agricultural and Livestock Economy (Imea). They organized and facilitated the gathering of companies for technological innovations in agriculture, such as:
- The IZagro Company recently presented an application that assists in the control of pests and diseases of various crops; it is an embedded digital tool that seeks to connect producers in their expertise and decisions.
- The CBC Negócios Company has presented its agribusiness machinery marketing platform to automatically reduce communication deficiencies between the suppliers and rural producers.
- The Stara and Falker companies have commercialized an agricultural implement with a sensor that measures the apparent electrical conductivity of the soil. To make these measurements feasible in difficult and inaccessible areas.

Also, Embrapa delivered a portable intelligent technology device. The readings obtained by this sensor correlate well with the physical attributes of soils, such as the texture and organic matter. Furthermore, the use of new sensors has aided decision makers in the generation of maps that can be used for management and soil sampling because zones with similar characteristics can be visualized in the property maps.

In fact, there are also sensors that are already available on the market that make it possible to perform chemical analyses of soils, such as those made available by the SoilCares company, which uses spectroscopy techniques to recommend the fertilization to be carried out on the properties.

Other research areas that have been stimulated are the use of varied sowing rates and the utilization of GNSS embedded into agricultural implements. Once management zones are delimited within crops with more productive areas, one management strategy is to sow varied populations of seeds and even different hybrids. In this context, a market solution was found by the Topcon company, which accommodates the entire sowing process. Such technology can allow the customization of the operations panel, i.e., using configuration wizards to start the process, import the map coverage, schedule the variable rate control of fertilizers or other products, and even decide how to prioritize the sowing process of the field. Some of those machines can already be operated 24 hours a day, thereby widening the short planting and harvesting windows. The latter yields productivity gains.

Along the same direction, the new John Deere tractors or even those developed by the Case company, incorporate the latest generation of embedded technology. The new tractors are equipped with powerful and economical engines, and automatic gearboxes with more than 23 combinations of gears. They feature advanced technologies, such as air suspension seats to reduce impacts, light emitting diode (LED) headlights and 360º xenon headlights to facilitate night work, autopilot and bedside maneuver assistance, audio packages with several speakers, universal serial bus (USB) inputs, auxiliary and external antenna, heaters and air conditioning systems with automatic temperature controls and digital monitors for the fuel level, engine temperature and rpm.

Furthermore, it is also important to mention the Canadian company Massey Ferguson, which is engaged in the production of agricultural machinery and operates in Brazil in association with the AGCO group. In recent years, they have launched a new motor-driven sprayer with electronic management, as well as a hybrid harvester either with a cabin or with a platform, all with features such as an electronic engine, 12-speed mechanical gearbox with mechanical or hydraulic reversing, autopilot option, manual gearbox with 12 gears forward and five aft, automatic transmission and ability to simultaneously operate implements in the front and rear. In 2018, the AGCO group has also introduced an exclusive production line of Massey and Valtra sprayers with versions for sugarcane and grain to the Brazilian production sector. In fact, they have presented innovations in their new grain harvester, as well as several tractors with mechanical or electrohydraulic reversal.

Moreover, other examples to be mentioned are those from the Jacto Company, which occurred in 2017, when they launched sprayers that included the concept of the Internet of Things (IoT), making it possible to connect the sprayers to the worldwide network of computers. The company has also considered cooperating with the Automotive Air Pollution Control Program (Proconve), which sets emission limits for pollutant gases for agricultural and road machinery.

On the other hand, in the field of machines for animal husbandry, another interesting example is that of the Casale Company, which has a complete line of intelligent mixers in its portfolio that improve the efficiency of the cattle rancher, such as a forage harvester, feed distributor and manure equipment.

Among all the mixers in Brazil, there is an equipment that is widely used, as it has uniform and precise self-loading silage technology that does not damage the silo. A technology is designed involving the milling with knives and an automatic drive for all types of bulk material facilitates this stage of the operation without waste occurring in the silage and the distribution process.

Also, harvesting and threshing machinery, straw and forage presses, lawn mowers, grain cleaning machines, and innovative sorting machines for eggs, fruits and other agricultural products have been made available by small or medium companies operating in Brazil. Among them are also machines and equipment for horticulture, poultry and beekeeping, including germinators with mechanical or thermal devices and incubation and poultry breeding facilities.

In addition, another innovative agricultural machine that was made available by Embraer to the agricultural sector in Brazil is a new version of agricultural aircraft certified to fly utilizing ethanol and with the capacity to realize wider aerial spray bands via an automated system to minimize the occurrence of drift during applications of pesticides.

Lastly, at present, there is still a large dependence on the international market with regards to access to UAVs (unmanned aerial vehicles), UASs (unmanned aerial systems), and drone technologies, i.e., customized to be used in Brazilian agriculture. Regarding to UAV research areas, despite the efforts in research and development already made, not only by Embrapa but also by most of the important Brazilian universities, the production sector has so far acquired such innovative solutions from the international market.

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The Valorization of Embedded Technology in the Sprayers to Obtain Operating Gains and Pulverization Quality

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The Brazilian economy and its development are directly related to agribusiness, where it obtains 22% of the Gross Domestic Product (GDP) of all other economic sectors. Large, medium and small farmers make up the producer market and develop an internal agriculture (CENTRO DE ESTUDOS AVANÇADOS EM ECONOMIA APLICADA, 2016).

Among the technological developments, those directed to agricultural machinery have been gaining more and more place in Brazil, the current farmers are acquiring knowledge of the importance of investing in technology to gain operational capacity and primarily improving productivity.

The evolution of implements and productivity in the Brazilian market gains importance for the exportation of products, where currently they have seven products among the ten most exported in the last twelve months worldwide. According to data from the Ministry of Industry, Foreign Trade and Services - MDIC, agribusiness represented 40.84% of the Brazilian trade balance in 2017 (BERNARDES, 2018).

A highlight of the segment of Brazilian agricultural machinery and implements is its ability to adapt to different sizes of farms. Thus both large and small farms can participate in the evolution of equipment due to a very heterogeneous structure with companies of various sizes and origins of different capitals, thus modernization agribusiness (LUCENTE, 2010).

Data provided by the Brazilian Association of Machinery and Equipment Industry (ABIMAQ) shows this heterogeneity among companies, where in 2015 it presented 740 registered companies (ABIMAQ, 2015). The Brazilian Institute of Geography and Statistics (IBGE, 2017) in the year 2015 presented 2,093 companies related to the manufacture of equipment and machinery for the agricultural sector (**Table 1**).

This demonstrates the evolution in research and development in the internal market to serve diverse categories of farmers. Agribusiness companies are aware of the need to invest in technology and modernize their equipment, as the farmers are increasingly demanding in this area.

Several researchers emphasize this development. Fernandes (2018) correlates the need for more agile production of food and its quality to technological development, believes

Table 1 Companies and indicators of economic concentration in relation to the variable occupied total of the largest companies by section, division and group of the classification of activities (CNAE 2.0)

Variable number of Company (unit) Brazil									
Year x Activity Classification (CNAE2.0)									
Years	2007	2008	2009	2010	2011	2012	2013	2014	2015
Brazil	1.678	1.759	1.791	1.888	1.892	1.971	2.083	2.074	2.093

IBGE (2017) Central Register of Companies- 28-3 Manufacture of Tractors and Machines and Equipment for Agriculture and Livestock.

that this need drives the agricultural machinery market. This permits the search for high technologies and results in operational efficiency and good production.

Silva (2015) has based on the same principles cited, where it is stated that the development of the agricultural machinery industry was the cause and effect of the need for machines with more technology and larger production in scales, which increases the number and size of manufacturers.

The multinational companies involved in the production of agricultural machinery and equipment see the South America as a great alignment for their development, since certain interests are based on the potential of the production, commercialization of products and the great demand of potential with these countries (LIMA, 2003; SILVA, 2015). For these companies, Brazil has become a favorable environment to consolidate with the purpose of establishing a platform to meet their interests in the conquest of new markets.

The agricultural potential of Brazil promotes interest of many groups in maintaining their businesses directed to this market The presence of natural resources such as fresh water, crop lands, technology and good productivity are relevant compared to other countries (Fernandes, 2018).

Research highlights the estimate that by 2050 there will be 9 billion people on the planet and to feed them global food production will need to increase by 60%. Therefore, Brazil's capacity to produce with sustainability and with respect for the environment, makes it emerge as an agricultural superpower (JOHN DEERE, 2018).

Many companies are investing in R & D (research and development) to achieve a quality and performance differential. Vian *et al.* (2013) already reported the concentration of the market and increase of scale of production. In this structure model, companies search to maintain a long-term relationship with the consumer, either through the credibility of their trademarks or through investments in research. Those that do not adapt to quality and performance end up suffering from these barriers that limit the development of organizations that can operate in a given market or segment (Silva, Vian, 2017).

There are many agricultural researches that focus on the efficiency of the application technology, since they know that good production requires good care during the crop cycle. Spray manufacturers are investing more and more in the quality improvements of spraying.

The implementations of new technologies available in the machines offer greater safety and efficiency to the production processes. The telemetry in this case assists the producer in a quality spraying, mapping the sprayed area and avoiding overlaps in the applications that would become waste (Jacto, 2018).

When talking about application technology, many variables are discussed, such as the nozzle type to be used, type of machine, type of product to be sprayed, weather condition at the moment of spraying and type of crop. For this reason, equipment with embedded technology allows precision in the quantity of the product in the target in question, obtaining better results in control. Towards a more sustainable agriculture, use of embedded equipment with improved technology would result in drift reduction and insertion of substances that could be harmful to the environment, (Jacto, 2018).

Therefore, the application technology must be prioritized among the investments in the segments of the agricultural sector. In addition to representing one of the largest expenditures in a production due to the high price of pesticides and its large amount applied, there may be application failures leading to failure of control of weeds or pests and diseases. This would affect the final production and may occur resource wastes and environmental contamination (SINDIVEG 2018).

The Jacto always linked in the need of its clients to invest in research and development of its equipment to provide good control and quality in the spraying of pesticides.

The last equipment released to the marketing by Jacto group was the Electro-Vortex system that comes to assist the farmer for gaining operational efficiencies and to maintain a good quality in the application.

The applications of low volume and operational gains have been highlighted. However, to realize this type of practice the farmer must invest in technologies to obtain good control and final production. The volume of the solution is important for the success of the application since it is very dependent on the type of target to be reached, product action, spraying technique and architecture of the plant in question (ALMEIDA, 2018).

Cultivars with higher index of foliar areas require a larger volume of spray solution when compared to cultures of lesser foliage. This should also be able to relate to the different stage of development of the crop, where they present a considerable difference in leaf area index (MATUO 1990; HOFFMANN; BOLLER, 2004; RODRIGUES-COSTA *et al.*, 2011).

Accordingly, the sprayers with high technology make it possible to spray qualitatively even in unfavorable situations, as in the case of low volume at high leaf density. To obtain operational gain and productivity the farmer must be aware of the need for investments in equipment with technology. This in return allows the farmer to maintain a good quality of spraying.

The new Electro-Vortex Jacto system is the combination of two technologies that includes the vortex air curtain and electrostatic charging, which enables the droplets to be directed to the selected target (**Fig. 1**). These negatively charged droplets are attracted by the plants that are grounded allowing a better distribution in the leaves and extracts of the plant. The vertical air curtain helps direct the droplets resulting in greater deposits and results in greater control.

This type of research has taken years and large investments to potentialize and modernize the sprayers by adapting them to the farmer's need in the production run.

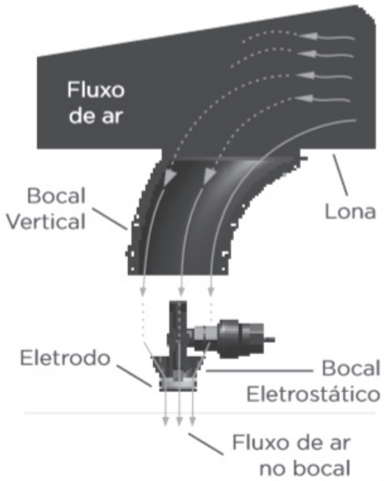

Fig. 1 Electro-Vortex Jacto system

The field results demonstrated in **Fig. 2** show a larger deposit of agricultural pesticides in the comparison of different application rates using the Electro-Vortex and conventional sprayer, emphasizing the need for investments in machine development and technologies to guarantee the quality of operations in the field (JESUS , 2019).

Conclusions

Research aimed at the development of agricultural machinery and equipment should be increasingly encouraged, as it allows the farmer greater security in production.

The need to increase crop yields over the years has made it possible to provide more advantageous and efficient alternatives to the farmer. Thus, in relation to the use of phytosanitary products, the sprayer is introduced as an important mechanism of application as it provides the farmer with greater precision and reliability in the work done in the field (ALONÇO *et al*., 2018).

The advancement of technologies and modernization of machines require more specialized manpower with the availability of clear scientific technical information resulting in precision in the work (DONALDSON, 1970).

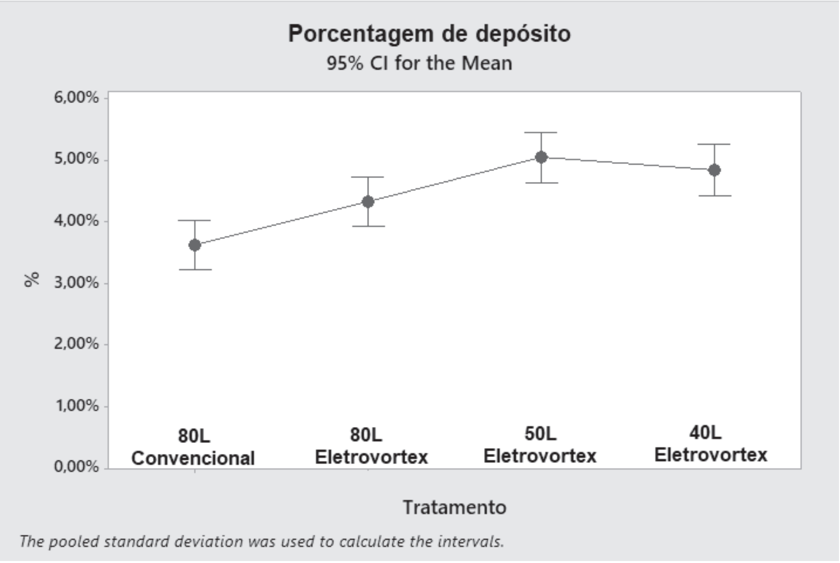

Fig. 2 Statistical result of the percentage of spray deposition carried out on cotton crop 2018, Mato Grosso state

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Situation of Agricultural Mechanization in Argentina - A Perspective

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Introduction

In this paper, the situation of agricultural mechanization in Argentina has been reviewed discussing the characteristics of agriculture in the country - what has been the evolution in the past, the current situation and the perspectives of the sector towards the future.

Details

Institutional Framework

The institutional framework of the sector is extensive; however, it does not have great strength. Different public and private institutions participate, and the most important ones are described below:

Private:

- AFAT: Association of Argentine Factories of Tractors and Other Agricultural and Road Equipment. It brings together all the tractor manufacturers, of which most are international companies.
- CAFMA: Argentine Chamber of Manufacturers of Agricultural Machinery. It is the chamber in which the manufacturers of agricultural implements participate. It is mainly made up of local companies, although a small number of foreign companies also participate.
- CECMA: CIDETER Business cluster (Regional Technological Information and Development Center of Agricultural Machinery). It is a public-private partnership whose purpose is to collaborate with the SMEs that constitute the Productive Pole of Agricultural Machines, raising the levels of quality, competitiveness and profitability. It is located in Las Parejas, province of Córdoba.
- AACREA: Argentine Association of Regional Consortiums of Agricultural Experimentation. It was founded in 1957 and has been the promoter of most of the technological advances of agriculture in Argentina.
- AAPRESID: Argentine Association of Producers of Direct Sowing. Founded in 1989, it has been a key promoter for the development of this production system, as well as other technological advances.
- AFAMAC: Association of Manufacturers of Agricultural Machinery and Agro Components of the province of Córdoba. That represents the industry of this province.
- FACMA: Argentine Federation of Agricultural Machinery Contractors, which brings together the associations of contractors in different regions of the country.

Public:

- Secretary of Agribusiness, National Directorate of Agro industrial Machinery. Have a limited operational capacity for the design of policies.
- Ministry of Production, Secretariat of Industry: It is where the most important decisions are made for the sector, since it deals all public decisions about economic, tariff and taxes.
- INTA: National Institute of Agricultural Technology. Founded in 1956, it has several centers specializing in agricultural machinery and has a strong interaction with the private sector.
- INTI: National Institute of Industrial Technology. It is not specific to agricultural machinery, but it has some centers that are related with companies in the sector
- MINCyT: Ministry of Science, Technology and Productive Innovation. Through some programs, it finances research for technological development that can be used by companies in the sector.
- Universities: There are few specific careers; one of them is the Engineering in Mechanization of Agricultural Production of the University of Morón. For many years the University of La Plata taught a Master's degree in Agri-

cultural Mechanization, in which many of the professionals who are now references in the sector were trained. There are some specializations and master's degrees on the subject and on security issues. Most of the professionals working in the companies come from the careers of industrial engineering and agronomic engineering. With the increasing importance of electronics, engineers in this discipline are being incorporated into the companies that manufacture agricultural machinery.

The Agricultural System in Argentina and the Impact on Mechanization

Although Argentina is not a developed country, it is one of the most competitive in the agricultural sector, as a result of comparative advantages: soil, climate, large pieces of land with good aptitude; as of the construction of competitive advantages, by means of the creation of productive systems suitable for the characteristics of the country, among which can be mentioned as the direct seeding system, the recent large scale investments in the oilseed industry and very efficient private ports.

Since the 1990s, there has been a technological development that has allowed an increase in the production of cereals and oilseeds from 36 million tons in 1990, to 65 million in 2000, reaching 130 million tons at present. In the same period the agricultural surface grew from about 20 million hectares to 37 million hectares.

This increase meant a change in the production system, tending to reach scale to reduce costs and increase competitiveness. A very significant number of small and medium size producers have abandoned the agriculture doing it on their own which has given rise to a system of rental of fields that currently exceeds 50% of production and the consequent specialization and increase in scale.

This model increased the participation of rural contractors, which although they had existed for decades, the increase in production on rented fields, based on sectorial but also external investments, has provided an opportunity for contractors, who through specialization and scale they have been able to acquire and renovate high performance machinery.

Although the production of cereals and oilseeds has expanded, Argentina is also a self-sufficient producer or even exporter in other products such as sugar cane, cotton, fruits, vine and wines, tea, tobacco, peanut, etc.

It is also significant to mention the importance of livestock, which is significantly lower than in the past, when Argentina was one of the world's leading exporters; but there is a production of meat and milk that also, in the last years has increased in the technology, so there are requirements for machinery for the conservation of forages and production of feed, served by the local industry.

History of Mechanization in Argentina

Argentina has a long history of agricultural mechanization, often linked to immigrants mainly of Italian origin who settled in the provinces of Santa Fe and Córdoba, and who very early began to manufacture agricultural implements, simultaneously with the beginning of agricultural development. They started to produce plows in 1878, threshers in 1910 and finally the first automotive harvester in 1929, all with fully national companies with innovations product of the inventiveness of farmers and manufacturers. The first nationally manufactured tractor had to wait until 1950 and it was through a development of John Deere.

The growth in agricultural production has implied a modernization of the machinery used and an increase in its scale.

In the last decades with the growth of the direct sowing system and the consequent increase in the use of agrochemicals, the use of automotive sprayers was strengthened; there are several national factories of high capacity operating equipment that compete favorably with those from abroad.

The industry continued to develop with ups and downs according to the macroeconomic situation of the country, with periods that due to the exchange rate and the lack of protection to the local industry. Importation was more convenient than the purchase of equipment produced in the country. However, when the macroeconomic conditions were favorable, the local industry was reborn and strengthened in a cyclical mechanism.

The Machinery Used Today

The most important machines in the current production system are the sprayers, the seeders (obviously with the tractor) and the combine harvester. There are no reliable statistics regarding the age of the equipment, since in the national census the average age of the tractors is recorded, which is very old due to the coexistence in the same category of modern equipment with great capacity for work, with others that perform minor tasks in the farms, that are old but have no major relevance for the productive system.

Most of the contractors that serve important land areas have updated equipment and are operating at large scale. Normally in combines, the average is of the order of five years and there is a permanent replacement looking for larger work capacity and better benefits in terms of quality. At the same time, the grain hauling equipment until the storage or the transportation, have grown in capacity constantly, to be consistent with the bigger working capacity of the harvesters.

Older harvesting machines also coexist but are used by smaller contractors, who work marginally in smaller farms or in less productive areas.

In most cases the owner of the harvesters works by himself, and has one or more people according to the number of equipment he has. Usually, there are no large companies that provide the harvesting services; these are single person or family businesses (**Fig. 1**).

Regarding the harvesting and storage system, in recent years the "silobag" have been developed which are cylinders of three layers of polyethylene with ultraviolet protection, with a length of 60 or 75 meters with a diameter of 2.75 meters with have a capacity of around 200 tons of grains (**Fig. 2**). These are located in the same fields, allowing the transportation when the grains are selling; making the transportation process more fluid.

In the case of tractors and seeders, the technology is also very advanced (**Fig. 3**). Due to the lower complexity in relation to the harvester, the equipment may be a little older, up to 10 years, if these have not been left out of the market due to obsolescence. A high proportion of the seeders have seed monitors.

Most of the crops are sprayed with automotive sprayers, in most cases the contractors do not use drags spraying, which are still in the market. These are preferably used in fields where the farmers work by themselves, because these are convenient due to the lower annual

a) Combine manufactured in Argentina

b) Combine and hopper

c) Harvesting barley

d) Combine equipment

e) Hopper and tractor

Fig. 1 Harvester in the farm

a) Doing a silobag

b) Silobag

c) Reparing a silobag

Fig. 2 Silobags

a) No tillage seeding with malting barley

b) No tillage seeder

c) No tillage seeder manufactured in Argentina

Fig. 3 Tractors and seeders

utilization since greater investment involved in automotive sprayers (**Fig. 4**).

The wide use of direct seeding makes the tillage machines have a secondary role in the current production systems, since they are used in a very small surface.

Precision agriculture has grown in recent years; being demanded by the most efficient producers, who require at their contractors planting monitors, yield maps in the harvesters and other technological advances. Many contractors in order not to lose their customers have incorporated these services. However, the use of precision agriculture for technical decisions to improve crop performance has not yet been generalized for various reasons; both because of the availability of time and knowledge of the producers and also because there is not enough agronomic experience to know what decisions to make with the results of precision agriculture.

The equipment and machines for the conservation of forages and the production of feed are mainly manufactured by local companies and are used mainly in the dairy production sector and in the feed lots.

The Agricultural Machinery Industry

The agricultural machinery industry is strongly concentrated geographically in the provinces of greater agricultural aptitude of the Pampas region with the following distribution: Santa Fe (44%), Córdoba (24%), Buenos Aires (21%) and only the 11% in other provinces.

Fig. 4 Sprayer manufactured in Argentina

For the most part, they are small and medium-sized companies with an average of 9 employees, although there are some larger ones with more than 200 workers.

As has been pointed out, in recent years the increase in the productive scale has determined by an increase in the power of the equipment. Nine out of ten tractors sold have more than 100 horsepower and the 13 brands of high power tractors have 63 models on the market that exceed 200 HP (Sargiotto, N, *et al*., 2018). This power is necessary for seeders that have work widths of up to 18 meters. Also during the harvest with the use of hoppers that have a capacity of up to 30 m3 of cereal; thus high power equipment are necessary.

Tractors from 100 to 140 HP have assisted traction and are used mainly in intensive livestock and other animal production systems. The 140 to 250 HP also have assisted traction and are used mostly for extensive agricultural use and harvest contractors. (Sargiotto, N, *et al*., 2018)

The equipment of more than 250 HP are used by large-scale agricultural producers and contractors, mainly for use with seeders of direct sowing of 15 to 18 meters of width of work. These are 4 × 4 teams of wheels of equal size and articulated. (Sargiotto, N, *et al*., 2018)

The transmissions used are of three types. Synchronized, which is increasing its use and have a wide range of working gears, gear inverters and reducers for jobs at ultra-slow speeds. The second type are the synchronized gearboxes achieving a balance between the speeds appropriate to work and the force required; while automatic boxes are also used with Power Shift and Hi-Low systems. (Sargiotto, N, *et al*., 2018)

Most of the new designs of the automotive sprays have 4 × 2 transmissions and there are 28% of the models with integral transmission. The trend is towards the use of the front engine. Currently in the national teams the power of the engines is from 120 to 160 HP although there is a tendency to further increase it. Imported equipment usually already exceeds this power. The width of work is greater than 28 meters and there are models that have up to 40 meters. There is a tendency to incorporate self-leveling mechanisms and the decrease the weight of the boom using carbon fiber. (Sargiotto, N. 2018)

The capacity of the tank is essential to increase the working capacity of the sprayers. At present, 40% of the models have tanks with capacities of 2,800 to 3,100 liters and 35% are already above this capacity level. The performance of the sprayer also depends on the load capacity, which is why many contractors have complementary equipment such as tanks to haul water in trucks or trailers. These complete the structure of the sprayers with safety equipment for the cleaning of drums. (Sargiotto, N. 2018)

Weeds detection is also being incorporated at a still very low level; based on the determination of the green matter index or chlorophyll sensors, which would allow a very significant reduction in the use of agrochemicals according to the distribution of the weeds in the plots. (Sargiotto, N. 2018)

Regarding harvesters; there is a clear tendency towards axial machines, since the international companies established in the country only manufacture these types, while the local brands have simultaneously both types in the market models with conventional threshing with other axial ones. The predominant working widths are between 35 and 45 feet (10.7 to 13.7 meters) and the engines have a power between 300 and 510 HP (Sargiotto, N. 2016)

As for sales, the sector has an irregular behavior, following the fluctuations of agricultural production and markets and also according to the prevailing macroeconomic situation in the country. This is why while in 2002 the machinery market was only 340 million dollars; while in 2011 it reached 1450 million dollars, with record exports made by 90 companies with a total value of 260 million, generating 90,000 direct and indirect jobs. (Bragachini, M. 2011). The sector represents 25.2% of the added value of the machinery and equipment branch and 1.1% of the industry. (Garfinkel, 2016)

Two stages can be established in the production of machinery, the first is the machining of parts, based mainly on the use of machine tools. The second stage consists in the assembly of these parts, together with other components with different degree of complexity and specificity, for example electrical, electronic, measuring, motor, rolling, etc. components, which are supplied by other industries and even some of these components come from import. (Garfinkel, 2016)

Nowadays, manufacturers integrate the production of their equipment with components of higher technology for precision agriculture which include the planting monitors, the performance mapping consoles, satellite auto-guide (automatic pilot), etc.

There is an extensive network of dealers in the country of the main brands of tractors, harvesters, sprayers and agricultural implements, which have specialized workshops for the repair of machinery. At the same time, there is a large number of workshops specialized in the repair of tractors and harvesters throughout the productive interior, which have highly complex equipment. The rest of the rural machinery is repaired in workshops of smaller dimensions and complexity or by the owners themselves

Regarding the human resources that operate the field machinery, there is a high level of capabilities, for regulations, such as to obtain a high quality of work and also to carry out repairs. The training, in most cases, is experiential .

In its own technological area, innovative machines have been developed in Argentina that have been adapted to the local production system then spread throughout the world. The first automotive harvester (Rotania, 1929) was followed by other innovative machines that were exported, such as the seeding machines for direct sowing, silo extraction bags, baggers and harvester heads. CIDETER together with INTA and CAFMA (Argentine Chamber of Agricultural Machinery Manufacturers), field demonstrations are being carried out in South Africa for direct sowing and experiences of this type have already been carried out in Kazakhstan, Russia and Ukraine, and Colombia (Borghi, 2018) .

Mechanized irrigation adds up to 405,000 hectares (Bragachini, 2016) and is mainly carried out with equipment manufactured in the country by international firms. The production of corn seed, cereals and some horticultural crops such as onions, potatoes and garlic concentrate the greater use of mechanized irrigation equipment.

There are emerging developments in the use of plant materials and animal waste for the production of energy, a field that will grow in the future.

Table 1 Sales of Tractors

Period	Total Sales	National Tractors Sales	Imported Tractors Sales
4º Quarter 2017	2,662	1,661	1,001
1º Quarter 2018	1,661	1,184	477
2º Quarter 2018	1,782	1,195	587
3º Quarter 2018	1,335	884	451
Total	7,040	4,924	2,516

Source: Instituto Nacional de Estadísticas y Censos. Informe de la industria de maquinaria agrícola, Tercer trimestre de 2018

Table 2 Sales of combines

Period	Total Sales	National Combines Sales	Imported Combines Sales
4º Quarter 2017	402	231	171
1º Quarter 2018	331	167	164
2º Quarter 2018	200	132	68
3º Quarter 2018	102	71	31
Total	1,035	601	434

Source: Instituto Nacional de Estadísticas y Censos. Informe de la industria de maquinaria agrícola, Tercer trimestre de 2018

Marketing Statistics of Agricultural Machinery

As a result of the macroeconomic crisis that broke out in 2018, the sale of equipment in recent months decreased significantly due to credit restrictions and due to increase in the value of the dollar, which is why buyers are impatient.

While working with the statistics officials for the last 12 months for this reason, the available information presented below corresponds to the last quarter of 2017 and the first three quarters of 2018 (**Tables 1-5**).

