Current Status and Future Prospect of the Agricultural Mechanization in Brazil

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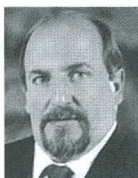
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Abstract

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 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

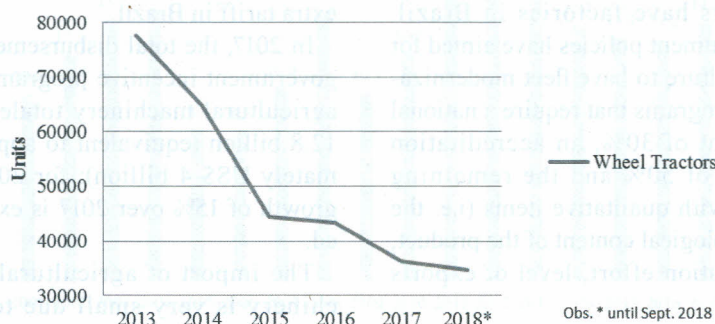**Level of wheel tractor production during 2013-2018* in Brazil**

Obs. * until Sept. 2018

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

BRAZILIAN PRODUCTION OF AGRICULTURAL MACHINERY 2013-2018*

Grain Harvesters
Sugar Cane Harvesters
Backhoe Loaders
Motorized cultivators *
Crawler Tractors
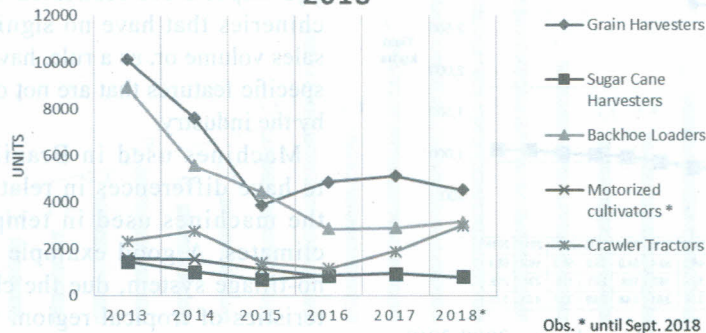
Obs. * until Sept. 2018

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

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,

Brazil: Harvested Area, production & grain yield - Rice, Bean, Maize, Soybean & Wheat -

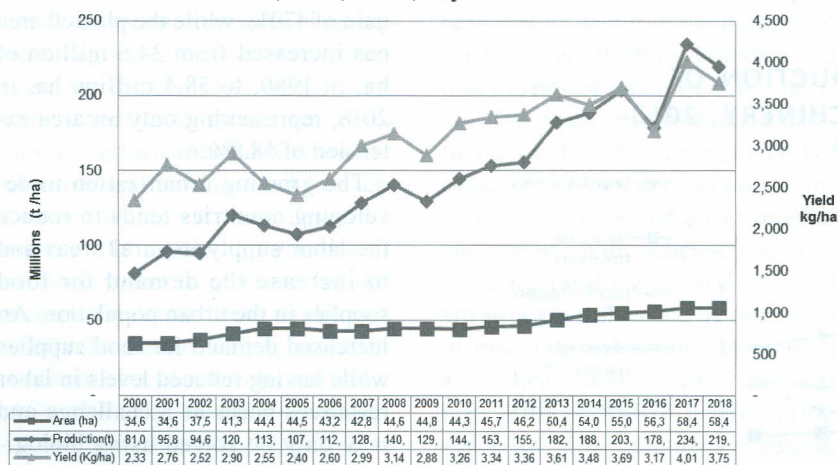|	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Area (ha)	34,6	34,6	37,5	41,3	44,4	44,5	43,2	42,8	44,6	44,8	44,3	45,7	46,2	50,4	54,0	55,0	56,3	58,4	58,4
Production(t)	81,0	95,8	94,6	120,	113,	107,	112,	128,	140,	129,	144,	153,	155,	182,	188,	203,	178,	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.

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.

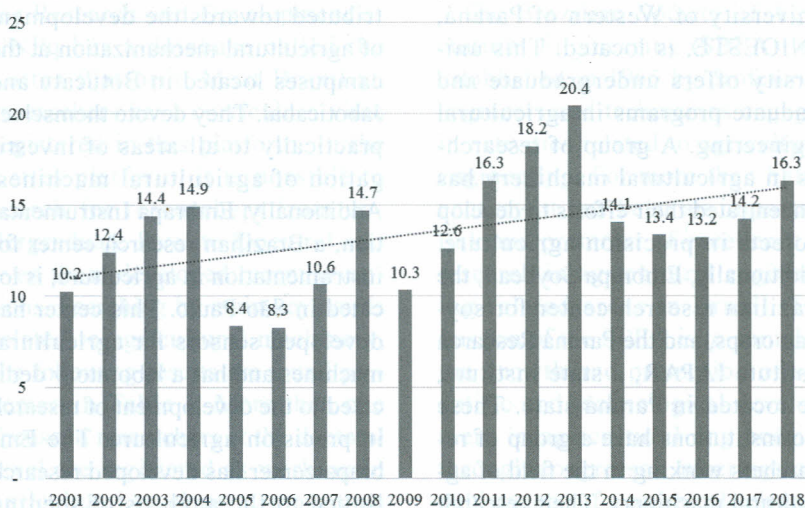Fig. 4 Agricultural Purchasing Power Parity(PPP)- ABIMAQ - in billions of R$ in 2018
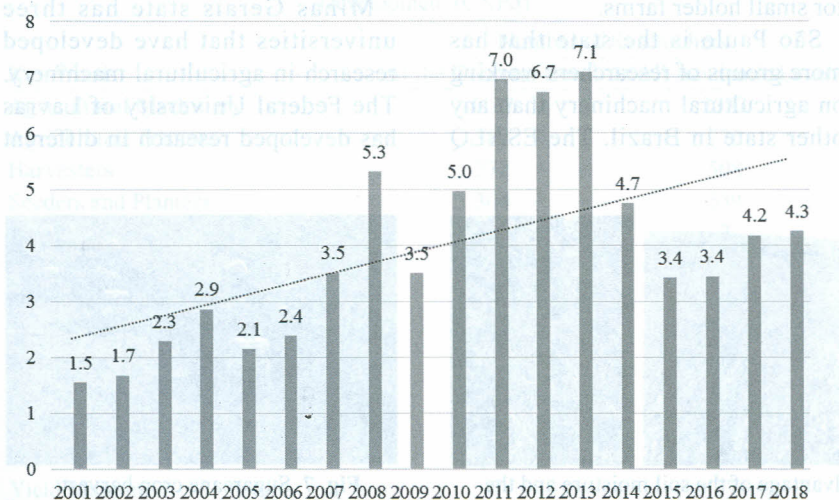
Fig. 5 Agricultural Purchasing Power Parity (PPP) - ABIMAQ - in billions of US$

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.

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

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)

Key-Words	Number of Researchers	
	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

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

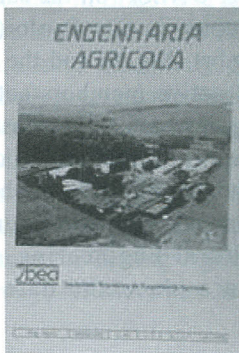**Fig. 9** National Congress of Agricultural Engineering, CONBEA, 2018, Brasília, DF

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 CON-BEAs, 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, in-

cluding 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 tech-

nological 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 Soil-Cares 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 360° 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, au-

tomatic 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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