Table 3 Production and sales of seeders

Period	Total Sales
4º Quarter 2017	661
1º Quarter 2018	155
2º Quarter 2018	518
3º Quarter 2018	596
Total	1,930

Source: Instituto Nacional de Estadísticas y Censos. Informe de la industria de maquinaria agrícola, Tercer trimestre de 2018

Table 4 Production and sales of Sprayers

Period	Total Sales
4º Quarter 2017	353
1º Quarter 2018	142
2º Quarter 2018	276
3º Quarter 2018	206
Total	977

Source: Instituto Nacional de Estadísticas y Censos. Informe de la industria de maquinaria agrícola, Tercer trimestre de 2018

Table 5 Sales of agricultural implements

Period	Total Sales	National Machinery Sales	Imported Machinery Sales
4º Quarter 2017	2,520	2,185	335
1º Quarter 2018	1,589	1,270	319
2º Quarter 2018	2,073	1,882	191
3º Quarter 2018	1,388	1,202	186
Total	7,570	6,539	1,031

Source: Instituto Nacional de Estadísticas y Censos. Informe de la industria de maquinaria agrícola, Tercer trimestre de 2018

Regarding exports of agricultural machinery, Argentina has a marginal presence in international markets, since these represent only 0.2% of the world's trade in the sector. In 2015 it was ranked 47th worldwide.

The national industry has had a very good time in terms of exports through an agreement with Venezuela, which allowed some 40 companies in Argentina to export their products, but did not have further continuity.

During 2015 sales of agricultural machinery to the domestic market reached 9,419 million pesos, equivalent to some US $ 1,000 million, of which 88% corresponded to national equipment and the rest to imports. In that same year, exports were US $ 139 million.

There are few exports of tractors, while those of harvesters reached 6% of total production and seeders, 9%, while in the case of implements, the amount reached to 23% of production, in value.

Future Trends

The future trend in agricultural mechanization will continue with the increase in the size of the machines; however, the greatest advances will be in the field of quality and monitoring of processes through the use of ICTs, a path already started and in the past years that will have a very significant development.

Environmental issues such as management in the use of agrochemicals; minimizing their impact on the environment is another prevailing trend worldwide and will also be strengthened in Argentina.

The intensification of livestock processes will continue; increasing the use of machinery for the conservation and supply of forage and the management of waste.

Conclusions

Argentina has an extensive network of companies and contributors related to agricultural mechanization. There is also an adequate insertion of national and foreign companies in this sector which generates some synergies.

However, operators are subjected to the situation of production and the agricultural market, so there are ups and downs in the sale of equipment which is enhanced by insufficient credit for investment in machinery. That is why in years of good production and agricultural prices there is a significant increase in sales which decline when these

a) Soybean

b) Soybean

c) Corn

d) Sunflower

e) Malting Barley

Fig. 5 Main crops

circumstances do not occur (**Fig. 5**).

Finally, the variable macroeconomic conditions of the country generate other constraints for a long-term harmonious development with implications not only in the domestic market but also for export.

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Present Status and Future Prospects of Agricultural Mechanization in Mexico

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Abstract

Agricultural mechanization in Mexico still ranges from hand tools, tools for draught animals and motorized equipment. Agricultural production by using adequate technology has concentrated on cereals for domestic consumption, where the use of tillage tools, planters, fertilising and spraying equipment and self-propelled machines for harvesting, have reached a high level of development. At present the mechanization index is 0.674 kW/ha of energy applied on farming activities. However, there are still areas where state of the art technology needs to be applied to improve efficiency and performance. The purpose of this study is to outline a general status of agricultural mechanization in Mexico and to draw basic guidelines for improving research & development on emerging areas. Emphasis is made on technological requirements for the main crops and small scale farming. In addition an overall view of current educational and research related to agricultural mechanization and its main fields and insertion of the participation of farm machinery manufacturing industry.

Keywords: Agriculture, farm mechanization, mechanical power, agricultural development smallholdings.

General Background

Mexico is located between 14 and 33 degrees North Latitude and covers an area of about 2 million sq. km and has a population of about 120.0 million people; the economically active population is about 55.6 million and around 12% are engaged in agriculture (INEGI, 2015). Although fundamental to rural employment, agriculture, forestry, fishing and agribusiness activities account altogether for less than four per cent of Mexico Gross Domestic Product (GDP) (**Fig. 1**). Mexico is a traditional agricultural country where 32.4 million hectares are devoted to raise crops; 6.6 million (20.3%) are irrigated and 25.8 million (79.7%) are rainfed (INEGI, 2017) (**Fig. 2**). According to plot size most of farming units are small, thus as agricultural mechanization is concerned, it

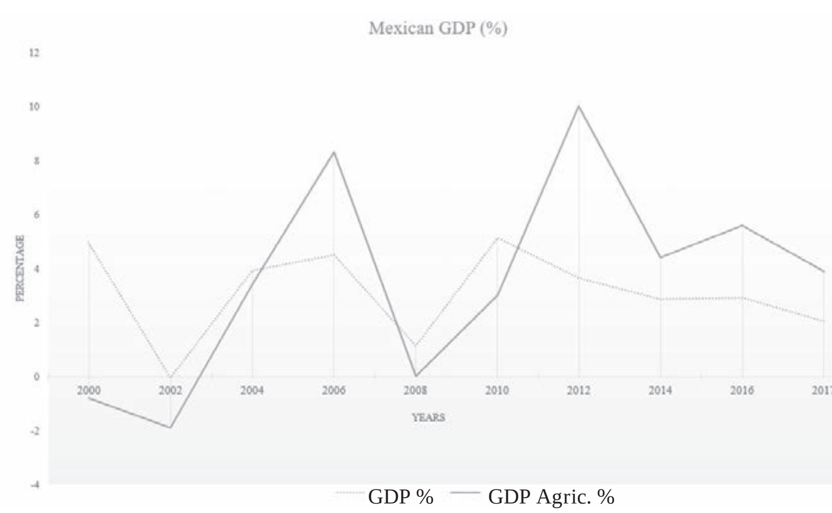

Fig. 1 Contribution of agriculture production to the Gross Domestic Product (GDP %)

can be said that it still ranges from hand tools, tools for draught animals and mechanised equipment. From the total planted area, around 18.6 million hectares are potentially subject to mechanization by using motorized equipment, so the total number of tractors available is 238 830, thus the tractorization index is 77.9/1 (ha/tractor).

Mexican agricultural market has diverse requirements regarding to agricultural technology usage. With a variety of climates and a large amount of arable land, the country is home to extensive, diversified and large-scale commercial agriculture. Since large numbers of farmland plots are quite small, their productivity is often low, sometimes rely on animal traction and frequently depend on manual labour (FAO, 2018). As a result, basic mechanization is still underway. While for commercial agriculture, technologies that enable farmers to raise crop quality, supplying improved inputs, increase productivity, and ensure food safety are essential, it is also more profitable. This is especially true for fresh produce, high-value specialty crops, red meat, poultry, and dairy.

Agricultural production has increased and concentrates on cereals for domestic consumption. This is achieved through using big machines, tillage implements and farm equipment, harvesting operations fully mechanised and efficient use of good quality seeds, fertilisers, pesticides and irrigation. Nowadays, in terms of energy applied on farming activities, the mechanization index is 0.674 kW/ha.

Mexico´s northern region has the largest number of tractors, although during the last two decades the rate of growth has decelerated, while the central region has the highest development, and the southern, it has always been the region with the lowest growth. It is also important to add that despite of a large number of tractors have ended its useful life, they are operative yet (**Fig. 3**). Although number of farm tractor assembled is recorded, it is not compulsory to register them once they leave the dealer premises, so there is a mismatch when presenting a precise figure about actual number of tractors for field work from the obsolete ones, even from those requiring major repairs.

There has been an accelerated increase of vegetable production particularly from protected and "controlled environment" agriculture (40% growth over the past 3 years). Its size is 40,800 ha and it is growing at a rate of around 13% per year, boosting the demand of specialized equipment for this industry. It demands a special type of mechanization and advanced technologies in order to obtain high quality produce (INEGI, 2012). Common greenhouse types include macro- and micro-tunnels, chapel- or multi-span designs, vineyards and high-technology polycarbonate-walled systems. Meanwhile, there are non-traditional crops and wild plants, which require special tools and machines for crop protection, harvesting and processing on-site (Ortiz-Laurel and Rössel, 2002).

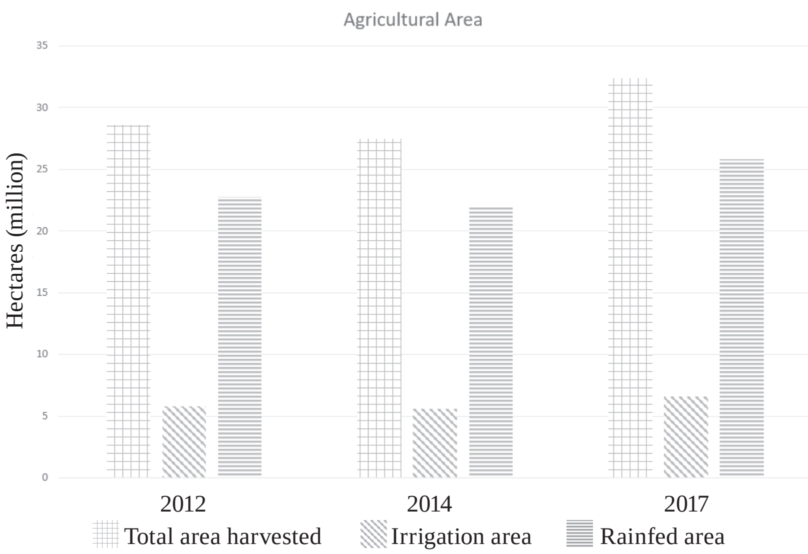

Fig. 2 Development and distribution of arable farmland area for crop production

Fig. 3 Assessment the obsolescence of agricultural tractors among several years span

Farmland Size and Crop Production

In Mexico, there is a wide range of land holdings, therefore in order to facilitate any analysis, data collection organizations have been classified as "production units", and group these by sorting on their plot size (**Table 1**) (INEGI, 2014).

Crop Production and Share of Agriculture to Gross Domestic Product

In Mexico there is a wide contrast of farming activities. Much of the land (11,783,683 ha) is cultivated by small farmers (3,083,844 production units with < 5 ha), with the largest concentration in the southern region. In contrast, the northern region distinguishes for having areas of large and high mechanized farms. Larger-scale Mexican farmers are aware that they can benefit from increased speed, accuracy and efficiency through the use of improved agricultural equipment. To meet the national needs for increased crop production and farm productivity, small farms have to adopt improved technology including mechanization of farming operations, and for the larger farms to keep abreast of current developments in agricultural engineering technology such as precision agriculture techniques.

Farmers are reluctant to adopt any new farming technologies if costs are increased or profits reduced. Although herbicides have assisted the economic viability of farmers and helped reduce the risk of soil erosion, there are many situations where weed control with sprays is more expensive than cultivation, and their use is seen as a potential ecological hazard. By spotting and spraying only weeds can reduce overall use of pesticides and increase adoption of sustainable tillage practices by farmers.

The objective for a high agricultural production is to project a highly efficient agriculture practice, market oriented and environmentally sustainable (**Table 2**) (INEGI, 2017). The food and agriculture sector accounts for 10.9% of Mexico's Gross Domestic Product (GDP), divided among the primary sector (52.3%) and the food and beverage industry (47.7%) (**Fig. 4**). This economic sector is highly globalized, with multinational investments in equipment and production processes, particularly in the food industry, and the larger Mexican companies can purchase new technologies on the international market, resulting in stronger ties with foreign suppliers.

Number and Level of Technologies Employed by Farmers

The average size of farms in Mexico is 8.37 ha. In these small farms, agricultural activities must be fully organized in order to be efficient and the work the machines are used for organized appropriately. There are suitable ways and conditions for managing crop production and its inputs, such as concentrating the production as a mean of organizing the production; climatic conditions; a suitable market; etc. The interaction between these elements is important in order to get a technique with quality and quantity for the nature biological process and the human being (**Table 3**) (INEGI, 2017).

Despite the available technology, unskilled farmers feel great concern for when achieving an adequate seedbed preparation, equally when managing a good germination and for reducing the rapid growth of weeds. Thus, proper training for farmers on managing novel apparatus and correct application of emerging processes is a very important issue. Equally, precise depth control in seedbed preparation is very important, as it conserves moisture, incorporates chemicals and creates a high quality soil structure for seeding. Correct decision making will facilitate to the control of seedbed preparation by changing the technology and by combining some processes as well as to reduce costs, such as practising rational techniques as minimum tillage or organic farming. In practice, the same applies for both dosing and correct distribution of fertilisers on the land in relation to how much the land itself is able to produce in present conditions, without attempting to modify it through untruthful corrective measures or improvements. There are not formal agricultural machinery hiring services, although owners can provide the service and charge the cost, once they finished their own cultural operations.

Similarly, the success of raising livestock and production of raw material for agroindustry had no effect on the development of locally manufactured agricultural machines. These farming enterprises generate 30% of Agriculture Domestic Product and receive only 9% of domestic production of agricultural machines. But the efficiency in this area is closely related to the level of mecha-

Table 1 Classification of basic arable farmland regarding to plot size and her corresponding designation

	Arable land (ha) 27,496,118 (100%)	Production units 3,286,465 (100%)
Irrigation farmland	5,576,992 (20.3%)	577,913 (17.6%)
Up to 0.2 ha (production for selfconsumption)	1,202 (0.02%)	13,820 (2.4%)
From 0.2 to 5 ha (transition)	800,078 (14.3%)	383,023 (66.3%)
More than 5 ha (commercial)	4,775,712 (85.6%)	181,070 (31.3%)
Rainfed farming	21,919,126 (79.7%)	2,861,092 (87.6%)
Up to 0.2 ha (production for selfconsumption)	4,380,152 (20.0%)	2,017,937 (70.5%)
From 0.2 to 5 ha (transition)	6,602,251 (30.1%)	669,064 (23.4%)
More than 5 ha (commercial)	10,936,723 (49.9%)	174,091 (6.1%)

nization rather than the production of crops.

As farming area is concerned, more than 50% of Mexico's cultivated land is arid and semiarid zones, where there is a low competition for crop production and a clear disadvantage with world production using a high level of mechanization. Cropping of special products in these regions require of adequate mechanization according to yield and quality demands.

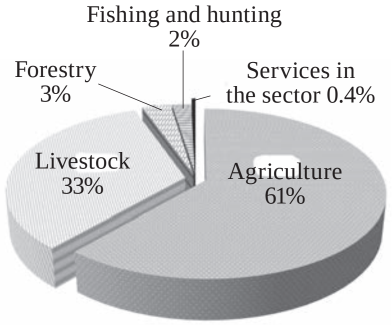

Fig. 4 Distribution of agriculture productive sections and their average contribution to the GDP

Educational and Research on Agricultural Mechanization

The Mexican Association of Agricultural Engineers (AMIA) was set up in year 1991. That year endorsed her first national congress, where water engineering, crop processing and farm mechanization were the main topics. This event had been programmed to take place every year, however due to budgetary restrictions for organizations and institutions; from 2017 it started to occur every other year. Currently, majority of technical programming and specialty conferences sponsored by AMIA are directed towards on-farm products. At present, congress

Table 3 Use of techniques and technology for improving crop yield productivity

Type of technology	2012	2014	2017
Total agriculture area of production units, ha	28,597,991	27,496,118	32,406,237
Fertilizers, %	65.5	68.8	68.2
Herbicides, %	61.7	62.7	66.9
Insecticides, %	45.3	48.2	54.8
Seed Planters, %	NA*	33.4	22.6
Conservation agriculture, %	12.9	23.2	16.3
Harvesters, %	NA*	18.6	12.4

*Not available

Table 2 Comparison of crop production from major crops cultivated in Mexico

	Planted area (ha)			Total production (t)		
Crop	2012	2014	2017	2012	2014	2017
Grains						
Rice	32,710	41,079	41,935	178,787	232,159	265,567
Kidney bean	1,700,514	1,773,997	1,676,230	1,080,857	1,273,957	1,183,868
Maize	7,372,218	7,426,412	7,540,942	22,069,254	23,273,256	27,762,481
Sorgum	1,937,009	2,078,497	1,456,330	6,969,502	8,394,056	4,853,110
Wheat	589,015	713,033	661,744	3,274,337	3,669,814	3,503,521
Soybean	144,000	211,531	266,499	247,500	387,366	432,927
Fruits						
Avocado	151,023	175,940	218,493	1,316,104	1,520,695	2,029,886
Strawberries	9,068	9,966	13,851	360,426	458,972	658,436
Persian lime	166,516	171,609	193,787	2,055,209	2,187,257	2,513,391
Mango	186,820	186,937	201,464	1,465,190	1,451,890	1,958,491
Apple	61,552	60,410	57,530	375,045	716,865	714,149
Cantaloupe	20,831	18,457	19,627	574,213	526,990	605,134
Watermelon	42,042	35,406	42,043	946,458	946,458	1,331,508
Orange	333,074	334,849	335,426	3,666,790	4,533,428	4,629,758
Banana	75,315	74,585	80,283	2,203,861	2,150,520	2,229,519
Grapes	28,941	29,466	33,713	375,298	335,739	415,889
Industrial crops						
Cacao	61,613	61,562	59,838	27,619	26,969	27,287
Coffee	737,376	748,285	722,444	1,336,882	1,166,025	835,380
Sugar Cane	777,243	828,745	836,109	50,946,483	56,682,689	56,954,993
Vegetables						
Italian zucchini	27,037	26,598	29,341	436,947	441,078	550,410
Onion	44,399	48,167	52,103	1,238,602	1,368,184	1,620,318
Green Chilli	138,188	148,969	161,285	2,379,736	2,732,635	3,296,875
Tomatoes	55,888	52,375	50,373	2,838,370	2,875,164	3,469,707

topics have grown to environmental engineering, renewable energy sources, biosystems engineering, construction of agricultural buildings, processing technology and storage of agricultural products and automation in agriculture.

Research on agricultural mechanization in Mexico started around 1970 inside a handful of motivated universities and research centers. Until AMIA was established, scientific papers on agricultural mechanization were dispersed though other scientific bodies. Thus, a sample of a bunch of papers from 9 years of congress proceedings, it was realized that farm machine design and field attachments represented almost 65% of total. They were followed by agricultural systems, management of agricultural machinery and conservation agriculture (Lara Lopez, 2000). However, large number of research was focused to developments with local or regional interest.

The new scientific and technological policies have given priority to projects originated from users with well-defined technological demands in order to outline research priorities and search for participation of private sector by giving specific strategies in promoting the collaboration with research and development centers (ITA, 2017). However, this situation gave more attention and assistance to high business agriculture setting apart the subsistence farming sector.

Financial Support from the Government

For almost three decades there has been a Government program for subsidizing crop production. The main purpose for this program is to motivate the rural and farming communities to invest into mechanization and associate mechanical equipment in order to increase food productivity. Greater access to government funding could reactivate a productive and sustainable agriculture and the food sector. It is also hoped that the program stimulates domestic manufacturing and tractor sales, as farmers can currently register for a government incentive program that covers 25% to 50% of the equipment purchase price. However, the main constraint for tractor manufacturers and dealers able to be registered as supplier, their machines should obtain a test certificate from OCIMA (Ayala Garay *et al*., 2013). The program is renovated every year, fresh budget is allocated and new rules are provided, so farmers have to accomplish the requirements in order to access to the benefit (**Table 4**).

Since smallholders lack of access to credit, it has been responsible for blocking investment in improved cultivation equipment and production techniques and other farm infrastructures. Small farmers are caught in a vicious cycle of poor productivity, low returns, insufficient income, and underinvestment. As a result, they cannot access to better technologies, such as fertilizers, irrigation systems or improved seeds, and are often poorly mechanized using inefficient and obsolete agricultural machinery and processing technologies. State mandated credit schemes and models of contract farming could be envisaged in this context (UNCTAD, 2013).

Table 4 Mexico's government incentives to promote agricultural machinery and farm equipment

Machinery and equipment	Amount of incentive	Constraints
Portable motorized equipment	Up to 50% of purchase price	Less than USD $2,000
Equipment and tools for precision agriculture	Up to 50% of purchase price	Less than USD $15,000
Tractors	Up to 50% of purchase price	Up to 125 hpFully certified by OCIMA
		Less than USD $10,000

Table 5 Development of the mechanical equipment industry for agriculture and livestock

	Manufacture, assembly and repair of tractors, farm machinery and tools for agriculture*	
Year	Number of establishments	Technical labor
1980	520	11 831
1985	614	7 754
1988	133	6 089
1993	123	5 822
1998	304	7 940
2003	303	10 078
2008	230	11 158
2014	232	11 890

*constructed by using several sources

Farm Equipment Manufacturing Capacity

Manufacturing industry has developed an important role in the generation and transference of mechanical oriented technologies. From a general point of view and parallel to a high degree of concentration of certain farming sub-sectors, usually there is a strong and sometimes weak growth and participatory level of the industry through providing updated mechanical equipment for agriculture use, as well as contributing to the process of technological change (**Table 5**) (INEGI, 2018). For instance, some specialized farm production industries in Mexico set up contracts with farmers while specifying the type of technologies for crop production, potential yields and crops purchase price. On the other hand, collaborative projects with business will enable students to become actively involved in the generation of solutions to challenging engineering problems and offer them the opportunity to learn how large projects are negotiated and managed.

However, there is a non-consistent production of key agricultural equipment. There are quite a few crops which are keen for expanding agricultural mechanization, such as several fruits, non-traditional crops (cactus pear, agave, etc.) and crops grown in greenhouses. Low crop yields and high farming production costs are endorsed to deficient technical skills on operation, maintenance and management of agricultural machinery. They all contribute for having a low productivity.

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Current Situation of Agricultural Mechanization in Mexico

by

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Abstract

The incorporation of modern machinery and technology, together with efficient management could generate viable alternatives to increase agricultural production in Mexico. In spite of its relevance, studies on the incorporation of machinery to rural activities are particularly scarce and many of its dimensions are still in the shadows. Therefore, the objective of this paper is to review the current situation of agricultural mechanization in Mexico.

Keywords: Tractors, machinery, implements, agricultural technologies.

Introduction

Agricultural mechanization is the application of technologies and greater power in agriculture. It includes the use of different types of tractors, as well as the implements of animal and / or human traction and simultaneously, the incorporation of social networks and their management for viable alternatives to increase production in agriculture.

An appropriate investment in mechanization can easily generate higher levels of agricultural productivity, which could guarantee that Mexican farmers have higher incomes thanks to the commercialization of higher production and, in the case of subsistence producers, who become net providers of food to escape from poverty. The use of appropriate mechanization processes in agricultural production has been decisive factors for the modernization and obtaining of greater achievements in some of the producers.

Therefore, the optimal determination of inputs use or factors of production is fundamental to directly affect the production levels of the agricultural sector (Terrones & Sánchez, 2010). Agricultural machinery allows improving the efficiency of agricultural work, to produce more and better products, through the use of tools and machines (manual, animal traction or motorized) with the least time, cost and physical effort possible (Ulloa, 1989, Paneque & Soto 2007, Ayala *et al*., 2012).

The use of agricultural machinery mainly tractors have become a central factor to develop high rates of crop rotation and to modify the infrastructure of the field as well as an engine to drive modern systems of irrigation, markets and warehouses, paths and roads, among other things (Palacio & Ocampo 2012).

However, Miranda *et al*. (2004), Soto *et al*., (2006) and Fernández *et al*. (2008) refer that to achieve the growth, optimization and organization of agricultural machinery in a country, it is necessary to carry out a detailed study of the situation and behavior of the technologies that are used and the possible alternatives that allow obtaining the desired objectives.

The incorporation of modern machinery and technology, together with efficient management, could generate viable alternatives to increase agricultural production in Mexico. In spite of its relevance, studies on the incorporation of machinery to rural activities are particularly scarce and many of its dimensions are still in the shadows. Therefore, the objective of this paper is to review the current situation of agricultural mechanization in Mexico.

Development

Mexico is considered a country of great opportunities in the agricultural sector, due to its great climatic and ecological diversity and the area dedicated to this sector.

According to National Institute of Statistic and Geography (INEGI, 2017), the total area of the agricultural production units is 110 million hectares (ha) and of that 32.4 million ha (29,4%) correspond to agricultural area. The remaining 706% are narrow, enclosed and other types of surfaces. Of the 32.4 million hectares of agricultural land, 21% has mechanized or automated irrigation and 79% depends on rainwater for its development (seasonal). It also has 17,388 units of protected agriculture, 54.1% of greenhouse, 9.4% are with shadow mesh structure and 2.5% are nurseries.

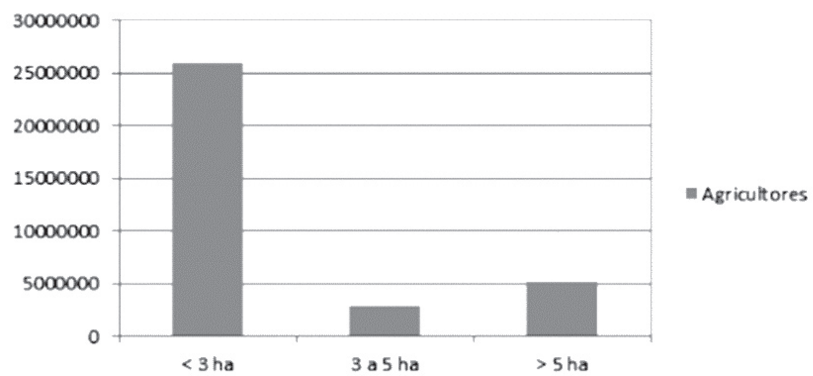

Fig. 1 Size Farms of farmers in Mexico (Source: IVE, 2006)

Therefore, Mexican agriculture is divided into a highly capitalized commercial sector, a sector of small farmers with links to the market, especially in the domestic market and subsistence sector that produces for the consumption of households and whose income depends to a considerable degree of external activities (Negrete, 2014). The mechanization levels of the country are in correspondence of these three sectors.

The above can be seen in **Fig. 1**. It is shown that, according to the Valencia Institute of Exports (IVE, 2006), 34% of the population of Mexico is engaged in agricultural tasks with very small land areas, generally belonging to smallholders and subsistence sector. Corresponding to this, the fact that 85% of the farmers do not have more than 5 ha of arable land and that among them, 90% does not reach to 3 ha, clearly indicates there is a great need for light machinery.

In zones of farmers with agriculture of small productive scale, animal traction and/or manual labor is still predominate. This is explained by the orographic and socioeconomic conditions that prevail in these regions. In seasonal agricultural regions with small areas, animal traction is generally used and research has been carried out with the aim of improving the conditions of the implements used in this type of agriculture (Fernández *et al.*, 2002; Arredondo *et al.* 2003, Diego, 2014). However, despite this, the truth is that there is a great demand for tractors among producers.

Most of the farms located in the regions of farmer agriculture, have a very small size, thus it will be useful (and profitable) for the acquisition of a tractor per farmer. Also the resources that the producers have are not enough to acquire the tractors. In this scenario, agricultural machinery becomes an effective instrument to perform the tasks requiring mechanization to sustain their production.

The dynamics of tractor use causes an underutilization of its power in most of the Mexican plots. This happens if it is considered that they have an average area "... of labor per unit of production ... low; that 91.1% of the producers in Mexico have average areas equal to or less than 7.65 ha, which seems to be a limitation for the development of agricultural production." (Cruz & Martinez, 2001).

According to Ramírez *et al.*, (2007), the modernization of the smallholding with capital-intensive technological packages is unfeasible in the agrarian structure of the country, mainly because the agricultural machinery is designed to cultivate large tracts of land and would remain idle for most of the agricultural cycle.

In the country, only 22.2% of 3,801,315 production units work with a tractor, while in the rest, draft animals and human force are used. The high levels of mechanization are generally associated with developed economies and with the production of commercial crops and exports, but simultaneously, resources from activities other than agriculture are those that can stimulate the adoption of technology (Clarke & Bishop, 2002). However, according to Terrones & Sánchez (2010), the demand for mechanized work or the use of the tractor is very sensitive to the variation in its price.

In this way, it is clear that at

present, the marginal value of the incorporation of machinery in less favored sectors but still remains superior to the contribution of most of the country, which indicates the relative lag of these sectors in this issue. Even the lacks in machinery allocation within these regions remain significant. In particular, it is observed that the regions with the least amount of hectares per farm have a smaller stock of machinery per worker, which highlights the fact that the size of the farm affects the ability of farmers to afford modern agricultural technologies.

Because of that it is necessary to promote research, design and development of tractors and agricultural implements for small producers and take into account, among other factors such as crop which it is intended for, type of soil, orography, low cost, needs and cultural aspects of the peasant group that will use them.

Situation of the Use and Possession of Agricultural Tractors by Producers

According to Perea (2011), the modernization of the Mexican countryside is going slowly and in reverse. Of the 23,883 tractors that are in Mexico, 54% exceeded its useful life, given that maintenance and operation is expensive due to rising fuel prices. In addition, to acquire a unit, a farmer needs an average of between 375,000 and 800,000 pesos. This technological backwardness that has been generated today in the Mexican countryside, there are 78,483 fewer tractors than 20 years ago. Of the total of agricultural machinery that the producers of the surveyed sample have, 85.42% of the tractors were acquired between 2001 and 2010, concentrating the highest frequency in 2007, (**Fig. 2**); being less than 5 years old. Similarly, Reina (2004) identified 324,890 tractors for Mexico, with an average power of 87 hp, for an area of 27.3 million ha.

However, in the VIII Agricultural and Livestock Census of 2007 (INEGI, 2009), it was reported that 95.5% of the total of tractors existing up to that time were functioning and were used in an agricultural area of 29.9 million ha. But the National Agricultural Survey (SAGARPA, 2017) revealed that 44.3% of the tractors used in agriculture have more than 15 years of utilization, **Fig. 3**.

According to the consultation, only 1.5 million production units have a traction vehicle for planting and harvesting food, that is, half of the units that exist in Mexico. In addition to the above, mechanization in Mexico lacks an adequate technological level which results in poor management or deterioration of resources (water, soil, energy) and increases production costs for farmers.

According to Negrete (2006), from an agricultural frontier with 24 million ha, with a surface suitable for mechanization, 18.6 million ha would require at about 360.000 tractors with powers of 50 to 60 hp. Also, Ayala *et al*. (2011) and INEGI (2009) stated that Mexican producers use tractors with a power between 60 and 85 hp in agricultural and forestry activities.

According to the statistics of SAGARPA (2017), in the current administration, 564 thousand ha of irrigation were mechanized surpassing the six-year goal of introducing technology in 480 thousand ha and 6.7% more than the realized in the same period of the last administration (528,359 ha). A total of 25

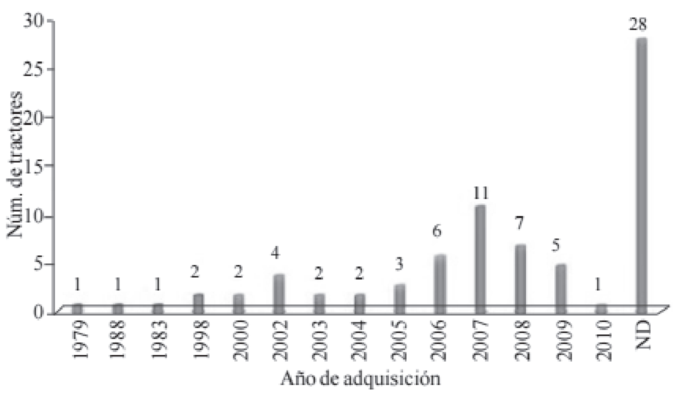

Fig. 2 Age of the tractors by year of acquisition. Larqué *et al*., 2012

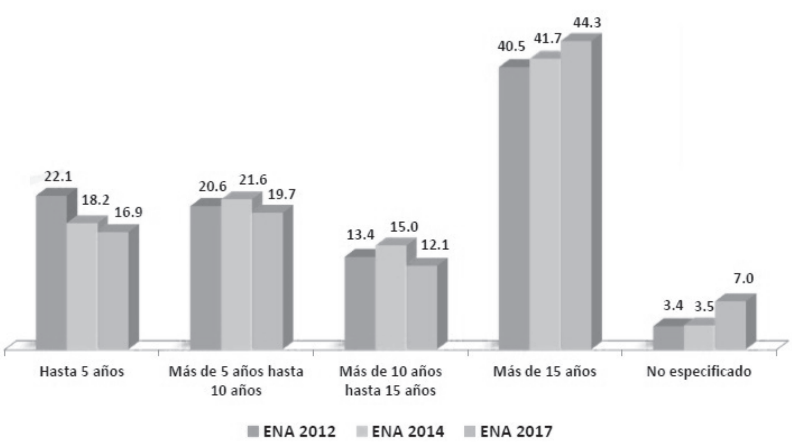

Fig. 3 Quantity of tractors existing in Mexico in percent and years of exploitation (Source: SAGARPA, 2017)

thousand hectares of protected agriculture were created and 168,440 equipment for the mechanization of the field were delivered, of which 21,937 were tractors and 146,503 were agricultural implements. Regarding the mechanization of the field between 2013 and 2017, nearly 150 thousand equipment were delivered, such as tractors (20,163) and power tillers, sprinklers and implements (148,257) to improve the productivity of the field. In 2017 alone, 6,278 tractors and 12,630 equipment were distributed, 2.5% and 45.1% more than the previous year, respectively.

However, it must be considered that the development of mechanization and the modernization of agriculture in Mexico will depend, to a large extent, on private initiative, but also on public policies aimed at improving the technical and financial capacities of producers. Because in any scenario, the role of the State is fundamental, especially with regard to research and development (R & D) and agricultural extension programs, in order to bring new processes and technologies to producers, as well as in the development and promotion of investment in agricultural infrastructure.

Production and Export of Agricultural Machinery

Since 1997, Mexican market of tractors is very stable and reports an average sale of 10,000 to 11,000 tractors per year (Palacios *et al.*, 2003). However, according to Flores *et al*. (2008), the total sale of 11 thousand tractors clearly represents a deficit on the total production, considering the potential market ranges between 15 thousand and 18 thousand units.

Palacios *et al.*, (2003) stated that since the early 1960s, Mexico began to produce tractor brands such as Ford (later New Holland), Massey Ferguson (MF), John Deere (JD) and International Harvester.

According to Negrete (2012), currently four companies offer tractors in the country with plants distributed as follows:

- John Deere composed of three plants, one in Garza García, Nuevo León, dedicated to the manufacture of agricultural implements. Another in Santa Catarina, Nuevo León, which is focused on the manufacture of buckets and components for industrial equipment and only the Plant Saltillo, Coahuila, dedicated to the manufacture of tractors.
- CNH of México is the company in charge of manufacturing and commercializing the brands of tractors and agricultural machinery Case and New Holland, CNH of México S.A de C.V.
- AGCO of México, S. de R. L. of C. V. It starts operations immediately with Massey Ferguson brand and later the operations for Challenger are incorporated. In Mexico, during 1996, AGCO Corp. acquired the facilities located in Queretaro to resume the production of agricultural tractors.
- McCORMICK Tractors of Mexico S. de R.L. of C.V. is a tractor company, which began its activities on May 14, 2003. It is located in Silao, Gto. In this plant, the McCormick tractors are assembled with 8 different models ranging from 40 hp (29.8 kW) to 230 hp (171.5 kW).

Marketing is concentrated with a network of distributors nationwide. Thus, John Deere includes 159 points of sale, NH groups 140 points of sale and Case 121, while MF 86 and McCormick 35. However, John Deere is considered the main producer and distributor of agricultural machinery, with an important presence (38%) in the Mexican market. New Holland and Case are its closest competitors, together they account for 29% of the market, while MF has 27%.

According to Flores, *et al.* (2008), in the period from 1980 to 2008, the average annual growth rate has been more accelerated in exports (13.33%) than in imports (4.32%). That is due to the fact that the business model of the production companies involves producing tractor lines in Mexico both for the local and export markets and exchanging final products with other plants in other countries.

Mexico is considered one of the main exporters of tractors in Latin America. The main destinations of Mexican tractors are USA, South Africa, Turkey, Thailand, Colombia, Ecuador and Venezuela. On the other hand, the commercial opening has also generated, for the Mexican industry, a growing import of products, due to the situation of the market coming from the United States, Turkey, Brazil, China and Japan mainly that represents a challenge for the national market, this being of great importance to maintain and elevate the quality of the productions.

Conclusions

- It is necessary to promote research, design and development of tractors and agricultural implements for small producers taking into account, among other factors cultivation to which it is intended, type of soil, orography, low cost, needs and cultural aspects of the peasant group that will use these equipment.
- The development of mechanization and the modernization of agriculture in Mexico will depend, to a large extent, on the private initiative, but also on public policies aimed at improving the technical, financial capacities of producers and research in this sector.
- Despite being one of the first producers and exporters of agricultural machinery in Latin America, Mexico has lagged behind in mechanization and agricultural production.
- There is no policy aimed at the development of agricultural

mechanization.

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Mechanization of Irrigation in Latin America

by

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Abstract

Mechanized irrigation systems include various irrigation techniques such as the central pivot, Sprinkler irrigation canyons, reel machines, micro-sprinklers, mini-sprinklers, bubbler irrigation of trees, drip irrigation and others. More than 66 per cent of Latin-American irrigation are located in Argentina, Brazil, Mexico and Peru, mainly with the surface irrigation technique. Brazil and Argentina are the main markets for mechanized irrigation systems. Therefore, the objective of this document is to review the current situation of mechanized irrigation in Latin America

Introduction

The size of the global micro and mechanized irrigation systems market was estimated at USD 8.15 billion in 2015 and is expected to gain momentum over the forecast period. The increasing global food demand is expected to drive the market growth. The rising need for water conservation, primarily in arid regions, is further accelerating the demand for these systems.

Micro and mechanized agricultural systems help in reducing water wastage, due to which the market is witnessing phenomenal demand among emerging nations. Small-scale farmers are emphasizing on implementing these systems in order to increase crop yields by utilizing minimum water. (Market Research Report, 2017)

Market Data Forecast: 2018 report that Latin America Mechanized Irrigation Systems - Market was worth USD 1.82 billion in 2018 and estimated to be growing at a CAGR of 11.1%, to reach USD 3.08 billion by 2023. Agriculture is one of the earlier occupations of man. Irrigation has always been a part of agriculture. Due to the depletion of water and extent of droughts, conventional irrigation methods cannot be used anymore. New irrigation methods using equipment designed for the sole purpose of irrigation such as Mechanized Irrigation Systems came into the market.

Irrigation systems are the set of equipment and management techniques that ensure the water collection, storage, transportation and distribution to the irrigators following a given method. (Santos Pereira *et al.* 2010).

Mechanized Irrigation Systems comprise various irrigation techniques such as traveler spray booms, the center pivot, micro sprinklers, mini-sprinklers, bubbler irrigation of trees, drip irrigation, hose irrigation and many more.

These methods are used to increase the productivity of the land in rainfall-deprived areas, by establishing sufficient water supply to meet the requirements of the growing population. The former aspects that were used to increase agricultural productivity, such as arable land, fresh water and good soil are diminishing due to the changing climatic conditions, increasing population and artificial fertilizer usage. Rising water scarcity issues have propelled the need of shifting towards advanced and automated irrigation systems. Irrigation mechanization focuses on to enhance water-efficient practices by using better technological systems, thus improving the economic viability and environmental sustainability of irrigated agriculture. (Absolute Market Inside, 2018)

Due to the depletion of water and extent of droughts, conventional irrigation methods are used less and less. New irrigation methods using equipment designed for the sole purpose of irrigation such as Mechanized Irrigation System is used today. Because of that, the objective of this paper is to review the current situation of mechanized irrigation in Latin America.

Development

Irrigation is a relevant factor in the increase of agricultural productivity and crop diversification. At present, the productive area with irrigation in Latin America and the Caribbean (LAC) is around 3% (Díaz-Bonilla *et al.*, 2013).

According to the same author, the growth of the irrigated area of LAC (54%) is greater than that registered worldwide (45%), and in countries like Brazil, that growth is much wider (85%)

The potential growth of agricultural production with irrigation is very high in many parts of the continent, but it is subject to important investments, to actions of resource administration resource that facilitate its use and to the creation of mechanisms that allow the optimization of the use of environmental services derived from water. Likewise, the expansion of irrigation must be linked to greater efficiency in the use of water and agricultural practices that favor water productivity. It is estimated that, on average, the total efficiency in the use of water for irrigation in developing countries is only 38%. It is because there are many losses by filtration and evaporation, mainly during storage and water conduction to the plots, and others, by the irrigation system used for its application to the plant. In LAC that efficiency is especially low and it is considered that it does not exceed 25% (Cisneros and Saucedo, 2012).

Although irrigated land does not represent a very large proportion of arable land (13%), it accounts for almost 67% of total water extraction. In several countries such as Argentina, Brazil, Chile, Mexico and Peru, irrigation is a significant component of agricultural production, particularly for export products. (FAO, 2015)

The distribution of the irrigated areas is far from being homogeneous; more than 66 per cent of Latin-American irrigation is located in four countries: Argentina, Brazil, Mexico and Peru. Nevertheless, when pondering the current importance of areas equipped for irrigation with respect to each country's cultivated surfaces, it is possible to see that the countries with relatively high levels of irrigation infrastructure, such as Brazil, Mexico or Argentina, have that infrastructure on a reduced portion of their agricultural surface. (FAO, 2016)

In Argentina the irrigation potential surface was estimated at 16 million ha, considering the soil surface without limitations and hydric resource available (FAO, 2016a).

Water collection for irrigation is mainly carried out from reservoirs and river diversions. In exceptional cases, it is pumped directly from the rivers.

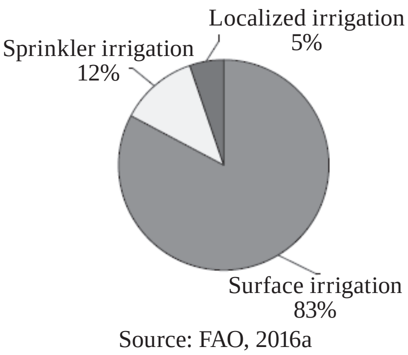
The total harvested area of crops with infrastructure for irrigation amounted to 2,300,000 ha in 2008. The most important crops with integral irrigation in that area are fruit trees, vine and olive tree with 559,000 ha (24%), vegetables with 312,000 ha (14%), industrial (sugar cane, tobacco, cotton, etc.) with 273,000 ha (12%) and other crops with 156,000 ha (8%). With complementary irrigation, the most important crops are cereals and oilseeds with 600,000 ha (26% of the total), forage crops with 380,000 ha (17%) and other crops with 20,000 ha (1%).

The efficiency of water use in traditional irrigation areas is estimated at around 35-40% on average for the country, while in the best areas an efficiency of less than 60% is estimated.

In 2011, the irrigation infrastructure surface was estimated in a high of 2,357,000 ha. The equipped area effectively irrigated was estimated at 2,162,100 ha, representing the 92%. The hectares supplied by gravity irrigation were estimated at 1,949,000 (83%), sprinkler irrigation supplied 281,000 (12%) and irrigation with some variant of localized irrigation another 127,000 ha (5%) as shown in **Fig. 1**.

Brazil reports that, in 2010, the irrigation potential was estimated at 29.3 million ha, and the area equipped for irrigation was estimated at 5.40 million ha (ANA, 2012), which represents 8% of the cultivated area.

Irrigation techniques differ within Brazil. In the South, Southeast and Centre-west, rice as well as some vegetable and orchard crops are irrigated by simple flooding or using



Source: FAO, 2016a

Fig. 1 Area % under irrigation´s techniques in Argentina furrow irrigation. Water is diverted from numerous small streams and conveyed to the farm-gates through earth canals. This technology, together with proper land preparation and some mechanization, yields a good return. These technologies, which are increasingly used in private and public irrigation schemes, range from mobile sprinkler lines to the modern center-pivot and other self-propelled irrigation equipment. In the Northeast, there is a strong increase in the use of localized irrigation, due to the water scarcity in the area. Over the last decades, the area with surface irrigation has decreased and that with sprinkler irrigation for grain production and localized irrigation for fruit and vegetables has increased. Total water use efficiency is estimated, on average, at 40-65% for surface, 60-85% for sprinkler and 78-97% for localized irrigation methods. (FAO, 2016b).

Surface irrigation represents 49% of the total area equipped for irrigation, while sprinkler and localized irrigation techniques account for 45% and 6%, respectively (**Fig. 2**).

In Mexico, according to FAO (2016 c) in 2013, the potential area of irrigation according to the aptitude of the land was 13.5 million ha, which are reduced to 9.8 million ha if the availability of water is taken into account. Most of the underutilized land is located in the humid tropics.

In 2009, the area with infrastructure for irrigation was 6.46 million ha, of which 3.46 million correspond to 85 irrigation districts (DR). The remaining 3 million ha had more than 39,000 irrigation units (UR).

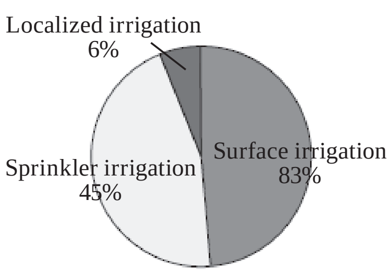
Mexico ranks seventh in the world surface with infrastructure for irrigation after India, China, the United States of America, Pakistan, the Islamic Republic of Iran and Indonesia.

In DR, the surface source can be a dam (70% of the total surface), bypass (17%) or direct pumping to the stream (2%), while the underground source is necessarily harnessed by pumping of wells (11%). In 2009, the DR used 28.9 km^3 of surface water and 3.3 km^3 of groundwater (CONAGUA, 2011a). The URs are irrigated mainly with groundwater, small storage and dams' diversion (CONAGUA, 2011b)

Improvements in irrigation efficiency have also had an impact on irrigation techniques. In this context, the government promoted a fertile-irrigation program in the 1990s, which aimed to increase the productivity of irrigated areas and reduce water consumption. Favored by this program, in the period 1993-1997, the area with sprinkler irrigation and localized increased by 135% (310,800 ha in 1997) and 119% (143,050 ha in 1997), respectively, while irrigation by surface it covered 5 802,000 ha or 93% of the total area. Much of the area under localized irrigation has been transformed for the irrigation of fruit trees. At present, approximately 80% of the surface area with irrigation infrastructure is irrigated with surface irrigation and the rest of the surface with pressurized irrigation (sprinkler or localized) (Consejos de Cuenca, 2006) (**Fig. 3**).

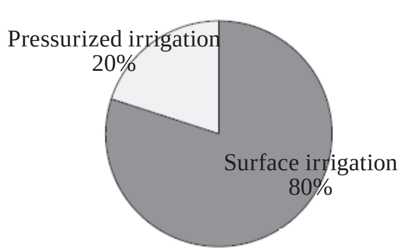
In 2012, Peru had a total area equipped for irrigation of 2,579,900 ha, of which 2,362,144 ha (92%) is irrigation by surface, 86,873 ha (3%) is sprinkler irrigation and 130,883 ha (5%) is localized irrigation (**Fig. 4**). The area effectively irrigated is 1,808,302 ha (MINAGRI / INEI, 2013).

It was reported by FAO (2016 d) that in this same year, the irrigated agricultural area was mainly in Costa region, where it represents 57%, in Sierra region it is 38% and in Selva region, only 5%. In Costa region, given the climatic conditions, it is difficult to develop agriculture without irrigation, only 5% of the total area under rainfed conditions is found in this region. Coast, of fertile but dry land, has large hydraulic infrastructures because of investments destined to the development of irrigation to encourage exports. In Sierra and in Selva, surface water supplies agricultural fields through irrigation by furrows. Irrigation systems consist of a network of open channels, generally unlined, with rudimentary water intakes and distribution systems that supply small plots mostly dedicated to subsistence agriculture.



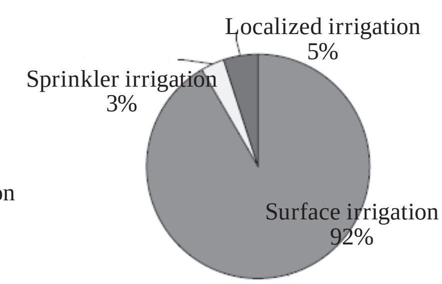
Source: FAO, 2016b

Fig. 2 Surface % under irrigation techniques in Brazil.



Source: FAO, 2016 c.

Fig. 3 Surface % under irrigation´s techniques in Mexico



Source: FAO, 2016 d

Fig. 4 Surface % under irrigation´s techniques in Peru

Market

Latin America market region includes countries such as Brazil, Mexico, Argentina, and remaining countries of South America. Brazil and Argentina have large population with huge demand for food and agricultural products and are the leading markets for Mechanized Irrigation Systems. Government subsidy policies and investments of private organizations are driving the market growth rate in this region. (Market Research Report, 2017)

Some of the key industries in the Mechanized Irrigation Systems market are Lindsay Corporation, Nelson Irrigation Corporation, Jain Irrigation Systems Limited, Driptech India Pvt. Ltd., Rain Bird Corporation, Premier Irrigation Adritec, Rivulis Irrigation, Netafim Limited, El Toro Company, T-L Irrigation, and Valmont Industries. (Market Data Forecast, 2018).

Conclusions

1. More than 66% of Latin America irrigated areas is located at Argentina, Brazil, Mexico and Peru, mainly with the surface irrigation technique.
2. Brazil and Argentina are the leading markets for Mechanized Irrigations Systems.

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Ecuador: Current Mechanization Status and Issues That Rice Producers Facing Now

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Abstract

Staple food is still occupied by the rice in Japan. Japanese Agricultural Equipment Manufacturers have developed mainly rice cultivation machines which meet the Japanese wet paddy field conditions and its farming scale size. Accordingly, to find and develop new market in foreign countries; whether Japanese Agricultural Machines would meet requirements of targeting country or not.

Set Targeting County

Preliminary marketing survey is quite simple; initially focusing on most essential points, that are: amount of Paddy/Rice production, its area harvested and producer's selling price of paddy. Such data are available through FAO-STAT, and GDP per person and scale-wise their gross income to know end-user's purchasing power; after that whether the products which is going to be promoted will meet the field conditions or not.

At the same time, check distributors which have sales net-work, servicing ability and financial power.

Most important key factor is the machine could be payable or not and also profitable or not.

Major demand of the machine purchased by the end-user is the profit. Machine's quality, performance, working efficiency and distributor's after sales services are just factors to support of their profit source.

In case, end-user can get good profit, it means this machine is accepted by the market, if not, it would just fade out from market. Because, for contractors agricultural machines are also one of the industrial machines for them.

The Setting

General Information

Area total: 256,000 km^2

Population: 16,390,000

GDP (Nominal): USD 6,640 per capita, Agricultural land holders: 842,882 (Ecuador Census 2000)

Currency: US Dollar since March 2000

Trade: Export: USD 183 million (2015, Central bank of Ecuador)

Import: USD 204 million (2015, Central bank of Ecuador)

Main exporting products: Foodstuff such as Banana, Cacao, Flower, Tuna, Shrimp (51.4%), Raw materials and fuel (39.8%), Industrial products (7.2%), others (1.6%).

Main importing products: Industrial Products (70.1%), Raw material and Fuel(18.7%), Foodstuff(10.6%) Others (0.6%)

Major trading partners

For Export: USA, Chile, Peru, Colombia, Russia

For Import: USA, China, Colombia, Panama, Peru

Agreement in December 2014. Ecuador became to join the EU and Peru and Colombia FTA. Announced that it will not enter into a FTA with May 2004 had been negotiated from the United States, relations with the United States was cooling of, but major trading partner is USA, this situation is still continued.

Characteristics of the Region

Ecuador has a total area of 283,561 km^2, Ecuador lies between latitudes 2°N and 5°S, bounded on the west by the Pacific Ocean, and has 2,337 km of coastline. It has 2,010 km of land boundaries, with Colombia in the north 590 km border and Peru in the east and south 1,420 km border. It is the westernmost country that lies on the equator.

Main land of the country can be divided by three (3) main regions except Galápagos Islands (**Fig. 1**):

La Costa: The coastal region consists of Esmeraldas, Manabí, Los Ríos, Guayas, Santa Elena and El Oro. These areas are most fertile and productive farm land, plantation's banana is one of major exporting products. This region is also where most of rice cultivating area exists.

La Sierra: La sierra consists of highland provinces such as Carchi, Imbabura, Pichincha, Tungurahua, Chimborazo, Cañar, Azuay,and Loja. Most of volcanoes are located in this region. Farm products are traditionally potato, maize, quinoa and coffee.

La Amazonía, La Amazonia consists of the Amazon jungle provinces—Sucumbíos, Napo, Pastaza, Orellana, Morona Santiago, and Zamora-Chinchipe. This region is primarily made up of the Amazon national parks, traditionally, Amazon Indian tribes continue living. It is also the area with the largest reserves of petroleum in Ecuador.

Fig. 1 Ecuador: Three main regions (Ecuador Black White Cevtor Image)

Annual Temperature and Rainfall (Quito and Guayaquil)

There is great variety in the climate, largely determined by altitude (**Fig. 2**). It is mild year-round in the mountain valleys, with a humid subtropical climate in coastal areas and rainforest in lowlands. The Pacific coastal area has a tropical climate with a severe rainy season. The climate in the Andean highlands is temperate and relatively dry, and the Amazon basin on the eastern side of the mountains shares the climate of other rainforest zones.

Almost all of the rivers in Ecuador form in the La Sierra region and flow east toward the Amazon River or west toward the Pacific Ocean. The rivers rise from snowmelt at the edges of the snowcapped peaks or from the abundant precipitation that falls at higher elevations. In the La Sierra region, the streams and rivers are narrow and flow rapidly over precipitous slopes. Rivers may slow and widen as they cross the hoyas yet become rapid again as they flow from the heights of the Andes to the lower elevations of the other regions. The highland rivers broaden as they enter the more level areas of the Costa and the Oriente.

In the Costa, the external coast has mostly intermittent rivers that are fed by constant rains from December through May and become empty riverbeds during the dry season. The few exceptions are the longer, perennial rivers that flow throughout the external coast from the internal coast and La Sierra on their way to the Pacific Ocean. The internal coast, by contrast, is crossed by perennial rivers that may flood during the rainy season, sometimes forming swamps.

Major rivers in the Oriente include the Pastaza, Napo, and Putumayo. The Pastaza is formed by the confluence of the Chambo and the Patate rivers, both of which rise in the Sierra. The Pastaza includes the Agoyan waterfall, which at sixty-one meters (200 feet) is the highest waterfall in Ecuador. The Napo rises near Mount Cotopaxi and is the major river used for transport in the eastern lowlands. The Napo ranges in width from 500 to 1,800 m (1,600 to 5,900 ft.). In its upper reaches, the Napo flows rapidly until the confluence with one of its major tributaries, the Coca River, where it slows and levels off. The Putumayo forms part of the border with Colombia.

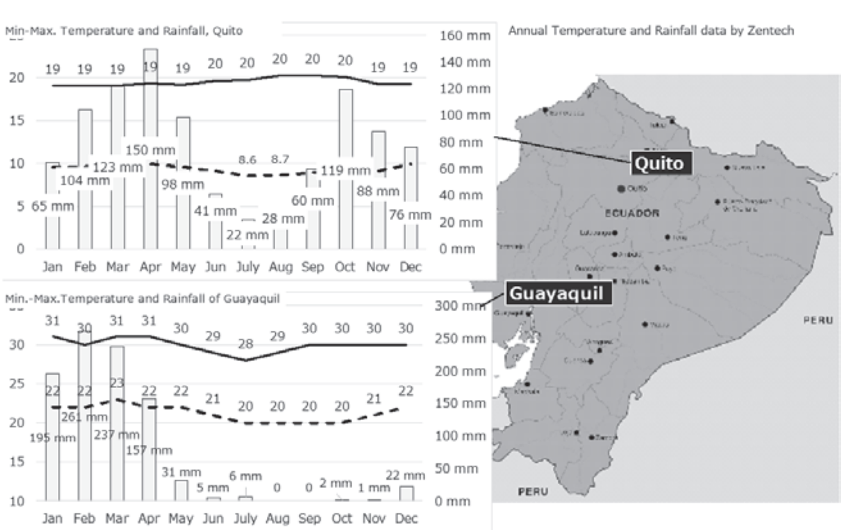

Fig 2 Annual Temperature and Rainfalll (Quito and Guayaquil)

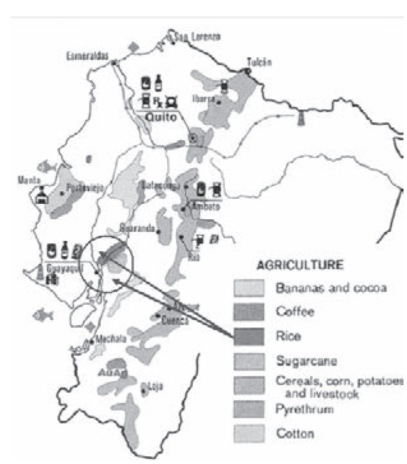

Fig. 3 Agricultural map of Ecuador

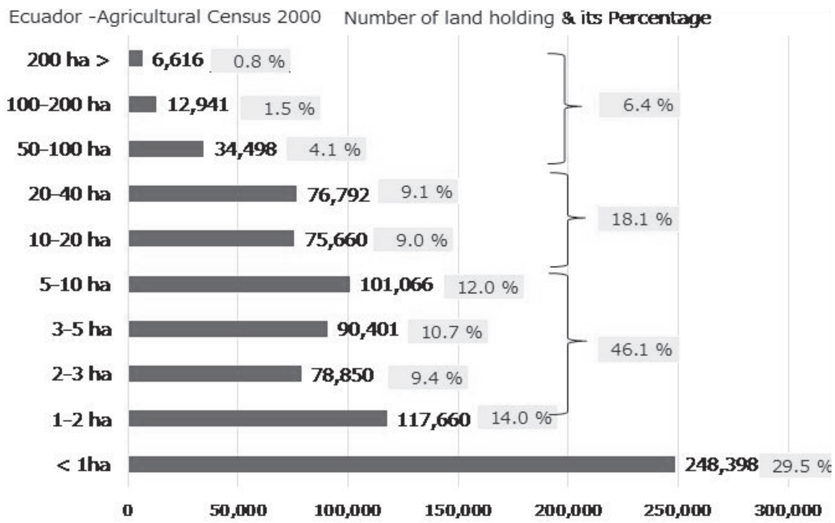

Chart 1 Scale wise Number of Land holdings and its percentage

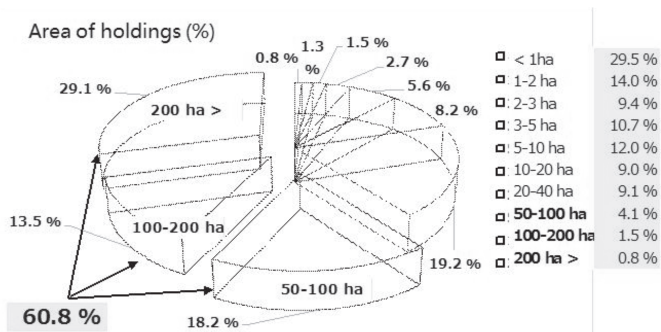

Chart 2 Area of holdings (%)

Table 1 Ecuador, Crops Top 20, Area Harvested and its production amount

2016, Area Harvested (ha)			2016, Production (ton)		
1	Cocoa, beans	454,257	1	Sugar cane	8,661,609
2	Maize	378,335	2	Bananas	6,529,676
3	**Rice, paddy**	**366,194**	3	Oil palm fruit	3,124,069
4	Oil palm fruit	263,839	**4**	**Rice, paddy**	**1,534,537**
5	Bananas	180,337	5	Maize	1,199,075
6	Sugar cane	104,661	6	Plantains	610,413
7	Plantains	94,911	7	Potatoes	422,589
8	Coffee	29,872	8	Fruit, fresh	232,497
9	Potatoes	29,635	9	Cocoa, beans	177,551
10	Manila fibre	28,852	10	Cauliflowers	122,334
11	Soybeans	26,280	11	Pineapples	116,044
12	Fruit, fresh	20,252	12	Onions	98,894
13	Beans, dry	18,767	13	Cassava	90,726
14	Beans, green	18,372	14	Mangoes	82,246
15	Cassava	18,045	15	Watermelons	79,920
16	Groundnuts	17,966	16	Oranges	75,333
17	Barley	17,320	17	Tomatoes	55,550
18	Mangoes	16,944	18	Papayas	50,901
19	Cauliflowers	15,795	19	Tropical Fruit	45,959
20	Rubber	13,857	20	Soybeans	41,788

Source: FAOStat

All of these rivers flow into the Amazon River. The Galápagos Islands have no significant rivers. Several of the larger islands, however, have freshwater springs although they are surrounded by the Pacific Ocean.

Ecuador Agricultural Map (Rice Cultivation Area)

Major Rice Cultivation area is North and East of Guayaquil city (**Fig. 3**).

North area from Guayaquil, there are so many large land holdings more than 100 ha or more.

East of Guayaquil, it is concentrated with small scale rice producers less than 10 ha which barely buy a China-Brand Diesel Power Tiller. Its retail price is US$ 2,800.

Ecuador—Agricultural Census 2000

Land holdings over 50ha share 6.4%, 10 to 40ha is 18.1%, 1ha to 10ha is 46.1% and less than 1ha is 29.5% as shown in **Chart 1**.

Over 50 ha land holder share 60.8% of agricultural land. In Ecuador, the landlord system still remains (**Chart 2**).

Farm products top 20: Area harvested and Amount of production, 2016

Rice is ranked 3rd in area harvested, and 4th in production on 2016 (**Table 1**).

Export and Import of Farm Products Top 20, 2016

As shown in **Table 2**, Major export farm product is Banana and main import item is wheat in amount but Soybean cake in value.

Producer's Price of Farm Products Top 20, 2016

FAOStat data shows producer's Price by US Dollar per ton.

Highest crops over 1,000 US Dollar per ton are Dry beans, Groundnuts, Peas, Strawberries and Maize (**Chart 3**). Rice, Paddy is ranked 15th, and its producer's price is 363 US Dollar per ton.

Scale Wise Producer's Turnover

Yield per hectare and Producer's Price data from FAOStat (**Table 3**). Scale-wise Producers turnover are calculation based and reference only.

Transition of Rice Production and Area Harvested (2007-2016)

Past 10 years (2007-2016) Paddy:

Table 2 Ecuador, Farm Products, Export and Import Top 20 on 2016

	2016						
	Farm Products Export	Q'ty (ton)	Value (× 1,000US$)		Farm Products Impoprt	Q'ty (ton)	Value (× 1,000US$)
1	Bananas	5,974,366	2,657,015	1	Wheat	936,338	228,778
2	Oil, palm	312,803	228,151	2	Cake, soybeans	918,262	362,531
3	Cocoa, beans	227,214	621,970	3	Oil, soybean	102,675	90,318
4	Plantains	201,903	84,990	4	Maize	76,573	43,502
5	Fruit, prepared	154,364	179,234	5	Sugar refined	47,006	24,881
6	Sugar refined	85,675	50,562	6	Apples	39,909	30,475
7	Pineapples	73,990	37,474	7	Bran, wheat	39,151	9,318
8	Vegetables, frozen	68,937	97,203	8	Oats	26,453	6,818
9	Mangoes	63,163	45,183	9	Barley	25,089	5,599
10	Food wastes	37,587	41,811	10	Oil, sunflower	22,767	24,145
11	Oil, palm kernel	22,565	28,755	11	Lentils	18,714	21,587
12	Sugar Raw Centrifugal	21,910	15,702	12	Malt	18,381	10,533
13	Coffee, extracts	19,416	129,557	13	Oats rolled	12,103	6,597
14	Juice, fruit	12,947	56,119	14	Garlic	12,070	16,246
15	Nuts, prepared	12,485	17,411	15	Oranges	11,728	3,116
16	Cocoa, paste	10,934	45,165	16	Cotton lint	10,931	18,860
17	Fatty acids	9,283	4,408	17	Fruit, prepared	10,458	12,647
18	Vegetables, preserved	9,231	14,752	18	Sugar confectionery	10,394	23,172
19	Sugar confectionery	8,865	36,557	19	Pears	9,858	8,639
20	Cocoa, powder & cake	6,426	16,888	20	Flour, wheat	8,673	4,374

Table 3 Calculation of scale wise income based on FAOStat

		FAOStat		Calculation base			
	2016	Yield (ton/ha)	Producer Price (USD/ton)	Income from 1 ha	Income from 10 ha	Income from 50 ha	Income from 100 ha
1	Strawberries	16.28	1,230	$ 20,020	$ 200,195	$ 1,000,976	$ 2,001,952
2	Tomatoes	31.42	507	$ 15,939	$ 159,394	$ 796,968	$ 1,593,937
3	Watermelons	15.06	501	$ 7,544	$ 75,436	$ 377,178	$ 754,355
4	Onions, shallots, green	8.27	586	$ 4,849	$ 48,487	$ 242,435	$ 484,870
5	Potatoes	14.26	335	$ 4,783	$ 47,828	$ 239,140	$ 478,280
6	Melons	9.43	503	$ 4,740	$ 47,395	$ 236,976	$ 473,952
7	Maize	3.17	1,077	$ 3,413	$ 34,135	$ 170,673	$ 341,346
11	Rice, paddy*	4.19	363	$ 3,039	$ 30,394	$ 151,971	$ 303,943
	* Double cropping on rice cultivation						
8	Cucumbers and gherkins	8.45	307	$ 2,596	$ 25,958	$ 129,792	$ 259,584
9	Cauliflowers and broccoli	7.75	326	$ 2,528	$ 25,281	$ 126,403	$ 252,805
10	Groundnuts	1.22	1,580	$ 1,927	$ 19,271	$ 96,356	$ 192,711
12	Lettuce and chicory	7.78	151	$ 1,175	$ 11,748	$ 58,739	$ 117,478
13	Chillies and peppers	1.88	613	$ 1,152	$ 11,515	$ 57,575	$ 115,150
14	Carrots and turnips	6.35	163	$ 1,033	$ 10,331	$ 51,657	$ 103,315
15	Seed cotton	1.33	744	$ 990	$ 9,899	$ 49,496	$ 98,992
16	Beans, green	1.45	675	$ 979	$ 9,792	$ 48,959	$ 97,919
17	Soybeans	1.59	593	$ 943	$ 9,426	$ 47,128	$ 94,255
18	Beans, dry	0.57	1,610	$ 918	$ 9,178	$ 45,888	$ 91,776
19	Barley	1.47	441	$ 648	$ 6,475	$ 32,377	$ 64,754
20	Cabbages	5.77	106	$ 609	$ 6,093	$ 30,466	$ 60,931

* Rank shows Producer's Price per ton.

area harvested 373,000 ha, production 1,558,860 tons; however, caused by current unusual weather, production data shows repeated up and down trend. Caused by severe drought, the rice area harvested was 1,478,000 ton on 2011 and dropped 228,000 tons than preceding year. Ecuador imported 45,000 tons of rice on 2012; its value was 18.1 million US Dollar (**Chart 4**).

Transition of Producer's Price of Paddy

Recently, Producer's price of Rice (Paddy) has gradually decreased. Colombia's Producers price is dropping down caused by the FTA (Free Trade Agreement) among Peru-Colombia, and following graph shows those three (3) countries' Producer's price converges to USD 300 per ton. And this level of pricing will be continued by this FTA (**Chart 5**).

Current producer's price of paddy on 2018; it has already fallen below USD300 per ton.

Agricultural Machines (Tractor and Combine Harvester) Import Statistics

On 2014, FTA and drought directly affected Tractor and Combine's demand in Ecuador. However, as for combine, demand is recovering rapidly due to the low price of China brand Combine Harvesters as shown in **Chart 6**.

Site Information

Rice Cultivation Season

In Guayaquil area, maximum temperature reaches between 28 to 30°C through the year.

Generally, the winter crop of rice cultivation is sowed from December to February, its harvest is from April to June. The summer work starts from May to July, its harvest time is from September to December (**Chart 7**).

The above double cropping period is a period of avoiding the rainy season where harvesting work is carried out at the end of the rainy season when the growing period comes from the rainy season from January to April.

Cultivation Style

Small scale farmer use Diesel Power Tillers for cultivation. According to customs statics, Ecuador imports 700 to 800 units of Chinese Diesel Power Tillers (12 to 14 hp), its retail prices are USD 2,200 to 2,800 (**Fig. 4**). Harvesting is done by contractor.

Farmers who do not own the tractor need to contract with the tractor

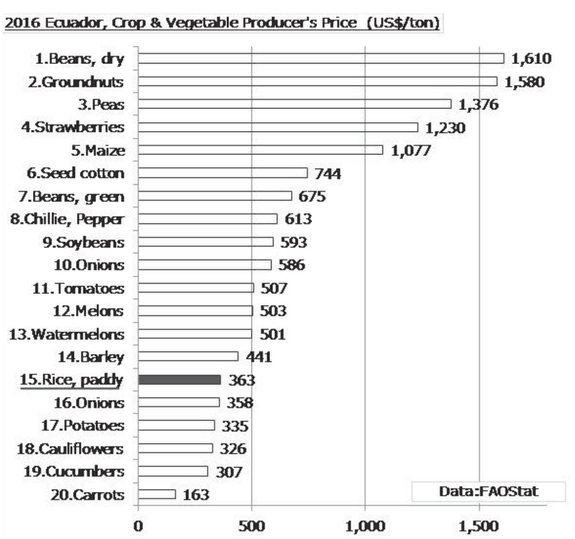

Chart 3 Producer's price of farm products top 20 on 2016

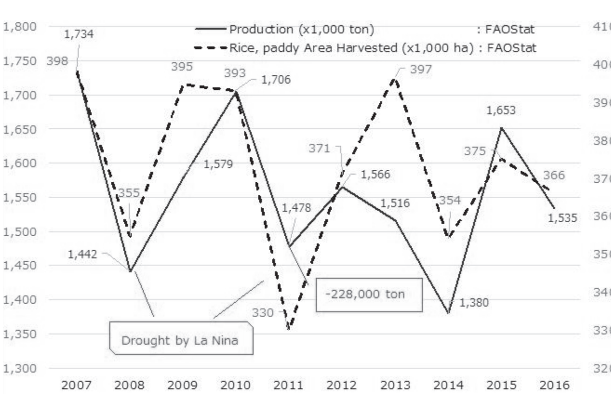

Chart 4 Transition of rice production and area harvested (2007-2016)

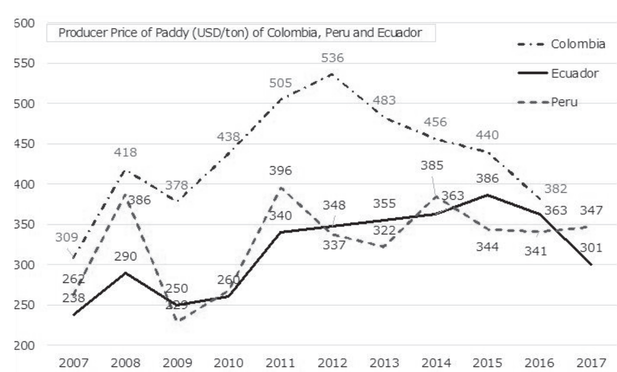

Chart 5 Transition of rice producer's price in paddy of three countries

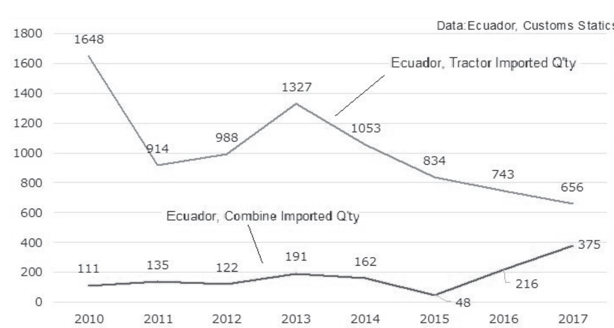

Chart 6 Transition of tractor and combine harvester import statistics

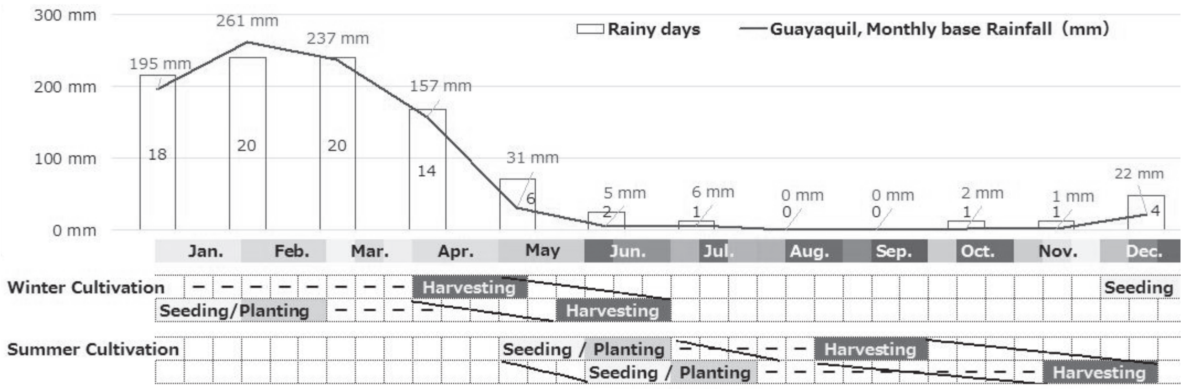

Chart 7 Rice cultivation season

Fig 4 Puddling by Diesel Power Tiller

Fig. 5 Plowing by Disc Harrow by 90 HP class Tractor

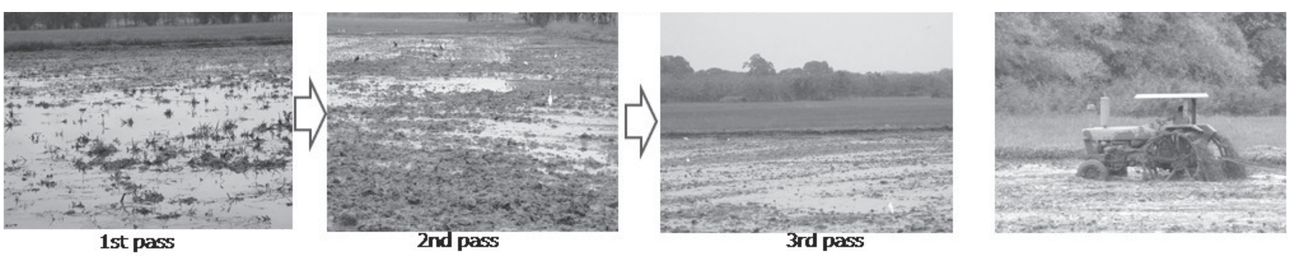

Fig. 6 After plowing, irrigate to the field, and puddling 3 times by Cage Wheeled Tractor

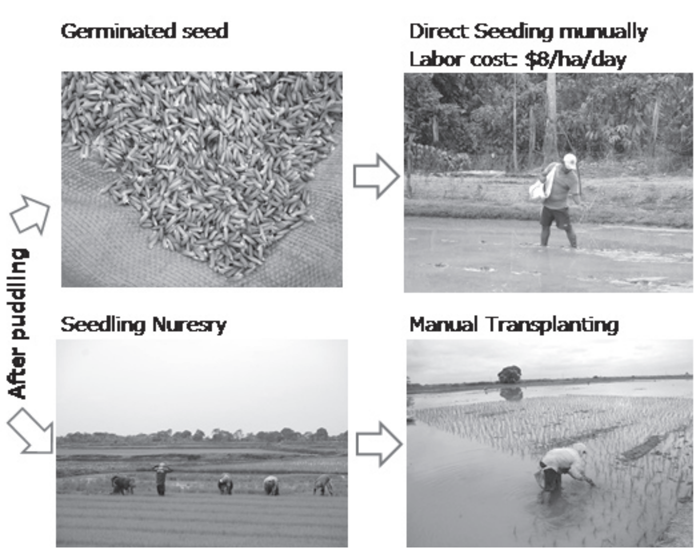

Fig. 7 Direct seeding and manual transplanting

Fig. 8 Manual weeding scene

owner for plowing work, the cost of which is USD 25 per hour and the price is decided. Incidentally, about 1 hectare of plowing work can be done in 1 hour (**Fig. 5**).

50 to 60hp class of tractors are used for puddling. After plowing, the paddy field is irrigated, and Cage wheeled tractor run around 3 times (**Fig. 6**). It's a habit from the old days of being determined by the per hour. Recent contract fee for puddling is USD16/hour, and it takes 3 hours for 1 hectare. To complete puddling, it costs USD48 per 1 hectare. Land preparation cost from plow to puddling per 1 hectare is:
($25 × 2 times) + ($16 × 3 hrs × 3 times) = $ 194 / ha

Recently, such European/USA band 50 hp class of tractors are imported from India.

After preparation of paddy field, planting style is split into two method, i.e. manual direct seeding and transplanting, both are manually done (**Fig. 7**).

Amount of seed for both of direct seeding and Transplanting are around 90 kg per hectare, its cost is USD 70.

Small scale farmers use Knapsack-sprayer for pesticide spraying, or manually weeding (**Fig. 8**).

And bigger farmer use articulated 16m width Boom Sprayer for pesticide spraying (**Fig. 9**).

Cost of pesticide is $30/ha a time;, most of producers apply minimum of 3 times.

But, for herbicide is not applied, even bigger farmer also employ labor for weeding due to less cost.

Over 200 ha land holders using 6 m width wheel type of combine harvester (**Fig. 10**). Good drainage because it is subjected to underdrain. But in muddy field, before importing full Rubber type of combine Harvester from China, the choice was Metal Half-Crawler Type, or just wait for field to be dry. But after introducing Chinese Full Rubber Crawler type of combine, it can be harvested April or May, after rainy season.

Distribution Channel of Rice

Distribution Channel of rice in Ecuador is quite simple. Rice Producer directly sell to Rice Miller and Rice Miller sell to Consumer in rural area. Such Rural Rice Millers works mainly for local consumers (**Chart 8**).

Rice Miller are located near by the city, such Rice Miller collects harvested paddy from 200 to 300 producers; however, Offer destination of producers are not necessarily the same every year. It depends on Rice Miller's offers to buy price of paddy.

Fig. 9 Pesticide spraying by articulated boom sprayer

Combine Harvester (harvesting width 6.0 m) (Wheel Type)

(Half-Crawler Type) (Front is metal crawler)
Combine Harvester (harvesting width 3.6 m / 4.6 m)

Combine Harvester (Harvesting width: 2.0 m) (Full Rubber Crawler Type)
Fig. 10 Combine Harvesters used in Ecuador

Rice Miller located nearby Guayaquil city which provide to shopping mall, such Rice Miller's annual capacity is around 500,000 ton, has Color Sorting Machine and broken rice mixed rate is adjusted to be less than 8% by Grader. Rice Miller's owner said there are around 10,000 small and big Rice Miller in Ecuador. Rice Miller's purchasing price is different by area. In case for self-consumption, milling charges at rice miller is 2 hours milling work and Rice miller takes 45 kg of white rice from requested rice producer.

Rice Producer's Annual Turn Over and Operating Profit

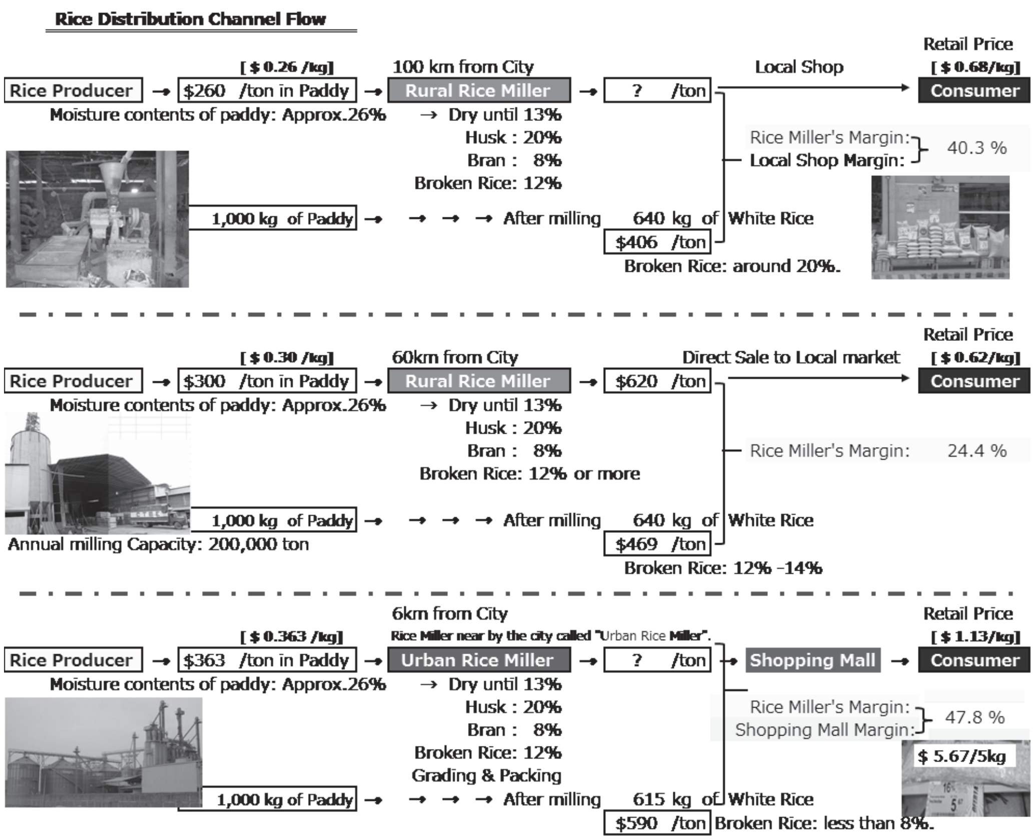

Chart 8 Rice distribution channel flow

Table 4 Rice producer's annual turnover and operating profit calcuration

Profitability of Rice Producer (No machine-owning basis)
Yield and Producer's price are national average basis on 2017

	No.	Description	National Average	Land Holding 20 ha/ season × 2 seasons	
Income	(1)	Yield in Paddy (ton/ha)	4.19	168	
	(2)	Paddy, Selling Price ($/ton)	300.7	on 2017	
	(3)	**Turnover**	**$ 1,260/ha**	**$ 50,400**	Cost (%)
Cost	(4)	Land preparation by Tractor ($/ha)	194	7,760	16.4%
	(5)	Rice seed Certified $70/45kg ($/ha)	140	5,600	11.9%
	(6)	Transplanting Labor Cost ($/ha)	200	8,000	17.0%
	(7)	Fertilizer ($/ha)	220	8,800	18.6%
	(8)	Pesticide $30 x 4 times ($/ha)	120	4,800	10.2%
	(9)	Manual weeding 10 Labors ($/ha)	120	4,800	10.2%
	(10)	Harvesting Cost ($/ha)	186	7,440	15.8%
	(11)	**Total cost**	**$ 1,180/ha**	**$ 47,200**	100%
			Production Cost	94.0 %	
Profit	**(12)**	**Operating Profit (3) - (10)**	**$ 80/ha**	**$ 3,200**	

* Data on production cost was obtained from an interview with rice producers on Nov. 2018

National average basis calculation of rice producer's annual turn over was Yield average 4.19 ton/ha × Producer's price USD 363/ha equals $1,521 on 2016, and USD 300.7 on 2017 as national average. Less than 20ha land holdings which are no machine owing zone, its annual turn over and profitability is calculated on national average base. In case, 20 ha land holdings by double cropping, its annual turn over was USD 60,840.- its operating profit was USD 18,440 on 2016, but on 2017, its turn over was USD 50,400.- and its operating profit had fallen down to USD 3,200.- Production cost has exceeded 94%, and they are shifting to direct seeding from manual transplanting save labor cost, in case of labor cost of direct seeding per hectare is USD8 per hectare only. Direct seeding can save $7,680 comparing manual transplant (**Table 4**).

Market price of certified seed (**Fig. 11**) is USD 70/45kg, just ventilated seed (**Fig. 12**) provided to usual farmer are half price. They also start to shift to purchase just ventilated seed. But, after seed selection with salt solution at gravity 1.12, around 20 percent of seeds of such ventilated seed were floated that affected germination ratio.

*Harvesting charge is determined by harvested number of bag, USD 2 per 45 kg/bag. Therefore, the rent in the lower yield field will be correspondingly lower, and high in high-yield fields. In case, 2,250 kg of paddy yield per hectare:

2,250 kg / 45 kg × US$ 2 = US$ 100/ha

In case, 4,190 kg of paddy yield per hectare:

4,190 kg / 45 kg × US$ 2 = US$ 186/ha

According to the story of a farmer who knew from the experience that the yield was 20% difference by hand planting and direct seeding, switching from manual transplanting to direct seeding, it was possible to reduce expenses of 7,680 US dollars by direct seeding the direct seeding, but because the rice price dropped by 10% and the yield was also dropped by 20%, after all, the profit has decreased considerably from 2017.

Table 5 shows three (3) rice producers' profitability by extensive and intensive different farming system on 2018. Every producer have over 160 ha land owner and those rice producers have their own machines such as Tractors, Pest control machines and Combine Harvester but its depreciation cost is excepted.

Fig. 11 Certified seedd by Ministry of Agriculture [USD 70/45 kg]

Fig. 12 Just Ventilated seed [USD 35/45 kg]

Table 5 Rice producer's annual turnover and operating profit calculation

Profitability of Rice Producer (No machine-owning basis)
Difference between Transplant vs Direct Seeding

	No.	Description	Manual Transplanting	Land Holding 20 ha/ season × 2 seasons Transplanting	Direct Seeding	Land Holding 20 ha/season × 2 seasons Direct Seeding
Income	(1)	Yield in Paddy	5.0 ton/ha	200 ton/20 ha	4.00 ton/ha	160 ton/20 ha
	(2)	Paddy, Selling Price ($/ton)	300.7	on 2018	280	on 2018
	(3)	**Turnover**	**$ 1,504/ha**	**$ 60,160**	**$ 1,120/ha**	**$ 44,800**
Cost	(4)	Land preparation by Tractor ($/ha)	194	7,760	←	7,760
	(5)	Rice seed Certified $70/45kg ($/ha)	140	5,600	←	5,600
	(6)	Transplanting Labor Cost ($/ha)	200	8,000	0	–
	(6')	Direct Seeding Labor Cost ($/ha)		–	8	320
	(7)	Fertilizer ($/ha)	$220 (400 kg/ha)	8,800	←	8,800
	(8)	Pesticide $30 x 4 times ($/ha)	120	4,800	←	4,800
	(9)	Manual weeding 10 Labors ($/ha)	120	4,800	←	4,800
	(10)	Harvesting Cost ($/ha)	222	8,880	178	7,120
	(11)	**Total cost**	**$ 1,216/ha**	**$ 48,640**	**$ 980/ha**	**$ 39,200**
			Production Cost	81.0%		88.0%
Profit	**(12)**	**Operating Profit (3) - (11)**	**$ 288/ha**	**$ 11,520**	**$ 140/ha**	**$ 5,600**

* Data on production cost was obtained from an interview with rice producers on Nov. 2018

For rice producers, production cost exceeds more than 50% and its management is not easy. Only Rice producer- the production cost is less than 50% by its high yield, but it's a quite exceptional case by the incentive farming such as 8 times application of pesticide and input 450 kg of fertilizer per hectare.

Main issue for most of rice producers is its selling price that has been dropping down 22 to 30% past couple of years. Aforementioned Rice Producer-A (Direct Seeding/Extensive), his production cost percentage was 42.9% at Rice selling price USD 363/ton on 2016, but its cost percentage rise to 69.7% now (**Table 6**). Rice Producer-B (Transplanting/Intensive), his production cost percentage was 47.2% on 2016, 61.6% on 2018 (**Table 7**). Rice Producer-C (Direct Seeding/Intensive), production percentage 27.9% on 2016, but now increased to 44.6% (**Table 8**).

It seems still it is getting good profit, but actual figure for a producers, production cost exceed 50%, its management will not be easy. And it's directly affect the purchasing power of new agricultural machines. Producers will refrain from buying

Table 6 Rice Producer- A (Direct Seeding and Extensive Producer) His turnover and operating profit calculation

Rice Producer-A: Direct Seeding/Extensive

	No.	Description	National Average	Land Holding: 160 ha/season × 2 seasons	
Income	(1)	Yield in Paddy (ton/ha)	2.25	720	
	(2)	Paddy, Selling Price ($/ton)	250	on 2018	
	(3)	**Turnover**	**$ 563/ha**	**$ 180,160**	**Cost (%)**
Cost	(4)	Land preparation Operator Cost by Full Time Worker			
	(5)	Seed (Ventilated) 90kg/ha ($/ha)	70	22,400	15.5%
	(6)	Direct Seeding Labor Cost by Full Time Worker			
	(7)	Fertilizer ($/ha)	100	32,000	22.1%
	(8)	Pesticide Apply 3 times ($/ha)	90	28,800	19.9%
	(9)	Manual weeding 10 Labors ($/ha)	120	38,400	26.5%
	(10)	Harvesting Operator Cost by Full Time Worker			
	(11)	Full time workers $386/month × 12 months × 5 Labors		23,160	16.0%
	(12)	**Total cost**	**$ 380/ha**	**$ 144,760**	**100%**
			Production Cost	80.4%	
Profit	**(13)**	**Operating Profit (3) - (12)**	**$ 183/ha**	**$ 35,400**	

*Chinese Brand Combine Harvester, and European Band Tractor owned

* Data on production cost was obtained from an interview with rice producers on Nov. 2018

Table 7 Rice Producer-B (Transplanting and intensive producer) His annual turnover and operating profit calculation

Rice Producer-B: Transplanting / Intensive

	No.	Description	National Average	Land Holding: 160 ha/season × 2 seasons	
Income	(1)	Yield in Paddy (ton/ha)	4.50	1,440	
	(2)	Paddy, Selling Price ($/ton)	278	on 2018	
	(3)	**Turnover**	**$ 1,251/ha**	**$ 400,320**	**Cost (%)**
Cost	(4)	Land preparation Operator Cost by Full Time Worker			
	(5)	Certified Seed 90 kg/ha ($/ha)	140	44,800	16.1%
	(6)	Transplant Labor Cost added($/ha)	100	32,000	11.5%
	(7)	Fertilizer 360kg/ha ($/ha)	200	64,000	22.9%
	(8)	Pesticide Apply 5 times ($/ha)	240	76,800	27.5%
	(9)	Manual weeding 10 Labors ($/ha)	120	38,400	13.8%
	(10)	Harvesting Operator Cost by Full Time Worker			
	(11)	Full time workers $386/month × 12months × 5 Labors		23,160	8.3%
	(12)	**Total cost**	**$ 800/ha**	**$ 279,160**	**100%**
			Production Cost	69.7%	
Profit	**(13)**	**Operating Profit (3) - (12)**	**$ 451/ha**	**$ 121,160**	

* European Brand Combine Harvester and Tractors owned

* Data on production cost was obtained from an interview with rice producers on Nov. 2018

Table 8 Rice Producer-C (Direct seeding and intensive producer) His annual turnover and operating profit calculation

Rice Producer-C: Direct Seeding /Intensive

	No.	Description	National Average	Land Holding: 170 ha/season × 2 seasons	
Income	(1)	Yield in Paddy (ton/ha)	7.00	2,380	
	(2)	Paddy, Selling Price ($/ton)	260	on 2018	
	(3)	**Turnover**	**$ 1,820/ha**	**$ 618,800**	**Cost (%)**
Cost	(4)	Land preparation: Operator Cost by Full Time Worker			
	(5)	Rice Seed: March 54 kg/ha ($/ha)	56	19,040	16.5%
	(5')	Rice Seed: July 75 kg/ha ($/ha)	78	26,520	
	(6)	Direct Seeding Labor Cost by Full Time Labors			
	(7)	Fertilizer: 450kg/ha ($/ha)	250	85,000	30.8%
	(8)	Pesticide: Apply 8 times ($/ha)	240	81,600	29.6%
	(9)	Manual weeding: 10 Labors ($/ha)	120	40,800	14.8%
	(10)	Harvesting Operator Cost by Full Time Worker			
	(11)	Full time workers: $386/month × 12 months × 5 Labors		23,160	8.4%
	(12)	**Total cost**	**$ 744/ha**	**$ 276,120**	**100%**
			Production Cost	44.6%	
Profit	**(13)**	**Operating Profit (3) - (10)**	**$ 1,076/ha**	**$ 342,680**	

* USA Brand Combine Harvester and European Tractors owned.

* Data on production cost was obtained from an interview with rice producers on Nov. 2018

machines under such situation.

Direction of Being Assumed Mechanization Style

The circumstance surrounding the rice producer on pricing issue, their selling price is sealed and limited due to FTA as rise in prices cannot be expected. Rice traders already know about this fact from its record. **Chart 9** clearly shows it.

Even if, aforementioned three (3) FTA counties producers rise rice price, at the same time, a trader imports cheaper rice from Thailand (producer's price: USD228/ton on 2016) or Pakistan (producer's price : USD 192.8/ton on 2016). This is not recognized at most of the individual level, but will be aware of the reality that as soon as the price does not rise up.

Furthermore, from 2019 TPP 11 (Trans Pacific Partnership) will be started, in these 11 countries, Viet Nam and Peru are participating. If rice is free trade agreed between Viet Nam and Peru, cheaper Rice come into Peru from Viet Nam, and after that there is a possibility to Peru re-export to Ecuador and Colombia. Under these circumstances, it is hopeless to expect pricing rise of rice.

Beside, young people hate working in the muddy rice fields, this is the world-wide the same.

This means labor cost will be increased or facing shortage of labor. Under these circumstances, Rice Producers seek most efficient and convenient machines in a muddy field or shifted to extensive farming.

For example, three (3) times puddling by direct coupled Cage wheel puddling is changing to Japanese rotary puddler (**Fig. 13**). It can be completed a puddling and leveling work by one time, it will change working style and saving 1/3 of time and 17% of working cost.

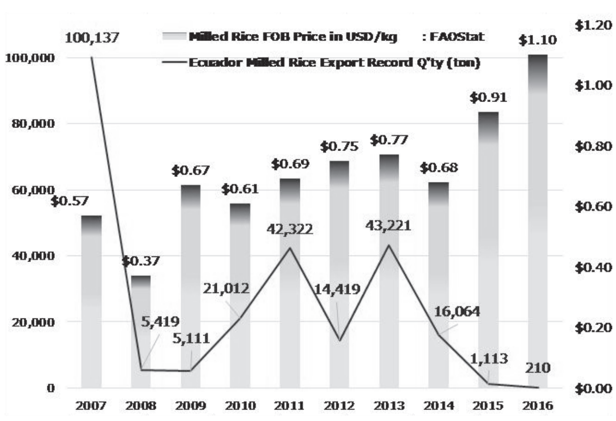

Chart 9 Ecuador milled rice export record (2006-2016)

Fig. 13 European brand Tractor 60 hp with Japan brand Rotary Puddler

For such tractor owner, it can be saving fuel cost also. Not only cost, but direct coupled wheeled tractor turn over to rear side, it causes of serious injury to operator sometime.

At the same time, heavy weight tractor is not preferred by customer, but light weight one like Japan brand tractors meet requirement for such paddy field.

Half-crawler type of combine dig a soil deeply at turning in a muddy field, most of rice producers are not willing to work as such places become deep (**Fig. 14**).

In the late of 2000's, after introducing several China brand full rubber crawler types of combines, it has been expanded immediately with low cost, compact and easy to handling (**Fig. 15**). But some of China Brand combines have already been withdrawn from market due to low quality. Comparatively, better quality China brands have remained in the market and expanded year by year.

Fig. 14 USA brand Half-Crawler Combine

Fig. 15 China brand Combine Harvester

Tractor Import Statics on 2017

Most of USA/EU brand Tractor manufacturer have their affiliate factory in Brazil, Mexico and India. The tractor exported from Mexico and Brazil are more than 80 HP tractors, and Indian made are 50 to 60 HP (**Chart 10**). Total cultivation area of Ecuador is 2.4 million ha, and area harvested 366,194 ha, most of them have double cropping, so that actual rice cultivation field is 183,097 ha. It is only 7.4 percent of all of cultivation area. A 200 HP tractor is used at sugarcane harvesting transporter. And/or 200 ha or more paddy field land holder also use such big tractor at paddy field at dry condition.

As far as the result of market survey, generally, tractors used in Paddy field are 90 HP class tractor with Tandem Type Disc Harrow for plowing purpose and 50 to 60 HP tractor for puddling use.

USA Brand Tractor manufacturer provide own finance with 10% of annual interest, Bank interest is 9%, but USA Brand manufacturer provide credit without any conditions and keeping top share in Ecuador

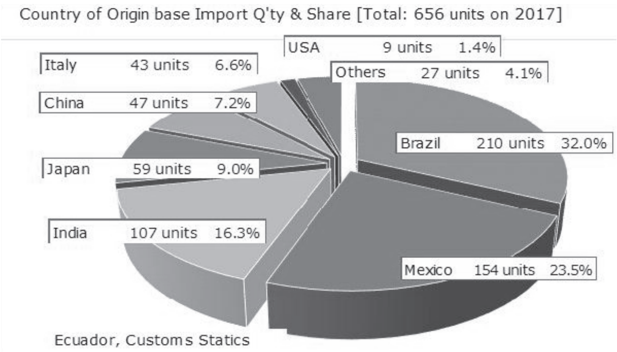

Chart 10 Tractor import statistics on 2017

Remark: 1) The prices was collected from the user, and the price and the actuallypurchased price are mixed.
2) All of models are 4 wheel drive and Open station type.

Chart 11 Retail price of USA/UK brand tractor

(**Chart 11**).

Combine Purchase Range for Each Farmland Owned Area

For the farmland holdings of 200 ha or more, such rice producers owned 6 m harvesting width USA/EU brand wheel type of combine harvester. Around 100 ha to 150 ha land owner purchased Half-crawler type of combine harvester, but at the time of renewing, they shift Japan/EU band Full Rubber Crawler Type of combine harvesters (**Chart 12**).

For 100 ha or less; such land owner have dashed to purchased China Brand Combine Harvester after being introduced around mid of 2000s. Such China brand combine owners /Rice producers not only harvest their own field but doing contract base harvesting and get harvesting charge to pay back combine's loan.

Market Price of Combine Harvester

The USA or Europe Brand Combine Harvesters (Harvesting width: 4 to 6 m)'s retail price is more than US$200,000, recently, those purchasing such new combine is very few, instead, second hand combine harvester is in a market with half price (**Chart 13**). Even the China brand, its quality has been improving over the past 10 years. The customers who purchase China brand combine harvesters are not so much satisfied with its quality and durability even if its durability is less than half than Japan/EU brand combine harvester. They will replace to new China combine harvester.

At initial years of mid of 2000's, some of low quality machine among several china brand combine harvester gives bad image of China Brand combine harvester. Some of customer said: "Cheap" does not meant always economical. However, comparatively good quality combine

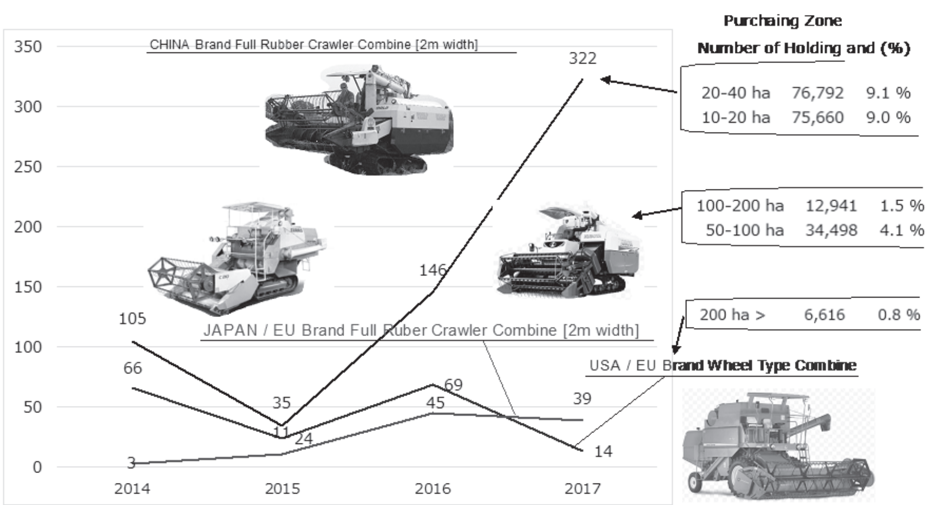

Chart 12 Combine purchase range for each farmland owned area

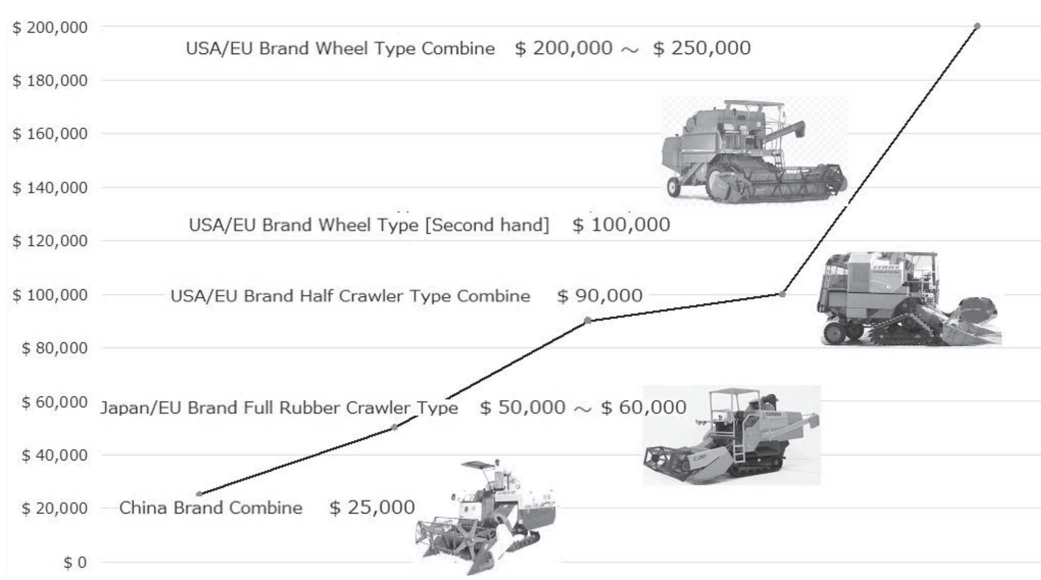

Chart 13 Retail price of combine harvester

has also been narrowed down in 10 years.

Daily harvesting efficiency: US$100/ha × 3 ha /day × 30 days × 2 seasons per year = US$18,000 as income, It can be paid within 1.38 years. These segments are increasing year by year. the lower producer's paddy price give a big boost to sell china brand combine harvester.

Conversely, big land holders over 200 ha or more; such producers are renewing to second-hand combine. So that this segment will shrink.

Future Direction of Rice Producer

As the rice (paddy) price falls, it is estimated that options that rice producers will take in the future will be the following three types.

Extensive farming:

Even though there is intention, it is not permitted in terms of cost; therefore, when it cannot afford cost, the reality is waiting just for extensive farming. Of cause, it will affect its yield, early and late, such rice producers face a dilemma.

Switching to crop rotation

Current single cropping farming shall be changing to crop rotation such as Rice-Soybean-Maize, actually, some rice producers already started crop rotation. As far as the producer's selling price is concerned, soybeans and maize are traded at high prices.

Producers trying to raise the yield and lower the relative cost:

Even in the same rice cultivation, the difference between the rice cultivation farmer and the farmer who carries out rice cultivation from the viewpoint of management is obviously different. However, increses in Paddy prices are beyond their control. So that the only way is increasing yield and lower the production cost.

Differentiation with China Brand Combine and Japan/EU Brand Full Rubber Crawler Type Combine Harvester

In the case of EU brand Full Rubber Crawler type of combine harvester's big advantage is durability, but it is not still approved among producers. Or Some people may trust their quality and durability from their brand name. But, import stattisics of combine harvester shows that lower price get advantage than durability.

Other point is follow up crop producer's tendency. That is some of the rice producers begin crop rotation such as Rice-Soybean-Maize, in case, combine harvester which can be harvested those three (3) crops by changing attachment, it will be met to crop rotation producers. China brand combine harvester already has Maize harvesting kit, but no Soybean kit yet.

Production Cost Down Consultation

Among rice production in Ecuador with an average yield of 4.19 ton/ha, some farmers have raised yields of 6 ton/ha or more, although the number is small, the common item is to introduce more than 400 kg of fertilizer per hectare in doing so. Comparing with Japan with different varieties and different climates is somewhat discouraged, but the amount of fertilizer application in Japan is now around 200 kg/ha, raising the average yield to nearly 7 tons. It is presumed that this difference is probably a difference in soil power accompanying the input amount of compost. It did not appear to any farmer when asked more than 20 farmers to apply organic fertilizers. It should improve the quality of soil by the simplest method plant-

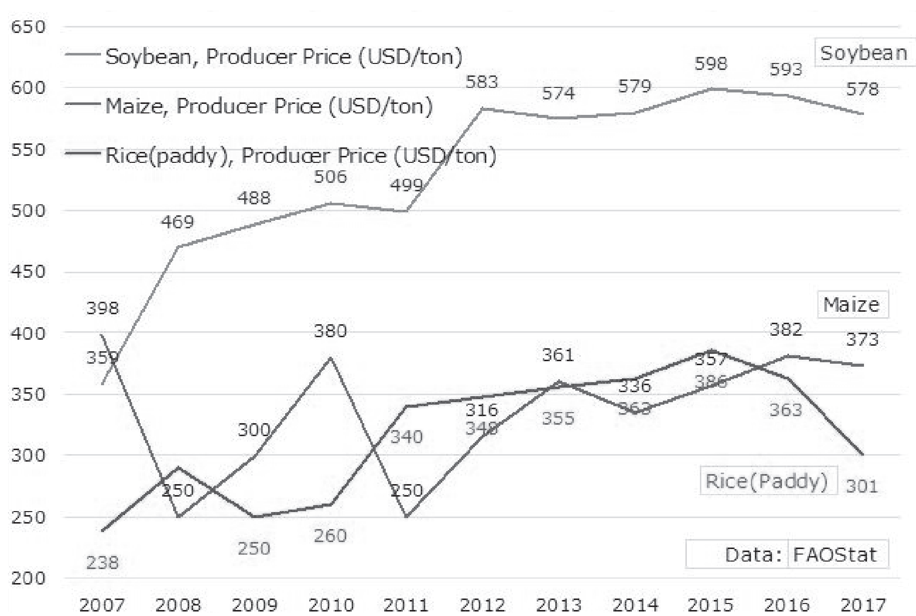

Chart 14 Transition of producer's price (Soybean, Maize, Rice)

ing the Leguminous plants such as astragalus after the crop which has been ever performed in Japan, and only leaving and unattended, and nitrogen shares increasing by air nitrogen fixation, and turning this over.

Furthermore, recommending the cheap organic quality manure for increases in production is being lowest. For example, in the case of strong fowl droppings of the urea, and casting around 1 ton per 1ha more than one month before the preparations or hearing such an expertise because probably it can be obtained the fowl droppings of the poultry farm gratis.

Conclusions

China brand made in China had been a mixture of “wheat” and “chaff” in its quality, but some China brand has come to a level that can no longer be marginalized. The manufacture should not focus to just competitor. In order for manufacturers not to be involved in price competition, it is necessary to think about the provision and structure of new proposal type products that truly benefit the crop producers.

Some points relate to the fields of agronomy, but given the fact that agricultural mechanization can consist based on crops, as a agricultural machinery manufacturer in these fields, knowledge at a level that advises agricultural management is necessary and not only thinking about selling just machines.

Acknowledgements

Everything quoted in this report is noted in that place. However, some of the maps have unknown exhibit source, and in that case it can be printed as such.

■■

Agricultural Mechanization in Ecuador

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Abstract

The objective of this paper is to characterize the current situation of agricultural mechanization in Ecuador, identifying the factors that limit its use in agriculture, mainly by small and medium farmers. This agricultural sector is little technically oriented with the exception of crops destined for export, which have adequate machinery and technology. According to the last National Agricultural Census realized in the year 2000, the country had 14,652 tractors, but there is not official information on the types of tractors and agricultural machinery at present. By means of the bibliographic analysis of the agriculture department databases, reports of crop performances, reports of other organizations, scientific articles and other bibliographic sources, it was determined that, at present, the operation of soil preparation is the most mechanized activity in the majority of the crops. Most of the small and medium farmers contract the services of soil preparation to informal contractors. The Ecuadorian agriculture is highly dependent on the import of agricultural machinery. China, Brazil, United States and Italy contributed more than 56% of the total of imports realized in 2017. An increasing trend in the machinery and technology used to stimulate the growth and the productivity of the sector has been observed. To carry out the strategy of agricultural mechanization, it is indispensable to qualify the producers, bearing in mind that 89.24% of them has not received training.

Introduction

Ecuador, officially named Republic of the Ecuador and located in northwest of South America, is one of the countries with major biological diversity in the world, with 14 terrestrial different ecosystems and 10 oceanic environments. After Uruguay, it is one of the smallest countries of the region. It is 256,370 km^2 and has 16,650,684 inhabitants, according to the Population Census and housing of 2010 (INEC, 2017). The country is divided in four natural regions: Costa, Sierra, Amazonía, and the insular region of Galápagos. Costa occupies near 26% of the area; Sierra 34%; Amazonía 37% and Islas Galápagos, 3% remaining.

The productive agricultural capacity of the country allows it to have a level of food self-sufficiency and cover 93% of the food demand for the internal production in the principal groups of food consumed by the population. The Ecuadorean agriculture is an activity of low external dependence and is very diverse, with more than 120 cultivated products, 58 of them are permanent cultures and 70 are transitory. Of the principal products, only for wheat, does not exist better ecological conditions in the country to generate a production that covers the national demand. The external demands of food are especially for differentiation of product, more than for absence of production. Only 2.7% of the food is imported, being 2.6% primary food and 0.1% industrialized (CIMNE-INER-INIAP, 2017).

Every region is characterized by enormous differences as for the climate, water resources, and types of soils, types of agriculture, crops, working population, and natural risks, besides historical - cultural and social differences. Items as rice, maize, banana, African palm, sugar cane, coffee, cocoa, between the principal ones, determine the production of Costa, for Sierra, the principal items are maize, potato, bean, among others. For the case of the Oriental Region, the production is marked by coffee, cocoa, ranching and sugarcane, among the most important.

In the agricultural sector of the country, there is great heterogeneity in land distribution, large extensions are property of a few owners and small extensions are property of many. There are producing units (major of 100 ha) with wide access to new technology, assistance, resources, high levels of productivity, and large extensions of land for supplying the external markets. On the other hand, there are small units (1-5 ha), called Productive Agricultural Units (UPA), with low levels of modernization, productivity and limited access to credit lines (Cevallos and Shkiliova, 2016).

In general, the technological level of Ecuadorean agricultural sector is low. The applied technology is characterized by a certain duality. A minority of capitalized producers that cultivate banana, horticulture, flowers and other crops (basic products of the country export) and use foreign equipment of high quality and carry out extremely sophisticated processes of production and distribution. On the other hand, the great majority of familiar farmers possess null or minimal technology. This situation provokes a poor performance of the lands (García, 2018).

The aim of the present work is to characterize the current situation of the agricultural mechanization in Ecuador, identifying the factors that limit its use in agriculture and the trends for its future development, by means of the analysis of statistical information, departments' database, reports, scientific articles, etc.

Details

Some Relevant Facts on the Development of Agricultural Mechanization in Ecuador in the 20th Century

As Ojeda (2012) referred, it is not known the exact year in which the Ecuadorean farmer used the tractor for the first time. There is information that indicates that the first tractors imported in the year 1924 were Caterpillar brand and in the decade of the 30s, the first International brand tractors were imported.

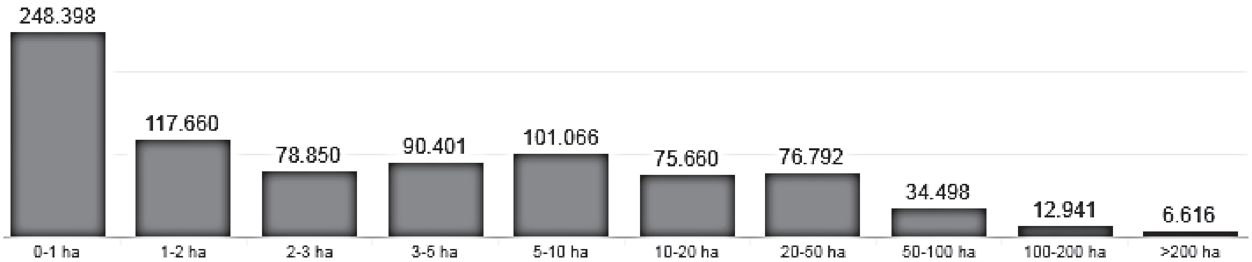
According to information of the Economic Commission for the Latin America (CEPAL), it is estimated that, in the year 1951, there were 930 tractors imported from the United States of America for agricultural works, that was, one tractor for every 677 ha. The use of tractors was principally in the hard labor of soil preparation and, in minor scale, for labors of sowing, weeding, and crop peel (CEPAL, 2013).

According to CEPAL (2013) and Ojeda (2012) among the principal reasons of a slow development of agricultural mechanization in the country in that epoch are the following:

1) Topographic slightly propitious conditions for the employment of large-scale machines.
2) Abundance of cheap workforce in Sierra in the first half of the 20th century.
3) Permanent plantations of cocoa, coffee and banana in Costa, which do not need much mechanization.
4) Operators' shortage and personnel prepared to select and / or adapt the machines to the diverse types of working and culture.
5) Lack of equipment's maintenance.
6) Lack of mechanical workshops and repairs.
7) Stealing for not having supplies.
8) Bad administration.

In the second half of the 20th century, several plans of mechanization were spread out, among them development of mechanization services in the provinces of Carchi, Imbabura and Loja in 1973, with the help of the section of Agricultural Mechanization, dependent on the Agricultural Engineering department of the Direction of Agricultural Development. In 1974, these services spread to Manabí's provinces, Bargain and Emeralds. Those were paralyzed later for several years. In 1972, the Commission of Studies for the Development of Cuenca del Guayas (CEDEGE) entrusted to engineer Guillermo Ojeda Lopez, the creation of a project of agricultural mechanization to give services to the farmers located in the area of the System of Irrigation and Drainage Babahoyo. This project was designed to mechanize the production of rice in order that it lasted seven years. Nevertheless, it worked for 17 years contributing to the development of the zone, failing in an inexplicable way, for bad administrative work and little knowledge of the persons involved (departmental chiefs) to manage an automotive agricultural park intensely enough (96 tractors, 25 combine-harvesters for rice and soy, numerous implements, etc.). In 1980, the National Program of Agricultural Mechanization was created along with previous agreement with the Government of Italy. All agricultural machinery provided was made by them, and it did not last more than a decade. In the same period, the Centers of Mechanization were created. In 1995, Project Fundagro began, it also failed inexplicably (Saltos, 1991; Ojeda, 2012; Reina, 2004).

At the end of the 20th century, it is possible to distinguish the following features typical of the Ecuadorean agriculture, which have a direct relation with the development of agricultural mechanization in the last years. In 50 years, the agricultural border has expanded from 6,399,700 ha to 12,355,850 ha. Land distribution has not changed substantially and it continues being deeply un-



Source: the III Register Agricultural Native, 2000

Fig. 1 Number of UPAs for size and surface according to the National Agricultural Census realized in 2000

equal. There is land control by a very small proportion UPA's -strongly linked to the agroindustry - and a trend to the fragmentation of small units (**Fig. 1**). Scarcely, 6,616 UPAs larger than 200 ha, concentrate 3,593,496 ha (29% of the national exploited surface), whereas 712,035 UPAs possess less than 10 ha. All them are 2,481,019 ha in total (Carrión and Herrera, 2012).

The park of agricultural tractors in Ecuador in the year 2000, ascended to 14,652 units, with a relation of only 40 tractors every thousand farms (CNA, 2002). According to Reina and Hetz (2004), this quantity did not satisfy the demand of permanent and transitory cultures and generated a deficit of 2,600 tractors, but without considering areas of cultivated pastures and resting, the deficit increased to 6,500 units.

Current Situation of the Agricultural Mechanization in the Ecuadorean Agriculture

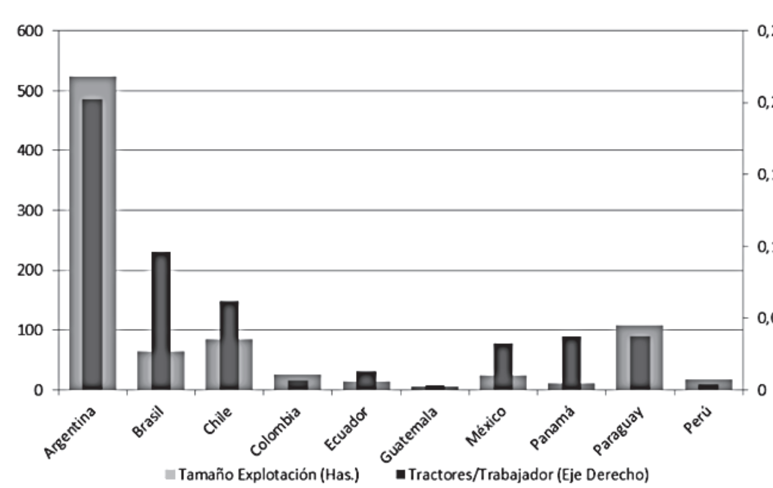
Ecuador, like most of the countries of Latin America and the Caribbean (LAC), shows significant lags in the incorporation of machinery and new technologies in the agricultural sector, which varies significantly between production systems, size of the farms, agroecological conditions and the socioeconomic situation of producers (ECLAC, FAO, IICA, 2017).

Fig. 2 shows the dependency of the endowment of tractors per worker of the size of exploitation in several countries of Latin America. There, it is possible to see that Ecuador is one of the countries with the lowest values of this indicator.

From the economic point of view, the small farmers usually lack the financial resources to acquire the machineries that need and face obstacles to access on credits. Mostly, the small and medium-sized farmers hire the services of preparation of soils to informal contractors who offer a rudimentary and general service, which is not a specialized service that takes into consideration the real needs of every producer. Only large farmers, who are the minority, have their own agricultural machinery and they are continuously updating their machinery with the latest technological advances available. The lack of machinery adaptable to the ecological and topographic conditions of the country, especially of small scale, in hillside and dedicated to horticulture is highlighted by Elverdin, Piñeiro and Robles (2018).

According to the Survey of Surface and Agricultural Constant Production, realized to 11,422 agricultural producers with transitory cultures in the year 2017, 80.02% of the surveyed persons, has realized at least an activity in which they use agricultural machinery for the preparation of the soil, sowing, development and crop of the culture (Salazar, *et al*., 2017) (**Table 1**).

Ecuadorean agriculture is highly dependent on some countries as for the import of agricultural machinery. The principal markets of imports in 2017 were China (26.22%), Brazil (14.93%), United States (10.96%) and Italy (4.53%). Only these four countries added more than 56% of the total of the imports realized by Ecuador in 2017. In **Fig. 3**, the great difference of the volume of imports opposite to exports is



*Número de tractores de 40 CV en uso equivalente.

Source: (Elverdin, Piñeiro, Robles, 2018)

Fig. 2 Exploitation and endowment of tractors for worker observed, which corroborates the expressed on the dependence on the part of the Ecuador on foreign machinery (García, 2018).

Among the principal exporting companies of agricultural machinery to Ecuador are John Deere, AGRO, New Holland, Massey Ferguson, CNH, CLAAS, CASE IH, Kubota, Same Deutz-Fahr and Watanabe, which have their national distributors and assure the technical service principally in the guarantee period, spare parts, trainings and organize agricultural machinery fairs.

In **Table 2**, labors mechanized in productive cycles of some principal cultures of the country are shown, emphasizing high values in the soil preparation in cultures of rice, quinoa and potatoes, as well as in rice harvesting. Whereas, the mechanization of sowing, fertilization and weed control brings minor percentages and in some cultures, it is void.

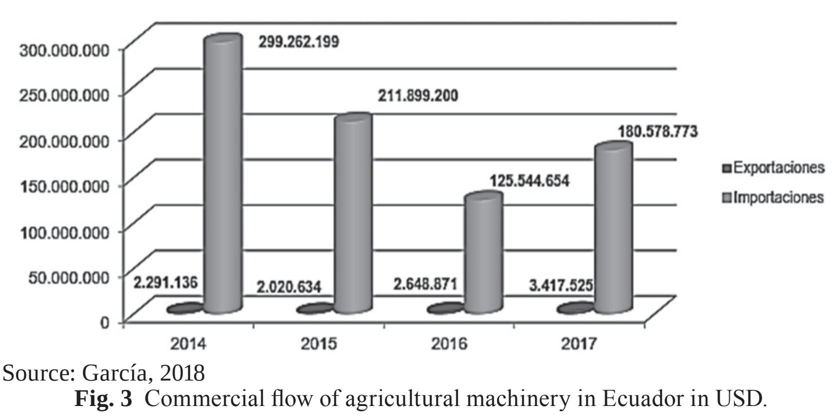
It should be noted that there is already a shortage of labor in the rural environment in the high periods of productive cycles (sowing, harvesting), so it is increasingly important for large and medium-scale farmers to consider the role of agricultural machinery, which allows productive and profitable farming.

In addition, it is necessary to emphasize the work that is realized by the modernization of agriculture of small farmers. With the purpose of helping to improve the productivity and the quality of life of small and medium producers, several projects, programs and initiatives are carried out by the Department of Agriculture. Among them, it is important to highlight the National Project of Technological Participative Innovation and Agricultural Productivity (PITPPA), directed to promote the reactivation of agriculture by optimizing technical assistance and extension, complementing with endowment of innovative technology, infrastructure and modern technological equipment. It is aimed at improving the productive traditional capacities of small and medium agricultural producers and the quality of life of the beneficiary population. As part of this project and of the strategy Hombro, a Hombro in order to use technology in land laboring, to diminish costs of workforce and to increase the production of small and medium producers, tractors, one-axle tractor, implements and other inputs were given to the producers associations and centers of mechanization were created. Nowadays, the government is stimulating the "Gran Minga Agropecuaria" megaproject, which includes the

Table 1 Agricultural producers with transitory cultures that used equipment for different labors in 2017

	Equipment use		Equipment property	
Type of equipment used	Yes	No	Own	Other's
To prepare the soil for cultivation				
Yoke	14.44%	85.56%	28.71%	71.29%
Tractor	46.68%	53.32%	12.70%	87.30%
One-axle tractor	6.76%	93.24%	39.16%	60.84%
None	40.55%	59.45%	-	-
To plant the cultivation soil				
Manual seeder	8.02%	91.98%	80.49%	19.51%
Mechanical seeder	2.43%	97.57%	56.31%	43.69%
Manual Transplant	0.40%	99.60%	83.78%	16.22%
Mechanical Transplant	0.37%	99.63%	88.24%	11.76%
None	89.52%	10.48%	-	-
For the development of crops				
Rounder	2.30%	97.70%	73.33%	26.67%
Cultivator-fertilizer	1.26%	98.74%	80.87%	19.13%
Gable	2.91%	97.09%	72.56%	27.44%
Stationary pump	6.96%	93.04%	90.57%	9.43%
Motor pump	29.80%	70.20%	83.26%	16.74%
Manual pump	63.23%	36.77%	91.21%	8.79%
None	32.17%	67.83%	73.33%	26.67%
To harvest the crops				
Combined thresher	0.73%	99.27%	41.79%	58.21%
Thresher	1.91%	98.09%	18.86%	81.14%
Fine grain harvester	12.67%	87.33%	14.16%	85.84%
Coarse-grain harvester	4.10%	95.90%	20.53%	79.47%
Other harvesters	1.52%	98.48%	25.18%	74.82%
None	81.06%	18.94%	41.79%	58.21%

Source: Survey of Surface and Continuous Agricultural Production (ESPAC) 2017.
Elaboration: Authors



Source: García, 2018

Fig. 3 Commercial flow of agricultural machinery in Ecuador in USD.

characterization of mechanization for small and medium producers, among other objectives.

An important aspect in this process is the training of workforces in use and maintenance of the equipment, in order to achieve an efficient and suitable utilization of the agricultural machinery. As Salazar, *et al.* (2017) reported, 89.24% of the producing persons had not received training in agricultural and cattle matters in 2017. Likewise 92.80% of the investigated farmers is not organized in producers' associations. This information indicates that the preparation of producing persons must be one of the principal priorities of the Department of the Agriculture, of the universities and other responsible organisms for this activity.

Current State and Future Perspectives of Agricultural Machinery Industry in Ecuador

The analysis of the agricultural machinery industry in Ecuador was realized as part of the project "Service of Consultancy to Elaborate a Diagnosis of Productive Linkages-Intermediate and Final Industries of Transformation" (MIPRO, 2015). It indicates that, the feasibility of production of self-propelled equipment (combine-harvesters, tractors, cutters, etc.), is dependent on the local production of diesel engines and the existence of specialized workforce. Both are not available in Ecuador. For these motives, it is not possible to have local competitive production of agricultural self-propelled equipment in the country.

On the other hand, it is highlighted in the study, that the segment of not self-propelled equipment (ploughs, harrows, drills, etc.) is simpler from the point of view of the productive process, it involves assembly and welding of metallic simple structures. The regular workforce of the metalworking industry is sufficient to satisfy the production of not self-propelled and there is no need of any other special element.

Considering the changes of area and productivity of the cultures with intensive mechanization (maize, rice, quinoa and potato), it is expected that the index of average mechanization weighted by hectare in the areas of intensive mechanization in 2025, grows 98%. The previous factors and the availability of inputs (steel, rubber, resins, etc.) create favorable conditions for the installation of a productive plant with the possibility of generating from 50 to 100 direct employments. With the amount projected of approximately of 70 million USD for the year 2025, it is supported the position of the segment as smallest of agricultural equipment inside the prioritized industries.

Table 2 Mechanized labors in productive cycles of some crops. 2017-2016

Crop	Mechanized labor, % Soil preparation	Sowing	Weed control	Fertilization	Harvesting
Quinua (2016)	98	4	2	2	-
Paddy rice (first four-month period, 2017)	89	24	9	21	58
Paddy rice (third four-month period, 2017)	93	7	18	0	77
Potato (2017)	89	0	1	3	0
Soy (2017)	79	38	24	14	18
Dry hard maize (2017)	39	38	16	14	27

Source: Reports of crop yields, 2017, MAG/CGSIN/DAPI; Monteros Guerrero. A. 2016
Elaborated by authors

Conclusions

- The agricultural Ecuadorean sector shows significant lags in the incorporation of machinery and new technologies for the small and medium producers, which lack the financial resources to acquire the machineries that they need. Most of them contract the services of soil preparation to informal contractors who offer a rudimentary and general service for all the farmers. The lack of machinery adaptable to the ecological and topographic conditions of the country, especially of small-scale farms, in hillside and dedicated to horticulture is highlighted.
- Big farmers, who are the minority, possess agricultural own machinery and modernize them constantly with the last technological available advances, principally in basic products of the country exports.
- High percentages of mechanization in soil preparation in cultures of rice, quinoa and potato, as well as in rice harvesting are evidenced. Whereas, the mechanization of the sowing, fertilization and weed control brings minor percentages and in some cultures it is void.
- Ecuadorian agriculture is highly dependent on some countries, principally on China, Brazil, The United States and Italy, as for the import of agricultural machinery. The industry of agricultural machinery in Ecuador, has not the local production of diesel engines and the existence of specialized workforce, which prevents to have competitive national production of agricultural self-propelled equipment. Favorable conditions exist for the installation of a productive plant for not self-propelled equipment (ploughs, seeders, cultivators, etc.).

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Mechanization of Cassava Cultivation (Manihot Esculenta L., Cranz) in Venezuela in View of Its Physical-Mechanical Properties

by

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Abstract

In Latin America, cassava is one of the most demanded agricultural product However, in most countries, rudimentary methods persist in harvesting, which is considered low in productivity. The objective of this research is to propose the main technological requirements for the mechanization of cassava cultivation (*Manihot esculenta* L., Cranz) in Venezuela in view of its physical and mechanical properties. In line with this, height of the plant (Htp), total mass of the plant (Mtp), maximum root length (Lrm), average diameter of the root (Dpr) and the resistance to extraction (Re) were determined in both varieties of cassava (*Manihot esculenta* L., Cranz var. *La Reina* and *Paigua Negra*). The results showed the main geometrical and energetic requirements for the correct selection of the machinery system to be used. Furthermore, some phenotypic differences of interest between the two cassava varieties are studied.

Keywords: cassava physical-mechanical properties, cassava mechanization.

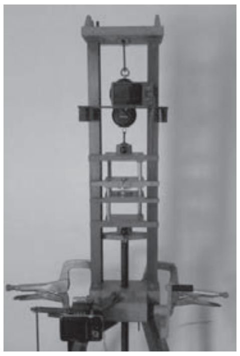
Introduction

The agricultural mechanization in the world has allowed a substantial increase in the work capacity, production, quality and reduction in human labor. For reasons of optimizing the administration of the agricultural machinery, establishing organization methods that assure the correct use of the mechanization means, increasing productive efficiency and guaranteeing that the machines fulfill their work with high quality and energy efficiency, it is necessary to carry out a detailed study about the cultivars properties and those main types of machinery available for its mechanization (Paneque & Soto, 2007; Dirven 2004; Araya & Quesada, 2000; Donoso, 2007; FAO/CIMMYT, 2018; Mrema *et al*.,2018; Cortés *et al*., 2010).

The knowledge in the physical-mechanical properties of agricultural products is important for the production systems mechanization, adaptation and operation of machinery, designing and constructing storage structures, assembling adequate transport systems, and packaging design and quality analysis (Buitrago *et al*., 2004; Ospina & Ceballos, 2002). On the other hand, cassava (*Manihot esculenta* L., Crantz) is one of the main products of productive interest in Latin America. Being a plant native to tropical America, it is regarded as a staple food by 17.8 million people in the world. Other than that, it is considered a crop with high potential for different industries (FAOSTAT, 2010). It is even included as a strategic item within the national economy plan up to 2030 in Venezuela (MCTI, 2014).

The mechanization of cassava cultivation is one of the main needs of agriculture in the southern region of Anzoátegui State, due to its demand as food in national and international markets and its application in the oil industry. The majority of the cassava production takes place in a country where indigenous communities are widely represented, consisting of small, medium and large farms. The indigenous communities have been practicing traditional methods for cassava production, thus, they lack modern and smart mechanization. Different researchers found that the different stages in using manual methods decrease productivity and dehumanize the process (Petrocelli, 2015; Ceballos & De la Cruz, 2002; Cáceres & Soto, 1997).

Cassava is a product that has been produced worldwide and its characteristics vary from one region to another depending on the climatic conditions, varieties planted, types of soil and topography. The most important cassava varieties cultivated in this region are *La Reina* and *Paigua Negra*, which is well-known by the producers. Unfortunately, they have very little knowledge about the physics and mechanical properties of those varieties that define the conditions for the complete process mechanization. Hence, this study is focused on proposing the main technological requirements for mechanization of the cassava production, according to its physical-mechanical properties in the state of Anzoategui, Venezuela.



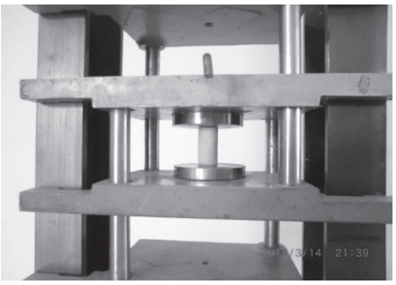


Fig. 1 Durometer used during the mechanical rehearsals of cassava specimens[BPM1][A2]. Griffini model, 2000 ± 0,01N, for laboratory.

Materials and Methods

Sampling and Determination of Physical and Mechanical Properties

The normal grid method was applied in a 1.5 ha of land where 20 plots and 20 cassava plants were extracted (one plant per plot, and the biggest three roots per plant) per each studied variety, *La Reina* and *Paigua Negra*, respectively. After that, the physical-mechanical properties were determined, according to the methodology proposed by Ospina & Ceballos, (2001) adjusted to the CATIE manuals (1981); Mohsenin (1970) and (Yirat, 2009).

The properties are determined by means of a digital scale model PCE-PCS 30 up to 30 kg ± 1,5 g; tape measurement (7m); dynamometer (Model PCE-FB 500 with precision 500 N 50 kg/ 0,1 N (10 g)), a stainless steel inclined plane and a durometer Griffini model, 2000 ± 0,01N, for laboratory. Using 20 cassava specimens (total of 20 per variety, one per root) of cylindrical shape, length 21,4 mm (**Fig. 1**), was determined the friction coefficient, while the bark rupture strength (Rc) (by puncture test) measurement was performed following the universal

Table 1 Comparative analysis of physical - mechanical properties of cassava

Variety	Mtp* (kg)	Htp* (m)	Dcr* (m)	Lmr* (m)	F (Mpa)	Rr* (Mpa)	Rrc (Mpa)	μ	Re* (kN)
La reyna	11.26	1.67	0.92	0.61	0.25	0.90	5.71	0,41	0.83
Paigua Negra	5.63	1.89	0.55	0,36	0.29	0.63	3.96	0.39	0.34

Total mass of the plant, (Mtp); Total height of the plant, (Htp); Diameter of the complete roots set, (Dcr); Length of the largest root, (Lrm); Resistance to extraction, (Re);
Friction coefficient, μ; Root compression strength, (F); Root rupture strength, (Rr);
Bark rupture strength, (Rrc); significant differences (*)

Magness-Taylor principle at room temperature (Adetan *et al.*, 2003); later from these previous specimens, using a metallic device with 10.8 mm of diameter were obtained 20 other cylinders without bark, for root compression strength (F) and root rupture strength (Rr) test (by compression between parallel plates) using the same principle.

Data Processing and Analysis

The data obtained from the experimental tests were processed using the specialized software STATGRAPHIC 5.1® to obtain the average values for the studied properties in both varieties. The linear regression technique was applied to obtain the dependency relationship between some properties of interest while a variance analysis was performed to determine if there are significant differences between the two varieties.

Results and Discussions

Physical and Mechanical Properties

The results showed significant differences between the two varieties in most of the properties analyzed, with p-value around 0,03 in those for a confidence level of 95 percent. **Table 1** shows the average dimensions by variety in the Anzoátegui region, in correspondence with the studies carried out by Petrocelli, 2015. The dimensions of La Reyna exceed the *Paigua Negra* in properties such as: total mass of the plant (Mtp), total height of the plant (Htp) and diameter of the complete roots set (Dcr), reaching a difference of 5.63 kg, 0.37 m and 0.25 m, respectively. In case of the total height of the plant Htp, the *Paigua Negra* rises up above La Reyna in 0,22 m. The knowledge of this last property is especially important to establish the regulation of the cutting height during the defoliation process before passing to the mechanized harvest. In this case, the cutting has to be regulated at heights between 1.5 and 2 m.

Properties like the total mass of the plant (Mtp), the diameter of the complete root set (Dcr) and the length of the largest root (Lrm) provide information about the total area covered by the plant below the ground, the working width of the extraction tool and also the number and containers dimension to be used during product transportation.

Analyzing mechanical properties, the coefficient of friction (μ) of the samples with respect to steel was 0.41 and 0.39 per variety, which corresponds to those reported by Padonou *et al.*, (2005) for agricultural products that range from 0.30 to 0.65; this indicates that during the design of machinery, technology can work with both varieties satisfactorily, based on the same criterion according to Villaseñor, (2005).

The La Reyna appeared to be less vulnerable to mechanical damages according to the average bark rupture strength (Rrc), exceeding the *Paigua Negra* variety by 30 percent. However, during peeling stage the higher Rrc value has a negative effect since it is also superior in size, in proportion to the weight of the bark and root diameter, as evaluated by Adetan *et al.*, (2003). On the other hand, in relation to the Root compression strength (F) per variety, by compressing 3 percent of the length of the test cylinder, *Paigua Negra* variety (0.29 MPa) exceeded La Reyna (0,25 MPa) by 13.8 percent, contrary to the results achieved in the Root rupture strength, (Rr), with 0.63 and 0.90 MPa, respectively. This behavior, although both roots have a slightly fibrous tissue, shows that the *Paigua Negra* responded to be more fragile from being less resistant to blows and cutting. These results influenced product handling and its response to mechanical damage, as expressed by Mohsenin, (1970) about biological materials when they are under the effect of static and dynamic loads.

The average resistance to extraction (Re) per plant was 0.83 and 0.34 kN for La Reyna and *Paigua Negra*, respectively. It is this property that defines the machinery power requirements during each labor, the technology and energetic cost and other aspects that depend on them namely fuel consumption

In addition, the results showed a strong relationship between the resistance to extraction (Re) and the total mass of the plant (Mtp) and root set (Mcr) in both varieties, with R^2 values ranging between 0.72 to 0.77 which indicates that variation in both varieties is explained mostly by exponential models (**Table 2**).

General technological requirements for the mechanization of cassava cultivation in Venezuela.

General Technological Requirements for the Mechanization of Cassava Cultivation in Venezuela

In the South American region, the common cassava seedling technique is in form of stakes, with a tendency to use semi-mechanized technologies, even when large areas are planted. Taking into account the soil characteristic in the area (sandy soil), it is recommended to plant the cassava with vertical stake at a depth of 0.005 m, for both varieties, even though the investigations

Table 2 Models that establish the relationship Re vs. Mtp and Re vs. Mcr of each variety

Variety	Related properties	Models	R^2
La reyna	Re vs. Mtp	$y = 70{,}02e^{1{,}034x}$	0.76
	Re vs. Mcr	$y = 298{,}3x^{-133{,}4}$	0.72
Paigua Negra	Re vs. Mtp	$y = 74{,}24e^{0{,}270x}$	0.73
	Re vs. Mcr	$y = 114{,}4e^{0{,}506x}$	0.77

suggest that the depth should not exceed 0.010-0.015 m and should have 3 to 5 knots, (Petrocelli, 2015). In addition, with the use of semi-mechanized planting , it is possible to use machines with the capacity to cover 2 or 3 rows simultaneously, spaced 1 m in between, as shown in **Fig. 2**. For the variety *Paigua Negra*, it is recommended to use a lower planting frame between 0.8 and 0.9 m, for increasing yield per hectare.

Harvesting or extraction from the ground must be done mechanized, reaching depths of up to 0.25 m in two rows simultaneously covering a working width of approximately 2m, considering the diameter of the complete roots set (Dcr) less than 0.9 in both varieties. The machine must have an average constant speed of 4 km/h, coupled to an energy source able to overcome a maximum resistance per furrow of 0,86 kN. For this purpose, there are semi-integral and integral machines (**Fig. 3**).

In the agro industrial processing of the product, during peeling, it is suggested by operation principle that the friction force should be between the cassava bark and the metal blades and have a capacity to process roots with diameter between 0.045-0.070 m (**Fig. 4**). The technology selection satisfy the parameters obtained during the root rupture strength (Rr) and bark rupture strength (Rc) tests, having as energetic source of an electrical or internal combustion engine with a working speed that oscillates between 70 - 90 rpm (Petrocelli, 2015), (**Fig. 4**).

In the case of the milling process, the power requirements that generate the compressive and rupture strength of both varieties must be satisfied, exceeding 700 rpm to achieve adequate shredding (**Fig. 5**).

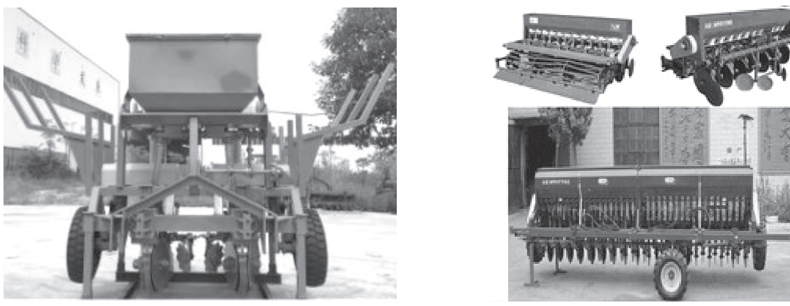


Fig. 2 Some prototypes of machines for planting cassava.
Source: [A5]https://spanish.alibaba.com/g/cassava-seeder.html

Fig. 3 Some prototypes of implements for cassava harvest with work tools in form of bolts and bars.
Source: http://www.planticenter.com.br/productos
https://spanish.alibaba.com/trade/search?fsb=y&IndexArea=product_en&CatId=&SearchText=cassava+harvester&viewtype=G

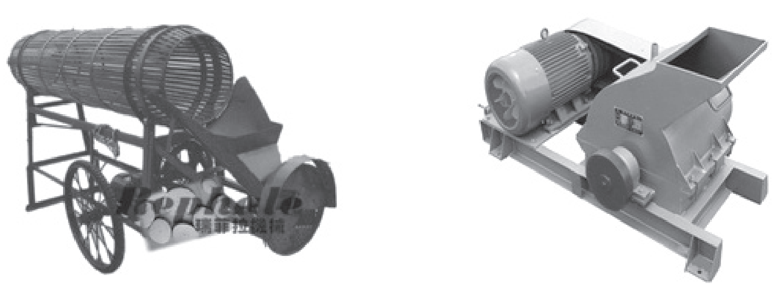


Fig. 4 Machine prototypes for cassava peeling or debarking. Source: https://spanish.alibaba.com/trade/search?IndexArea=product_en&CatId=&fsb=y&SearchText=cassava+peeling+or+debarking

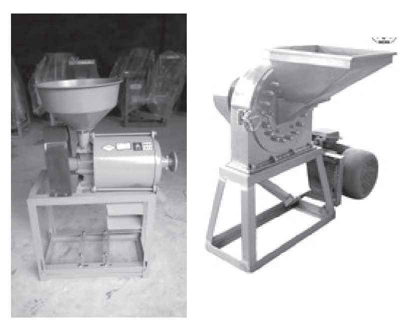


Fig. 5 Some machine prototypes for cassava milling
Source: https://spanish.alibaba.com/trade/search?IndexArea=product_en&CatId=&fsb=y&SearchText=cassava+milling

Conclusions

Physical and mechanical properties of cassava varieties (*La Reyna* and *Paigua Negra*) are in a range that satisfied the main technological requirements for the mechanization of cassava cultivation in Venezuela.

The results obtained in this study could be helpful in technology designing and administration as well as for the development of a technology transfer strategy to improve the efficiency during cassava planting, harvesting and post-harvesting processes.

Proposed methodology could be enabled to provide suitable opportunities for large-, medium- and smaller-scale farmers compatible with local economic, social and developmental conditions in Venezuela.

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■■

Abrasive Wear Assessment under Laboratory Conditions in Disks of Tiers Used in Venezuela

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Abstract

In Latin America, the conventional method in soil tillage is generally carried out with farm instruments coming from Brazil, Argentina and United States, which are mostly employed in abrasive soils. The objective of the investigation is to determine the behavior of hardness and abrasive wear resistance in Argentinean, Brazilian and North American disks of tiers used during soil tillage at José Inacio Abreu e´ Lima Company, Anzoátegui, Venezuela. The wear rehearsal was carried out to 18 specimens (6 per type of disk) in a conventional device for metal roughing and smoothing at constant revolutions (100 rpm), under three different loads (70, 90 and 130 N) using the soil as abrasive material. Hardness is determined using an automatic harness and the wear was measured through the loss of mass. The hardness average for the Argentinean, Brazilian and North American disks was 105.17, 930.03 and 100.47 HRb, while the loss of mass as a consequence of the abrasive wear was of 0.06, 0.60 and 0.20 g, respectively. The adjusted models for the mass losses in the disks of tiers denote a lineal increment in the abrasive wear with the increase of work time and the increase of the interaction force soil-specimen under laboratory conditions. This study can constitute an important reference for manufacturers and importers of this kind of implements in the region.

Key words: wear, abrasive, disks, tiers

Introduction

The wear associated to hard micro particles, fibers or hard and rough bodies that is present in several tribological systems brings serious consequences for the economy of many countries every year (Kushwaha & Shi, 1991; Fielke *et al.*, 1993; Bhakat *et al.*, 2004; Bayhan, 2006; Pérez, González & Toro, 2010). This constitutes a constant problem around the world because it generates high economic losses. In countries like Canada, Australia and Turkey, it has been estimated that these losses oscillate between 20 and 50 million dollars (Bayhan, 2006; Pérez *et al.*, 2010). The costs generated by the abrasion are even accentuated in underdeveloped countries since the reinstatement is much more onerous due to the cost of the imports.

Bhakat *et al*. (2004), expressed that in the specific case of agricultural tools, their failure is associated to the wear caused by abrasion of soil, which influences directly the loss of its original shape, dimensions and, consequently, the labor quality and productivity. Furthermore, the agricultural tools are usually less effective during overgrowth control, tilling and planting, which could increase traction requirements and losses in time from repair (Bayhan, 2006). The organs (means) of work in the tillage implement are subjected to abrasive wear during their interaction with the soil. It occurs due to a micro cut mechanism or detachment of small volumes of their metallic surface, to the detachment due to the plastic flaw of the metal superficial layers and for the detachment of the rusty layers of this surface. Aspects like organizational and human factors are related directly with the utilization and constructive characteristics of tillage tools (Sánchez 2010; Herrera, 2010).

Different authors Hutchings (1992), Rodríguez (2009), Alcántara, Ferníndez & Rodríguez (2013), have studied the main causes of wearing in tillage tools and they have made some recommendations to increase the useful time of their work organs. In all cases, it was highlighted that the factoring materials of these farm tools influence their wear resistance.

Wear assessment of tillage toozls have traditionally used analytic and experimental methods, the latter being the mostly used, where it is recommended to consider the mechanical properties and the metallurgical structures of the tools. Regarding the mechanical and structural properties of the material, hardness, chemical composition and thermal treatments should be included. The ideal state would be that the tools have higher hardness levels than those of the abrasive material. However, even with that may potentially increase the tool fragility. Fortunately, with thermal treatments, it is possible to diminish fragility from further resistance to impact forces.

The behavior of several agricultural tools, as a cause of the wear, has been previously studied; nevertheless, there is not enough information related with the disk tiers (Hossne, 2004; Hossne, 2006 and Rodríguez, 2009). In Venezuela, this kind of agricultural tool is vital in soil preparation and is widely used in the productive area named Mesa of Guanipa, of which is the site for a national project for intensive planting of soybeans. Consequently, there is a need to carry out studies about the resistance to the abrasive wear and the quantification of the losses for such cause.

Taking into account the importance of the wear in tillage tools and the necessity to continue investigating this problem in Venezuela, the present work is focused on the assessment of the behavior of the hardness and the resistance to the abrasive wear of disk tiers from Argentina (Model Inaagro 1BQX), Brazil (Model Bellota InPHlniun) and USA (Model 670 Hard-flex) used during soil tillage at José Inacio Abreu e´ Lima Company.

Table 1 Physico-chemical properties of the Mesa Guanipa soil

Physico-chemical Property	Value
pH	4.5-5.1
Phosphorus	<5 µg/g
Calcium	10-70 µg/g
Magnesium	5-60 µg/g
Potassium	10-30 µg/g
Iron	0.5-30 µg/g
Copper	0.1-0.7 µg/g
Manganese	0.5-12 µg/g
Zinc	0.1-1 µg/g
Organic matter	0.1-1.3 %
Electric conductivity	0.1-0.3 ds/m

Source: INDER/INIA (2012)

Materials and Methods

Abrasive Material Collection

The soil samples (abrasive material) were taken in the integral company José Inacio Abreu e´ Lima, located in Simón Rodríguez municipality Edo. Anzoátegui corresponds to a productive area, which is specifically at the 8° 55’ 19 ‘’ North latitude, and at the 64° 26’ 2 ‘’ West longitude, 350 m above sea level,. The soil collection was performed by opening a soil profile of 60 cm wide and 60 cm depth in three horizons (different depth): horizon TO (depth 0 to 15 cm), horizon B (depths 15 to 30 cm) and horizon C (depths 30 to 50 cm). Soil collection sites were selected from three layers coincident with the transition horizons to obtain 18 kg of soil divided in 9 samples (three per horizon, 2 kg per nylon bag). All collected samples were taken to the laboratory for further analysis. The mass was measured using an electronic scale LG-1001[a] with maximum capacity of 2,500 g ±0,1 g.

The samples were blended and sieved using different sieves (0.30, 0.250, 0.212; 0.150 mm) according to standard ASTM E - 11/95 to standardize the abrasive material particle size (ASTM, 2000). Some of the soil physical and chemical properties are shown in **Table 1**.

Abrasive Material Humidity Determination

The determination of the humidity in the abrasive material was carried out through the gravimetric method using an automated convective stove model Venticell operated within the temperature range =10-400 ºC to obtain a humidity lower than 0.05%, which is according to ASTM G 65 standard (ASTM, 2000).

Test Sample Specimen Obtaining

Test sample specimens were taken from the areas vulnerable from abrasive wear, which is 50 mm away from the external border, avoiding the disk edge area. A total of 18 samples of sizes 30 × 30 mm was obtained, of which 6 samples were from each type of disk (3 per disk, separated around their diameter at 120o between them) according to their respective origin (Argentinean, Brazilian and North-American). Using a revolvable circular saw for metals, the cutting process was accompanied with a coolant liquid (it dilutes) to conserve the original structure of each metal disk.

Material Hardness Determination

To obtain the hardness of the test sample material for each type of selected disks of tiers, an automatic harness Rockwell 963-231D was used, which belongs to the laboratory of metallurgist in PDVSA Company at San Tomé. Once all sample surfaces were cleaned with a dry cloth, the device was gauged with a sample pattern. Then, the indentations in different areas of the smooth surface of each sample were carried out using HRb scale. There were 6 test samples for each disk mark, 3 measurements in each of them for a total of 18 measurements for each type of disks.

Abrasive Wear Assessment

The test was based on the procedure C recommended in the standard ASTM (2000). For the available materials, the load should be between 45 and 130 N with a minimum testing time of 60 min. The selected forces were 70; 90 and 130 N, at constant revolutions (100 rpm); the abrasive material was substituted (0.5 kg) every 10 minutes to avoid decrease of particle size. The wear determination was performed by means of the loss of mass of each specimen based on the theory of the abrasive wear ASTM handbook (2000). The test samples were weighed before and during the wear tests, in an interval of 10 minutes until the completion of an hour of experimentation for each value of force, using an electronic scale AND model of maximum capacity of 120 g ±0.0001.

This rehearsal was carry on with a conventional apparatus of metallographic smoothing for determination of the abrasive wear resistance in the different specimens, a machine with a rotational disk (Struers brand- model Labopol), having maximum rotation frequency of 500 rpm with a holder arm of 250 N maximum capacity, which applies the load perpendicular to the disk surface by means of screws. The duration of the abrasive wear assessment was 60 min.

Table 2 Characteristics of disk tiers according to the country of origin

Country of origin	Brand and model	Characteristics
Argentina (ARG)	Inaagro 1BQX-1.3	No. Disks: 14 Diameter: 18 inches Hardness: ≥ 90 HRb Thickness: 5 mm Arrow: 90
Brazil (BRA)	Bellota Amazone InPHlniun	No. Disks: 12 Diameter: 24 inches Hardness: ≥ 55 HRb Thickness: 6 mm Arrow: 70
United States of America (USA)	670 Dura-flex	No. disks: 32 Diameter: 22 inches front section and 24 the back one Hardness: 90% and 110 HRb Thickness: 5 mm Arrow: 120

Source: Medina (2017)

Table 3 Descriptive statistical results obtained during the mass measurement per test specimens according the disks origin

Applied Force (N)		Argentinean	Brazilian	North American
70	N	6	6	6
	Minimum (g)	22.46	25.87	24.58
	Maximum (g)	22.47	26.00	24.62
	Arithmetic mean (g)	22.46	25.94	24.59
	Standard Desv.	0.03	0.05	0.05
90	N	6	6	6
	Minimum	22.41	25.37	24.47
	Maximum	22.46	25.50	24.58
	Arithmetic mean	22.44	25.45	24.54
	Standard Desv.	0.02	0.05	0.04
130	N	6	6	6
	Minimum	22.38	25.32	24.37
	Maximum	22.43	25.37	24.41
	Arithmetic mean	22.41	25.35	24.39
	Standard Desv.	0.02	0.02	0.02

Results and Discussion

Hardness Test Result

The average hardness reached values were 105.16; 94.03 and 100.46 HRb for the Argentinean, Brazilian and North American disk tiers, respectively. Brazilian tier disks had the lowest hardness, while the Argentinean and North American disks reached values of over 100 HRb, which presupposes smaller levels of wear under real conditions of utilization. In all cases, the values agree with those given by the makers in their technical specifications for each case, in this study. The characteristics of the principal disk tiers used in Venezuela are shown in **Table 2**.

Abrasive Wear Behavior

Table 3 shows the descriptive statistical results obtained during the mass measurement per test specimens based on the disks origin. The maximum values of standard deviation belong to the initial mass of each specimen. As it can be observed, each kind of disk presents different initial mass when the experiment starts, which is a consequence of the material and the superficial finished that differs for each disk type in the successive stages of experiment. The minimum value of mass was concluded from the experimental measure, which was taken 60 minutes later for each force measurement. The last value was taken as the initial mass for the next experiment according to each force used.

The mean loss of mass, due to the abrasive wear during the whole experiment, was of 0.06; 0.60 and 0.20 g, for the Argentinean, Brazilian and North American disk tiers, respectively. In addition, the obtained losses of mass are represented in the function of the applied loads, **Fig. 1**, is presented to show high exponential correlation among these magnitudes.

The mass loss and the applied force denoted a strong and inverse dependence adjusted to an exponential model with determination of coefficients were 0.999, 0.877 and 0.995, for the Argentinean, Brazilian and American disks, respectively (**Fig. 1** and **Table 4**).

This research has demonstrated the influence of the material type and the applied load on the abrasive wear, which arises in soil tillage tools in Latin America. Moreover, it was confirmed that increasing the hardness increases the wear resistance too, coinciding with Kruschov (1974), whose research results showed a linear relationship. The differences in the mass loss obtained in each rehearsal infer that the abrasive wear in each sample takes place in a different way, which, under identical experimental conditions, is only attributable to the structural particularities of the material the disks are made of. This completely agrees with the results obtained by Herrera *et al*. (2010), Nalbant & Palali (2011) and Kushwaha & Shi (1991). Finally, it was found that Argentinean disks composition showed the highest resistance to abrasive wear, while the Brazilian had the least resistant.

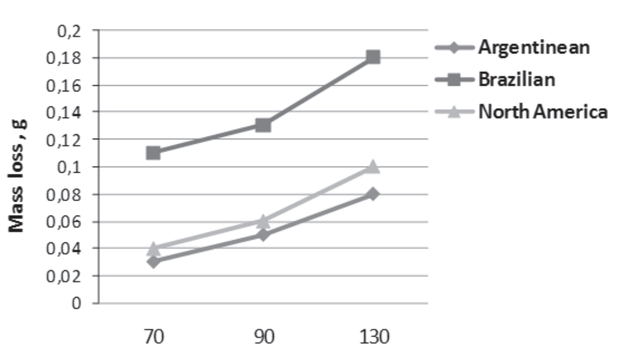

Fig. 1 Relation between mass loss and force for each type of disk

Table 4 Regression analysis between the loss of mass and the force applied during the experiment

Country of Origin	y	R^2
Argentinean	0.018e0,490x	0.999
Brazilian	0.081e0,246x	0.877
North American	0.024e0,458x	0.995

Conclusion

Through this research, it is possible to conclude that the average hardness of the tested disk of Argentinean tiers Inaagro 1BQX, Brazilian bellota InPHlniun and North American 670 Hard-flex models were 105.17; 93.03 and 100.47 HRb, with mean wear during the test of 0.06, 0.6 and 0.2 g, respectively. An exponential relationship was found when abrasive wear increased as the interaction forces increased under laboratory conditions. Based on technical approaches and the present study results, the Argentinean prototype of disk tiers is most advisable for intensive soil tillage in sandy soils. Therefore, Argentinean disk tier is recommended to be used in the Guanipa Mesa at Anzoategui state in Venezuela.

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Future Trends in the Chilean Agricultural Machinery Industry

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CHILE

Abstract

The principal objective of this work is to identify the future trends in the agricultural machinery industry according to the specific features of the Chilean production systems. These features are related to the different weather conditions along the country as well as the fragmentation degree of the agricultural productions, aimed mostly to the export market. Government policies support the mechanization of small farmers according to their requirements. The research on agricultural mechanizations is carried out by universities supported by enterprise or governmental funds, aimed to develop automated and robotics systems.

Introduction

According to Chile's National Institute of Statistics (INE) 2017, Chile's demographics shows a trend analogous with countries having relatively greater development, of which have birth rate reduction, increased life expectancy (80 year) and a decreasing rural population (13 percent), which, overall, affect the workforce availability and increasing costs. Chilean farms are typically small size, in fact, 73.4 percent of farms are smaller than 20 hectares, while 19 percent are between 20 and 100 hectares, and only 7.6 percent are larger than 100 hectares. Nevertheless, when they are characterized by surface, 93 percent of the areas are properties larger than 100 hectares, while only 2.4 percent of the total area is distributed among properties of less than 20 hectares (ODEPA, 2017). Regarding the ownership of the land, they are distributed as follow: 75 percent for enterprises, 19 percent for men and only 6 percent women. These features of the Chilean agricultural production system indicate that there are different worlds in the same country, one with bigger areas and highly competitive, which leads to the export market, and small farms, with the owner sharing their time between the agricultural activities in their farm and others bigger farms. This second kind of agriculture is characterized as to be survival agriculture, with low degree of mechanization and technical expertise. This is the reason why the Chilean government maintains the Institute for Agricultural Development (INDAP), a state organization that executes the policies for bringing technical support and funding to induce a change in the production paradigm of these small-scale farmers.

Notwithstanding, the agriculture sector has tackled difficulties such as scarcity of workers, high labor wages and energy costs, a drop in international prices, and adverse climate conditions. However, growth in the agriculture sector was observed to be approximately 3.1 percent in 2017, which is nearly double the rate of the country's overall projected GDP growth of 1.6 percent. Recently, in February 2018, the agricultural sector grew 3.7 percent, which is 0.4 percent more than the Chilean average economy (ODEPA, 2018).

In the context of the difficulties mentioned, agricultural companies and farmers have decided often to repair and maintain existing equipment rather than investing in new ones or taking the option of purchasing emerging brands from China. Nevertheless, the incorporation of agricultural equipment and technologies remain as the best option,

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given Chile's agricultural export industry, which is one of the top 10 producers worldwide—remarkable, for a country with just 17 million people (Lathrop, 2018).

Due to the heterogeneous composition of the Chilean agriculture and the lack of an updated agricultural census (last date from 2007), the annual crops (grains, potatoes, industrial crops) are not considered in this paper. Instead, it focuses in the new trends on production and their mechanization requirement; nevertheless, it includes the major trends in viticulture and fruit culture (**Table 1**).

In order to characterize the current mechanization situation, a number of questions related to the problems and requirements of the farmers were answered.

Current Status

Can Farmers Use Their Machinery Without Difficulties Such As Long Distance or Lack of Repair Parts?

Due to the Chilean geography, most of the agricultural activities are developed in the Central Valley, which is no more than 150 km wide. Through the middle of this valley runs a highway populated by small cities every 20 km and major cities every 50 km. Consequently, farmers in the worst case scenario need to travel for 30 min to a repair shop and has the possibility to obtain repair parts from major cities. Depending on the kind of parts, it takes 24 to 48 hours to get it.

Is There Any Government Programs/Policy to Promote Agricultural Mechanization?

There are short time programs aimed at small farmers. For example, the INDAP through the Local Development Program (PRODESAL), between 2010-2013, delivered 265 tractors and 1700 motocultivators (**Fig. 1**). Recently, two programs, the Investment to Productive Strengthening (IFP) and the Indigenous Territorial Development Program (PDTI) are active programs aimed to encourage the farmers associative work. Furthermore, these programs allowed the timely development of agricultural work, optimization of time, reduction of costs and improvement of yields, making possible the productive development of indigenous lands (**Fig. 2**).

What Type of Machinery Is in Demand, But Is Not in The Market?

There is a growing demand for small equipment for weed control intended to be operated in greenhouses and small organics farms. Chile has different needs with respect to other South American countries. In fact, Chilean small farmers require smart machinery to apply localized pesticides, or similar is applicable with smart machineries directed to organic farming practices. Even the bigger-scale Chilean farmers require small power tractor

Table 1 Annual evolution of cultivated area in main fruit (2010 – 2017) (ODEPA, 2018)

Species	2010 (ha)	2011 (ha)	2012 (ha)	2013 (ha)	2014 (ha)	2015 (ha)	2016 (ha)	2017 (ha)	Variation (%) 10/17	Participation (%)
Table grape	52,655	53,851	53,523	53,727	52,234	48,593	48,582	48,202	-8.5	15.3
Walnut	15,451	16,254	18,256	18,989	24,404	27,941	30,964	35,277	128.3	11.2
Avocados	34,057	36,388	35,679	36,355	31,727	29,908	29,933	30,078	-11.7	9.5
Red apple	27,633	27,633	28,811	29,888	29,698	29,081	29,168	29,052	5.1	9.2
Cherry trees	13,143	13,174	15,198	16,243	16,933	20,591	24,498	25,109	91.0	8.0
Olives	12,874	15,091	16,650	18,307	19,737	20,221	20,343	21,904	70.1	6.9
European plum	12,442	12,456	12,883	12,583	11,796	11,988	11,952	12,001	-3.5	3.8
Peach canning	10,676	10,662	10,722	10,643	10,140	9,521	9,481	9,173	-14.1	2.9
Kiwis	10,922	10,920	11,916	11,086	10,632	9,717	8,866	8,720	-20.2	2.8
Pear	6,225	6,547	6,720	7,185	7,299	8,537	8,781	8,671	39.3	2.7
Almond trees	7,617	8,545	8,621	8,548	8,569	8,089	8,113	8,341	9.5	2.6
Green apple tree	7,396	7,396	7,768	7,657	7,509	7,124	6,895	6,884	-6.9	2.2
Orange trees	7,435	7,839	8,004	7,836	7,452	6,686	6,766	6,659	-10.4	2.1
Lemon trees	7,235	7,106	7,714	7,094	5,993	5,905	5,911	6,297	-13.0	2.0
Nectarines	5,376	5,350	5,317	5,338	5,209	5,340	5,339	5,101	-5.1	1.6
Japanese plum	6,209	8,545	6,047	5,971	5,612	5,352	5,326	5,030	-19.0	1.6
Fresh consumption peach	3,249	3,224	3,205	3,204	2,787	2,019	2,015	2,000	-38.5	0.6
Damasks	1,469	1,405	1,234	1,406	1,094	886	887	753	-48.8	0.2
Other fruit trees	25,426	26,078	36,597	38,001	38,218	39,087	45,706	46,483	82.8	14.7
Total	267,491	278,462	294,865	300,061	297,044	296,587	309,528	315,735	18.0	100

as compared to Argentina or Brazil.

Main Information Sources

The main sources of information are the VII National Agricultural Census of 2007, the Ministry of Agriculture, the Institute of Agricultural Research (INIA), the Office of Studies and Agricultural Policies (ODEPA), the Center for Information on Natural Resources (CIREN-CORFO), the Machinery Importers Association, agricultural mechanization experts of Chilean universities, and managers of agricultural enterprises.

Fig 1 Representative of INDAP delivers a moto-cultivator to farmer. (Castro, 2016)

Fig. 2 Representative of INDAP delivers a tractor and balers machine to the indigenous community (Troncoso, 2019)

Characterization of the Weather Condition

Due to its geographical characteristics, Chile has various climatic conditions throughout its diverse regions (Novoa y Villaseca, 1989). From arid to semi-arid weather conditions in North and Central -north regions to Mediterranean in Central and South Central regions.

Characterization of the Chilean Demography

According to INE (2018), the workforce at country level was 7,697,297 in 2007 and 8,627,665 in 2016, meanwhile the agricultural workforce dropped from 747,989 in 2010 to 728,663 in 2017. That means a reduction of the agricultural workforce, although there was massive incorporation of immigrant workers in the last five years.

Characterization of the Chilean Agricultural Machinery

According to Mac-Carte (2017), the Chilean import machinery market grew from US$ 73 million in 2009 to US$ 272 million in 2013, turned out tripled in the last five years. These numbers are higher than the GDP of the sector that grew at annual rates of 6.7 percent and that the agricultural input market did so at rates of 12.5 percent per annum. The main machines imported in 2013 were tractors, covering 45 percent of the total with a value of US$ 122 million, followed by grain harvesters (16 percent). Chilean customers are accustomed to competitive prices due to the openness of the economy. Moreover, because of the country's economic condition, machineries increased their price—sensitivity, given opportunities to emerging brands from China. The analysis of machineries evolution by categories over time showed that tractors have grown their imports market shared by 6 percent, from 47 percent in 2009 to 53 percent in 2014, unlike the harvesters that was reduced by 7 percent, from 22 percent to 15 percent between the same period.

On the other hand, imports of tractors with diesel engines of less than or equal to 200 HP, between January and July 2017, were US$ 687.4 million while in the same period of 2018 they were US$ 71.6 million, which implies a fall of 90 percent. Moreover, imports of diesel-powered tractors with power over 200 HP were US$ 137 million between January and July 2017, while for January to July 2018 they reached US$ 168 million, which means an increase of 23 percent (Servicio Nacional de Aduanas de Chile, 2018).

Table 2 Working day demand per cultivar (SNA, 2018)

Cultivar	Area (Ha) 2007	Area (Ha) 2016	Harvest (Working day/Ha)	Working day by cultivar 2007	Working day by cultivar 2016	Growth (Working day)
Apple	34,972	36,063	40	1,398,887	1,442,528	43,641
Avocado	26,759	29,933	40	1,070,360	1,197,320	126,960
Blueberry	5,665	15,801	250	1,416,140	3,950,125	2,553,985
Cherry	9,922	24,498	80	793,767	1,959,864	1,166,097
Japanese Plum	8,437	5,326	40	337,498	213,024	-124,474
Kiwi	8,347	8,866	80	698,691	709,304	10,613
Nectarine	6,819	5,339	40	272,772	213,560	-59,212
Orange	8,210	6,766	40	328,406	270,624	-57,782
Peach	13,152	11,496	55	723,358	632,302	-91,056
Pear	6,227	8,781	40	249,075	351,252	102,177
Table grapes	50,846	48,582	80	4,067,714	3,886,576	-181,138
Total	189,910	232,415		11,558,005	15,445,757	3,887,752

Results and Discussions

Evolution of the Cultivars and Its Areas

Berries, cherries and walnuts have experienced a strong growth in the last year (**Table 1**). Nevertheless to mention that according to mechanization experts, until now, there is a deficit of specialized machinery. Additionally, table grapes still have low degree of mechanization because of the intensive labor involvement (**Table 2**).

Need for Special Machinery

Berries harvesters for fresh fruit market

One of the key areas for the Chilean agriculture is the berries sector, more specifically the blueberries sector. The blueberries (*Vaccinium myrtillus*) markets have experienced a huge growth in the last decade, growing from 1000 ha in the year 2000 to almost 17,000 ha in the year 2018 (ODEPA, 2018). This production is aimed at fresh export market. In this way, this production demands a careful harvest due to the long travel time, to the final consumer. Nevertheless, Chile suffers a scarcity of workers, especially in the harvesting season. The reason why the industry demands for specialized harvest machinery is because it is not yet fully available in the international market. Because this is especially needed, it is only shared with Argentina, which has reduced blueberries production. All other countries are closer to the final market than Chile; thus, they can tolerate a superior level of mechanical damage without experimenting a significant loss of quality.

The present trend to solve the worker's scarcity is turning the production to the frozen products. This market has a high tolerance to the mechanical damage due to the short time between the harvesting and the frozen process. Consequently, that allows the introduction of mechanical harvesters. However, the orchards are not prepared to mechanical harvest because it is not as effective as needed. On the other hand, new plantations are designed to incorporate mechanical harvesters, so we envision the incorporation of more mechanical harvesters.

Flowers handlers

The Chilean government through INDAP has policies for productive reconversion from traditional small survivor agriculture to the flower's production in greenhouses. Therefore, there is a special need for small cultivators and mechanical handlers for the seeding nursery. Furthermore, this kind of agricultural machinery is mostly for aged people.

Chicory harvesters

Chicory is produced only in two narrow regions in the word. The first region covers the following countries namely Belgium, Holland and a small part of Germany. Whereas the second region is in the Central Valley of Chile. Nevertheless, these two regions have significant weather and soil differences. The European region has a snow season that prevents any kind of re-bloom of the chicory after its harvest. On other hand, in Chile, due to the soil condition that doesn't allow the extraction of the entire chicory's roots, and the absence of snow induces chicory's re-bloom when the second crop, in the annual rotation, is in its first growing stage. In consequence, a high power, high flotation harvester, with a special extraction mechanism for the deepest part of the root is specially needed in Chile.

Need for Smart Machinery

As aforementioned, the core of the Chilean agricultural production is aimed at the export market. In this sense, the Chilean agriculture produces under international normative and standard. On the other hand, Chile has a high level of phytosanitary control and is free from most of the plagues and diseases that affect its neighbors (SAG, 2018). Accordingly, one of the important tasks, the consumer awareness has risen regarding the pesticide application. Pesticides are widely used in Chile, aligned with the intensive production systems that the Chilean farmers conventionally use. For this reason, Chile needs smart machinery to reduce the use of pesticides, which for example allows application of herbicides specifically on weeds. Other example of smart machinery for pesticide application is the selective pesticide's application in fruit trees, where only the canopy is covered by the pesticide, avoiding the space between trees, and the precise application of hormones can be done for flowers or fruits. Considering the above-mentioned issue, the Field Robotics lab of the University of Concepción has developed prototypes of a system based on ultrasonic sensors, images and LIDAR to reduce the pesticides in vineyards and fruits trees.

Vine, Pruning Machine and Harvester

Chile has an extensive tradition in wine production taking into account its market demand in the domestic and export market. Chilean growers have incorporated modern technology to the different stages of production, being early technology adopters. Although they were the early adopters of harvesters and pruning machines, they had some adverse implications from the lack of trained operators and maintenance personnel.

Energy Efficient Machinery

In Chile, there is a need for energy-efficient machinery, in particular high power tractors, harvesters and equipment, since the cost of fuel is constantly arising. These kinds of machinery and equipment reduce time, production cost, energy in the extensive agriculture (Fernández, 2016) or small horticulturist (López, *et al*., 2009).

The Chilean agricultural productivity has increased in recent years and it needs to keep increasing. This implies increasing demand for new and higher efficiency machinery, technology or irrigation systems. To keep up with the international competitive market, the Government of Chile should continue to reduce production costs through application of modern agricultural mechanization (Lathrop, 2018).

Future Trend of the Chilean Mechanization

As a response to the challenge of increasing food production, researchers of Mechanization and Energy Department of the University of Concepción and several agricultural enterprises are working together in the use of automation and robotic technologies, aimed to control weeds by chemical and physical means. For example, a medium-sized robot, that identifies weeds by visible/infrared images, performs weed control by laser and herbicide with high precision and accuracy.

Moreover, robots and devices for selective spraying system have been patented (Correa, 2015). These systems are designed and developed to detect the canopy and reduce the pesticide use in vineyard. At the same time, these systems can provide on-the-go alerts and traceability data while dosage of pesticides, tractor speed, temperature, humidity, and wind speed of the pesticide application task has validated (Reyes *et al*., 2012). Nevertheless, in Chile this kind of technology will be applied gradually. Moreover, emphasis will be given on robotic equipment such as drones, unmanned tractors for planting (autopilot are widely introduced), harvesting, spraying, and weed control particularly in organic production. More mechanization and automation will be necessary to keep the actual growing rate due to the involvement of aged people in agriculture. Finally, the agriculture sector is one of the most vulnerable Chilean economic sectors from the adverse impacts of climate change (Ponce *et al*., 2014). Therefore, they will need a high degree of adaptability by developing their capabilities.

Final Commentaries

Chilean fruit culture depends on a variety of climatic events and the wide spectrum of crops. Due to its export market orientation, fulfilling and maintaining high production and quality standards is required, hence, the need of special agricultural machinery is obvious. The market has evolved into the incorporation of high-power tractor and high power harvesters, but at the same time, needs to incorporate a higher degree of mechanization in order to keep the competitiveness in production for the small-scale farmers. Government policies are aiming to improve the mechanization levels focused on small farmers through the introduction of moto-cultivators and equipment according to their specifics productions systems. Most of the researches are carried out by the universities aimed mostly to specific production problems like reduced use of pesticide in fruit trees and weed control for small and organics farmers.

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Present Status and Prospects of Agricultural Mechanization in Cuba

by

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Abstract

The present work was carried out with the objectives of analyzing the current status and prospects of agricultural mechanization in Cuba. To complete the stated objectives, an analysis was conducted of the current state of industrial and commercial areas in this sector, as well as of the policies established by the country's management in this regard. The study allowed concluding that the modernization of agricultural mechanization makes it possible to directly increase productive yields and increase technological efficiency in production processes. There is a need to strengthen the extension services of agricultural mechanization at all levels of agricultural production, as well as to boost local and artisanal industries, with the objective of diversifying production and reducing imports. Moreover, it was found out that the introduction of renewable energy sources and automation in agricultural processes constitutes a priority for the country's management and that the joint work among universities, research centers, companies and agricultural producers would constitute a strength. Lastly, it was confirmed that the compliance with ergonomic and safety standards of machinery to be introduced under production conditions need to be certified and checked by a team of researchers belonging to the Ministry of Agriculture.

Introduction

The increase in agricultural production is one of the vital tasks of the Cuban nation due to the importance of satisfying the domestic demand of agricultural products as some of these very dependent on imports. Agricultural mechanization is one of the fundamental activities that determine the fulfillment of the aforementioned objective.

Agricultural mechanization in Cuba has been a process that has evolved steadily in the time since the triumph of the Revolution in 1959 and so have the research and development in this field.

In 1959, the numbers of tractors available in Cuba for agricultural production did not exceed 9,000, being mainly low power, so that most of the agricultural work was done manually or with the use of animal traction (mainly with oxen) for which rudimentary implements were used.

One of the first measures of the revolutionary process was the supply of tractors and agricultural machines to the farmers and the organization of cooperatives for a better use of land nationalized to the landowners.

Since that moment, agricultural mechanization was considered in an integral way, and for it the first Systems of Machines were elaborated, that is, the lists of technical processes to use for each crop and activities, with their characteristics and variants according to the conditions of production. These were recommended from the results obtained in the tests and investigations, and the equipment that still did not exist in the country, but needed to be developed or imported was also defined. This also defined the further work of research and testing, based on the technical exploitation and organization of machinery, repair, technical maintenance, pieces recovery, fuel saving, between other aspects.

As a result of the research and test work, the machine line for the mechanized harvesting of potato was introduced into the country, coming mainly from Canada; the combine harvesters and other Italian equipment for the cultivation of rice and tractors of diverse types coming mainly from the Union of Soviet Socialist Republics (USSR); systems of machines for animal husbandry mainly from the German Democratic Republic (GDR) and the USSR. Also, the Australian line of equipment for the cultivation of sugarcane, and the development and production of machines for citrus fruits, consisting of pruners, self-unloading trailers and broad-based cutting machines were introduced.

Respect to the production of vegetables, precision sowing, tomato production in high quarries made with multiple collectors were introduce throughout the country and systems of production were experimented and introduced on a certain scale in harvesting systems with harvesters of tomato, carrot, cabbage and bean harvesters. For bean crops, machines for cutting and plant pre-shredding were introduced and developed, as well as various models of threshers.

With the demise of the socialist system of countries, there was an acute shortage of fuel, spare parts and other inputs in Cuba, which were previously received at low prices (MINAG, 2002).

Consequently, in the middle of the nineties, the stock of tractors aged and in poor technical condition (approximately 79% of the existing tractors had more than 15 years of utilization), an aspect that directly influenced the technical availability of these equipment. Similar situation presented with the other machines and implements and other agricultural technical means.

In 1998, a record of tractors and self-propelled harvesters were made available and it estimated that there were 105,000 tractors in the country.

At present, the country has 63,433 tractors, 51% of them belongs to state entities and the remaining 49% to private owners. (Suárez and Ríos, 2018) (**Table 1**).

As it is shown in the **Table 1**, the total of inactive tractors exceeds 8,000 units, being an element that limits the efficiency and productive capacity of the nation. Another element that significantly influences the quality of agricultural processes is the high level of obsolescence that agricultural technology has, reflecting that more than 60% of tractors and agricultural machines exceed 30 years of utilization. On the other hand, the elements that favor the technical inactivity of these energy sources are the lack of batteries, tires, lights and the problems with the hydraulic system.

Starting from the above, among the actions undertaken by the Science and Technological Innovation Entities to face the existing crisis, implements and conservationist technologies with mechanized traction and animal traction were developed.

At present, Cuban scientific entities, such as the Center of Agricultural Machinery Development (CEDEMA), the Institute of Agricultural Engineering Research (IAgric) and the Center of Agricultural Mechanization (CEMA), continue to carry out research on the development and evaluation of equipment and modern technologies that allow gradually replacing the obsolete equipment.

Table 1 Existence of tractors in Cuba

	Private Owners	State Entities	Total
Total of tractors	31,029	32,404	63,433
Total of inactive tractors	_-	_-	8,046

State of the Industrial and Commercial Sector of the Agricultural Machinery in Cuba

In a study carried out by Gea (2017), it is stated that Cuba is a socialist market, where the means of production and the totality of national companies belong to the state, in such a way that the Cuban economy is based on a central planning where the state is the intermediate and final claimant in most of the businesses. Thus the state is the only economic agent through importers and state companies and the clients are in any foreign trade operations and the partners in any investment.

Specifically, the field of agricultural machinery that is comprised of manufacturing and marketing of equipment, vehicles and implements used in production including the variety of accessories or parts of machinery, tools and facilities, such as plows, harrows, greenhouse, drying facilities and irrigation systems.

In Cuba, there is a low level of agricultural machinery production. At industrial scale, agricultural trailers, plows and harrows are produced (**Fig. 1**. **a** and **b**). At small-scale or artisanal scale, drying equipment, facilities for food processing, such as mills for animal food production and for conserved food are produced as well as other equipment and manual implements for cultivation.

Although the production of agricultural machinery and equipment is low at "Héroes del 26 de Julio" Mechanical Enterprise the company has worked in manufacturing of more complex self-propelled means, such as rice small-harvesters and intermediate transport for rice (**Fig. 2 a** and **b**).

The design of the small rice harvester was finalized in Cuba and it is currently produced and assembled in China by specialists from Cuba and the Asian nation. Later it will be introduced in the Cuban fields where the corresponding tests will be carried out by technicians, specialists and researchers from the Institute of Agricultural Engineering Research (Iagric) of the Ministry of Agriculture. In the case of intermediate transport of rice (TPA-3500), this equipment makes it possible to reduce the cycle time of the harvest-transport-reception process since it establishes an interconnection between the harvest link and the transport link.

Fig. 1 Production of agricultural machinery in Cuba:
a) Implements produced in the "Héroes del 26 de Julio" Mechanical Enterprise, Holguín province, **b**) Agricultural trailer produced in the Agricultural Mechanical Industry (IMECA), Artemisa province

Fig. 2 Self-propelled means developed in Cuba:
a) small rice harvester, **b**) intermediate transport for rice (TPA-3500)

Table 2 National production of agricultural machinery and equipment (thousands of units). Source: ONEI (2015)

	2011	2012	2013	2014	2015
Total	7,781	779	1,177	1,354	1,043

Table 3 Total import of agricultural machinery and equipment (thousands of euro). Source: UN-Statistics (2015)

	2011	2012	2013	2014	2015
Total	49,837.52	54,138. 61	99,226.8	58,403.54	149,058.58

Fig. 3 Tractors imported into Cuba:
a) SONALIKA tractors from India,
b) YTO tractors from the People's Republic of China.

Obviously, the productions reached by the nation do not cover all the requirements demanded by companies and producers, an aspect that leads to the importation of agricultural machinery and equipment.

According to the National Office of Statistics and Information (ONEI) in 2015, the local production of agricultural machinery and equipment barely exceeded one million units, with a considerable decrease compared to the production reached in 2011. However, in a study carried out by UN -Statistics in the same year, it is seen that the financial amount used in the importation of agricultural machinery and equipment exceeded 149 million euros in 2015, appreciating an increase compared to 2011 by over 70%. These productive and economic balances are shown in **Tables 2** and **3**.

Among the main exporting countries in this sector are China, India, Brazil, Belarus and Spain where the most relevant item in 2015 were agricultural and forestry tractors and China being the leading nation with exports exceeding 42 million euros.

In the case of China, this nation maintains and consolidates commercial relations with Cuba, an example of which is the supply of 587 tractors in 2015 coming from the Chinese group YTO (**Fig. 3b**), a leading group in the manufacture of agricultural machinery worldwide (Cubared, 2015).

Recent Cuban newspaper reports inform that in early 2018, India contributed to the development of Cuban agriculture by donating 60 tractors and other agricultural implements such as plows, rotovators, cultivators, lawn mowers, trailers and spare parts (**Fig. 3a**), (Peraza, 2018).

For its part, the Telegraph Agency of Belarus (BELTA) in 2018 reported that the Minsk Tractor Factory (MTZ) is working on to supply more than 940 tractors to Cuba in 2017. It exported 150 units of agricultural machinery to the Caribbean nation (BELTA, 2018).

Established Policies

From the above mentioned descriptions, it can be seen that the technological dimensions in agricultural mechanization are the most sensitive aspects because a correct technical state of the machinery resources, a level corresponding to modern agriculture and a conservationist exploitation of soil properties must be guaranteed. In this aspect, the following targets can be suggested:

- Increase in the productivity of technical resources;
- Use of mechanized technologies that do not produce or reduce as much as possible the damage to the soil;
- Gradual renovation of the machinery stock and its infrastructure;
- Alternative use of animal traction;
- Improvement of the technologies used for food production;
- Implementation of renewable energy sources in agricultural production processes;
- Development of the automation of agricultural production processes;

With respect to the policies established, the country's management, the Ministry of Agriculture (MINAG) and the Sugar Industry Business Group (AZCUBA) have undertaken and fulfilled the suggested targets supported by the scientific-research work carried out by the universities and research centers in the country. Among these results are the following:

Those obtained by the Agrarian University of Havana, the Central University of Las Villas and the University of Camagüey, with respect to the performance of technological and exploitation evaluations of the latest generation of sugarcane and rice harvesters (**Fig 4 a** and **b**). These show that these machines reach the highest values of productivity when the fields have high agricultural yields and there is a stock of spare parts suitable for the specific technical conditions of the harvest brigade. They behave that way, if, in addition, the operator has experience and the technological process is organized efficiently [Matos et al. (2010, 2012), Martínez *et al*. (2011), RRodríguez et al. (2015), Morejón *et al*. (2018)].

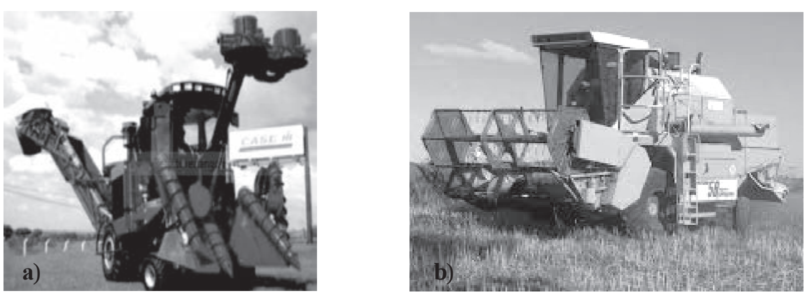

Fig. 4 Modern technologies introduced in Cuba for the harvesting of sugarcane and rice: **a**) CASE sugarcane harvester machine; **b**) CLAAS rice harvester machine

Fig. 5 Production of biodiesel in Cuba: **a**) *Jatropha curcas* crop in Granma Province, **b**) Biodiesel production plant from *Jatropha curcas* in Guantanamo Province

Regarding the implementation of renewable energy sources in agricultural processes, several results have been obtained, among them, those obtained in the framework of the BIOMAS-CUBA project conceived and developed by "Indio Hatuey” Pastures and Forages Station for obtaining biodiesel from the *Jatropha curcas*. That research showed that the average agricultural yield of this crop was 3 t/ha (**Fig. 5a**) with a productive potential of 1,836 L/ha of vegetable oil equivalent to 1.36 t/ha of biodiesel (**Fig. 5b**) (Suárez *et al*., 2011). These authors referred that this biofuel has approximately the same caloric value as diesel fuel of fossil origin and can potentially be used as fuel in tractors and other agricultural equipment thus making it possible to reduce production costs and the production of a cleaner and less polluting energy.

Finally, regarding the automation of processes in agriculture - the Automation, Robotics and Perception Group (GARP) of the Central University of Las Villas has developed a group of robotic applications among which are drones for precision agriculture (**Fig. 6**) The technology that makes use of satellite images, global positioning systems (GPS) and aerial photogrammetry (Pérez, 2018). This technology is used to obtain models of crop surfaces and plant height, to discover empty spaces without adequate exploitation, analyze the composition of soils, evaluate nitrogen deficiency in the soil and

Fig. 6 Use of drones for precision agriculture

determine the vegetation indexes. In the same way, these are useful in the cadastral updating of lands and the delimitation with a high degree of precision of the cultivation areas. In addition, this group works on automatic irrigation systems to achieve greater efficiency in the use of water in agriculture and in the configuration of the data collection system of CASE IH AUSTOFT-8,000 harvesters installed by the manufacturer in order to take advantage of these data to improve the technological efficiency of the harvesting process (Pérez, 2018).

Conclusions

- The modernization of agricultural mechanization makes it possible to directly increase productive yields and increase technological efficiency in production processes.
- Extension services for agricultural mechanization should be strengthened at all levels of agricultural production.
- New technologies and machinery imported or developed in the country should comply with ergonomic and safety standards that is certified and checked by a team of researchers before its introduction in production conditions.
- The use of renewable energy sources and the automation of processes in agriculture are a priority for the country's management.
- There is a need to strengthen local and artisan industries with the aims of diversifying production and reducing imports.
- The joint work between universities, research centers, companies and agricultural producers guarantees to increase the efficiency and effectiveness of agricultural processes as well as the conservation of technological resources, soil, water and atmosphere that are sustained in the implementation of scientific results, development and scientific-technological innovations.

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◆ **BELAGRO / BELFARM**
June 4-9, Minsk, BELARUS
http://ifw-expo.de/exhib/belagro-belfarm-2019/

◆ **XXXVII CIOSTA & CIGR Section V International Conference**
June 24-26, Rhodes, GREECE
http://ciosta2019.com/

◆ **VDI conference on "Automation and Robotics in Agriculture"**
June 26-27, Berlin, GERMANY
https://www.vdi-wissensforum.de/en/event/automation-and-robotics-in-agriculture/

◆ **2019 EFITA International Conference**
June 26-27, Berlin, GERMANY
https://www.vdi-wissensforum.de/en/event/automation-and-robotics-in-agriculture/

◆ **ASABE 2019 Annual International Meeting**
July 7-10, Massachusetts, USA
https://www.asabe.org/Event-Detail/2019-annual-international-meeting

◆ **AGRI INTEX 2019**
July 12-15, Coimbatore, INDIA
http://www.agriintex.codissia.com/

◆ **Potato Days Turkey**
August 22-24, Konya, TURKEY
https://en.potatodaysturkey.com/

◆ **CIGR First Section 5th Interregional Conference & 2nd Conference of the Pan African Society for Agricultural Engineering (PASAE - AfroAgEng)**
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http://5interreg-2ndpanafricconf.ma/

◆ **IDF World Dairy Summit**
September 23-26, Istanbul, TURKEY
http://www.idfwds2019.com/

◆ **22nd FOODAGRO AFRICA 2019 in Kenya**
October 3-5, Nairobi, KENYA
http://africabizevents.com/fc/

◆ **The 1st International Conference on Research of Agricultural and Food Technologies (I-CRAFT2019)**
October 3-5, Adana, TURKEY
http://www.icraft-conference.com/

◆ **8th Asian-Australasian Conference on Precision Agriculture**
October 14-17, Punjab, INDIA
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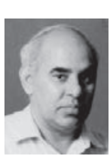
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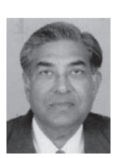
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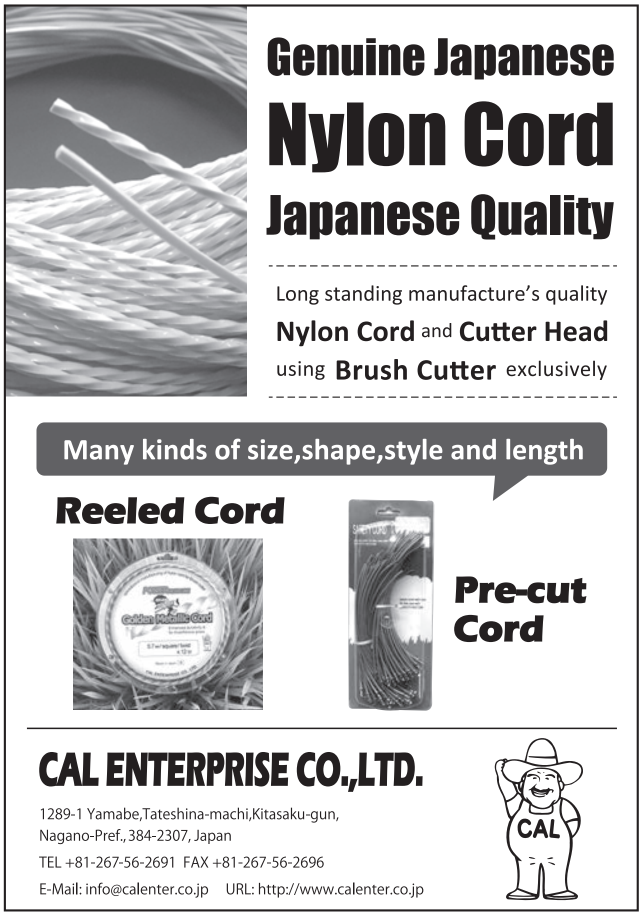
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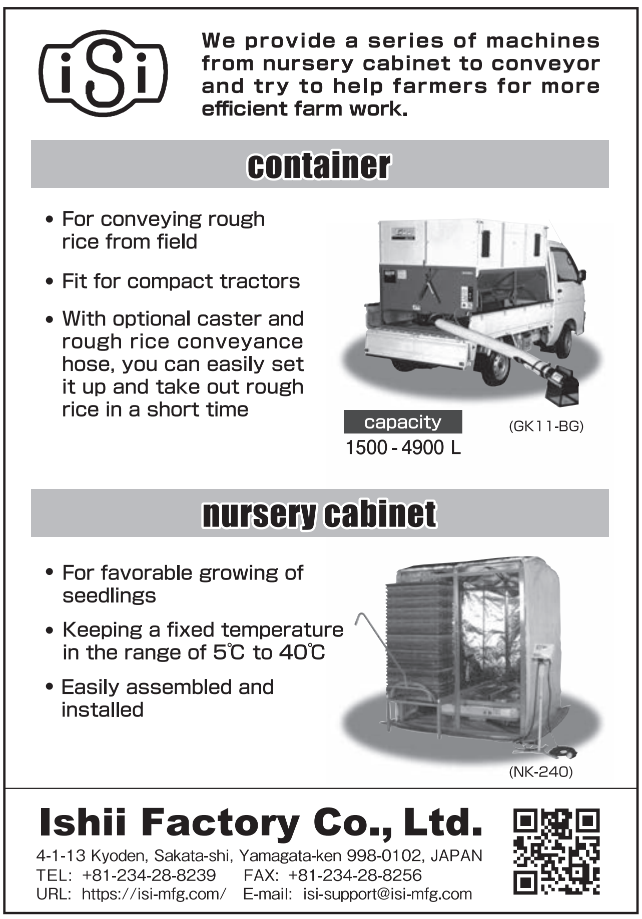
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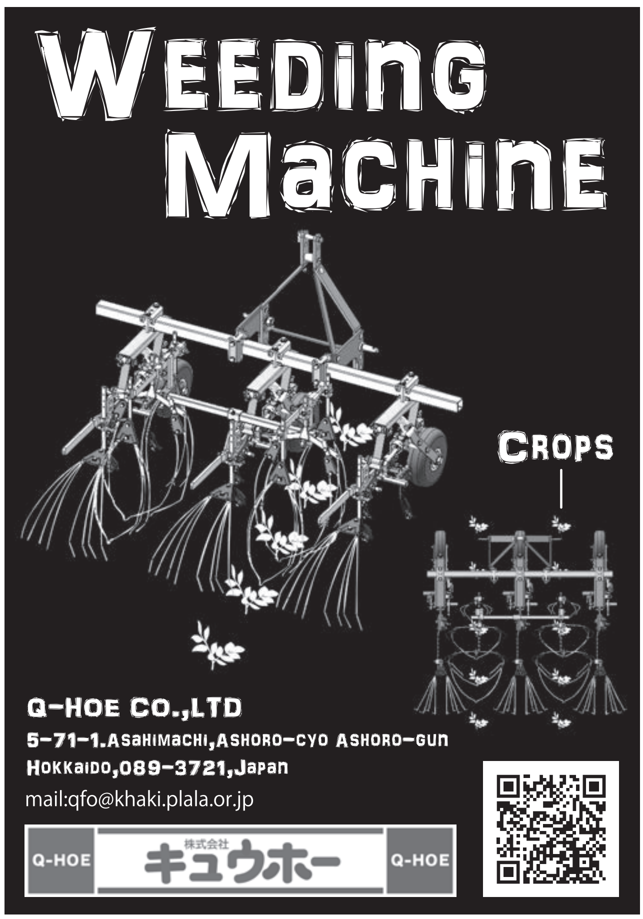
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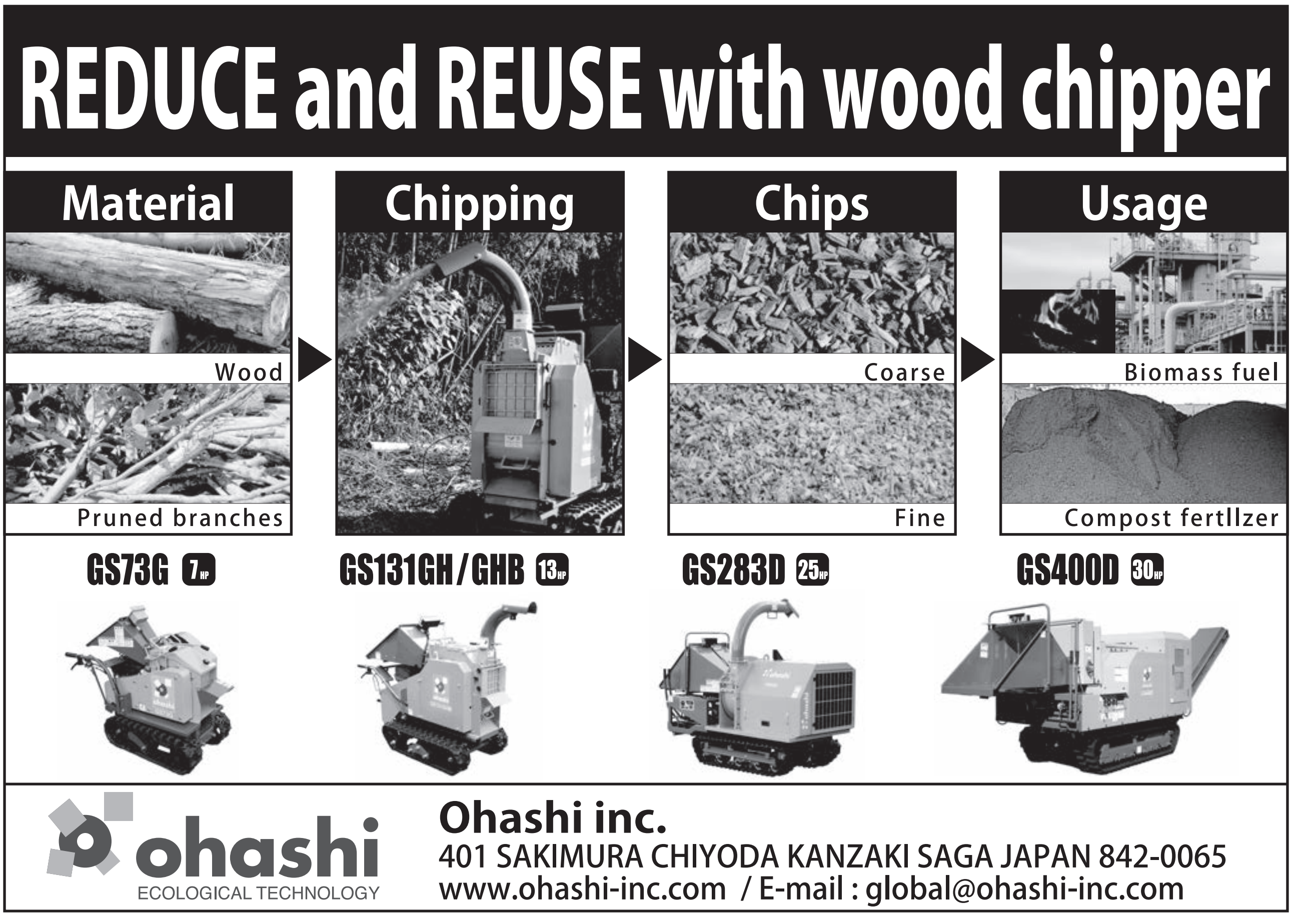
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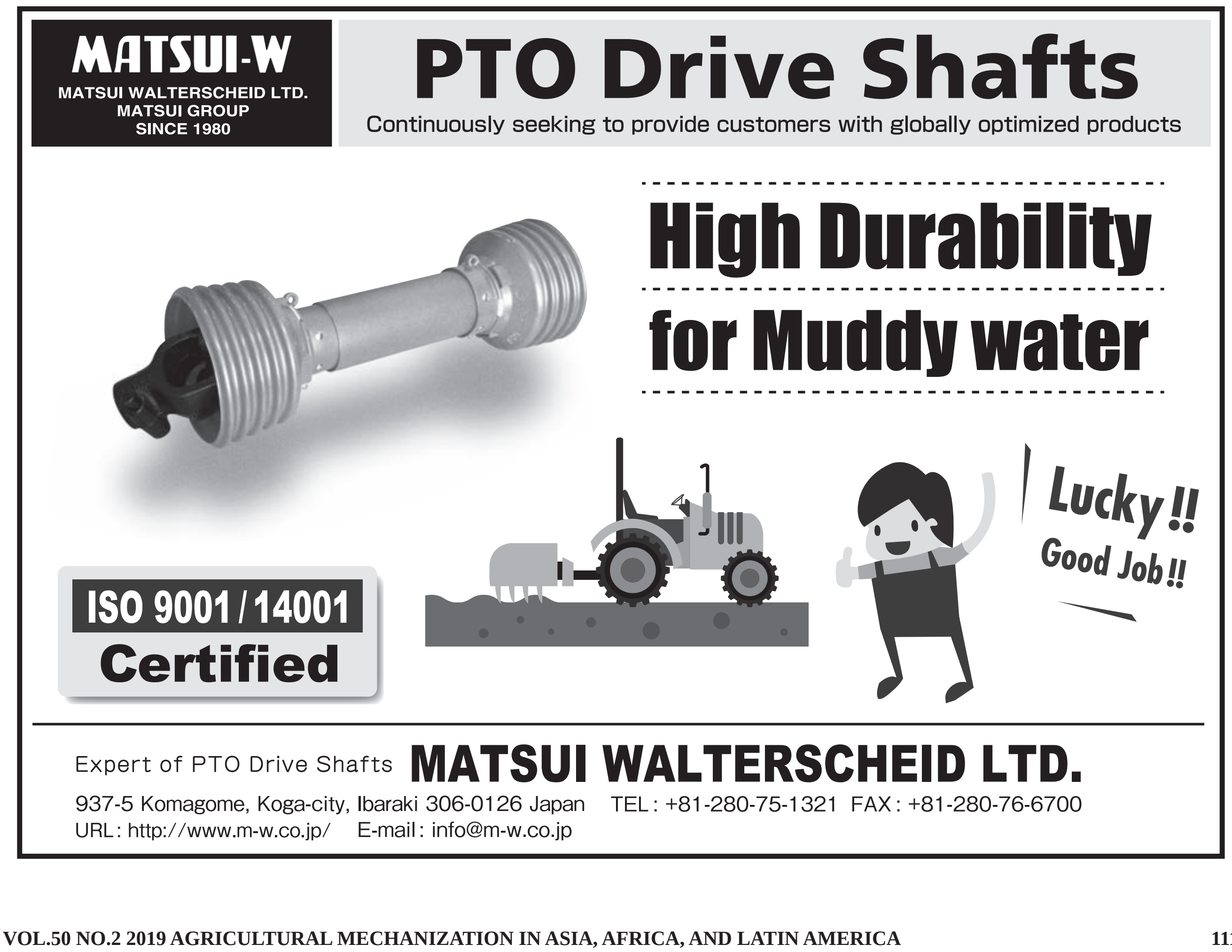
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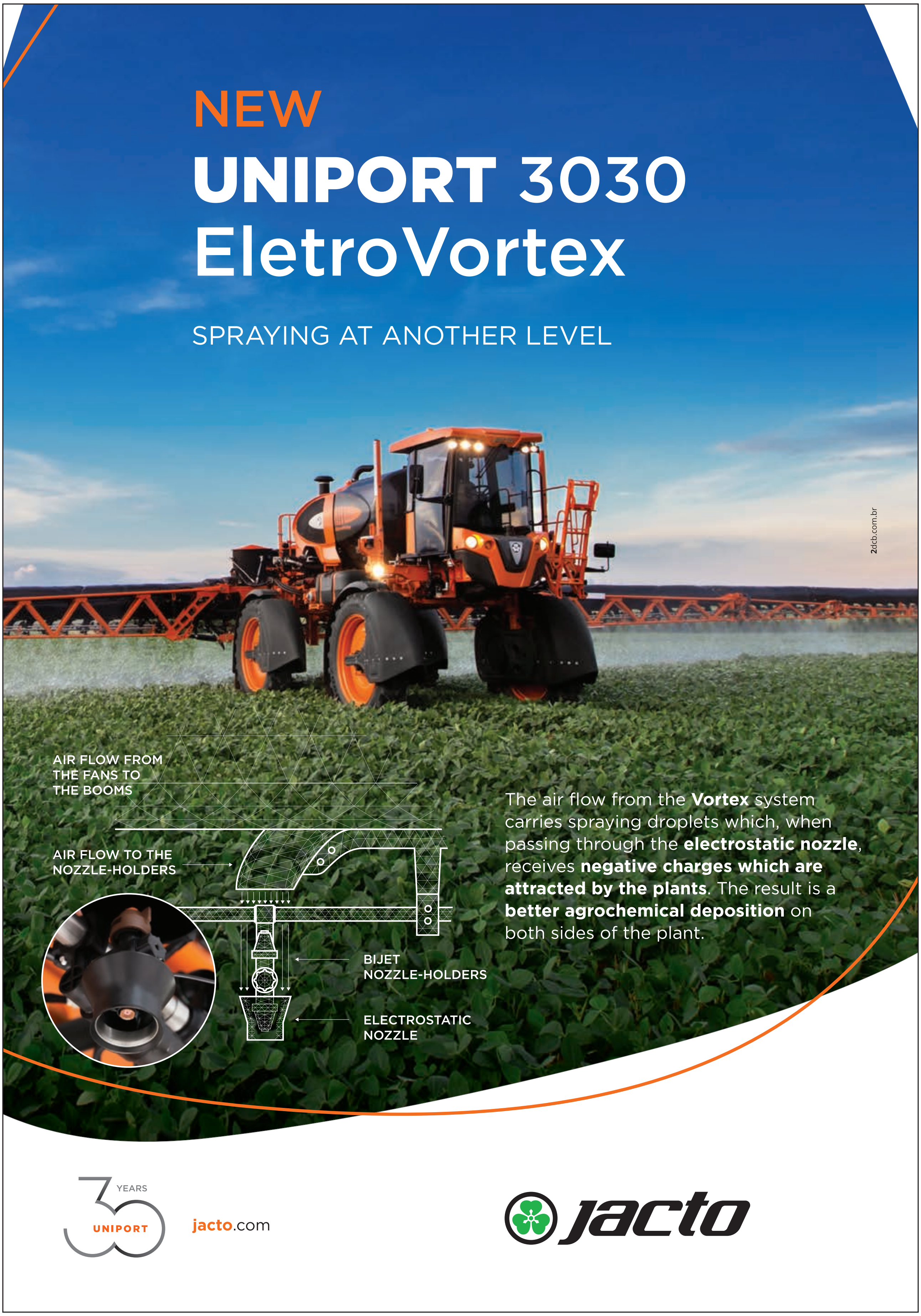
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