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Article

Agriculture 4.0: Origin and features in the world and Brazil

Agricultura 4.0: Origem e características no mundo e no Brasil

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Abstract: The Fourth Industrial Revolution has stimulated the development of new technologies and techniques that are changing the global production system. The objective of this paper is to analyze the stream of innovation of Agriculture 4.0, as well as its origin and features, and describe a specific case, the Piracicaba Agtech Valley. Agriculture 4.0 is a digital model of agricultural production guided by high-performance manufacturing and is a result of a long historical process of technological development. The innovation in the agricultural sector in Brazil is essential to the maintenance of its competitiveness. However, the 4.0 concept of production is still a challenge the country needs to overcome. Agtech startups are working as a solution for technology diffusion. The Piracicaba Valley Agtech, in the state of São Paulo, is a successful case of Agriculture 4.0 concept development.

Keywords: agriculture 4.0; innovation; Agtech; Brazil.

Resumo: A Quarta Revolução Industrial estimulou o desenvolvimento de novas tecnologias e técnicas que estão mudando o sistema de produção global. O objetivo deste artigo é analisar o fluxo de inovação da Agricultura 4.0, bem como sua origem e características, e descrever um caso específico, o do Vale Agtech de Piracicaba. A Agricultura 4.0 é um modelo digital de produção agrícola pautado pela manufatura de alto desempenho e é resultado de um longo processo histórico de desenvolvimento tecnológico. A inovação no setor agrícola no Brasil é essencial para a manutenção de sua competitividade. No entanto, o conceito de produção 4.0 ainda é um desafio que o país precisa superar. As Agtechs estão trabalhando como uma solução para difusão de tecnologia. A Agtech do Vale do Piracicaba, no estado de São Paulo, é um case de sucesso no desenvolvimento do conceito Agriculture 4.0.

Palavras-chave: agricultura 4.0; inovação; Agtech; Brasil.

Introduction

Innovation is a process, which happens from a creative idea, of creating or changing an activity developed in the past, which can result in improvements both internally, such as increasing efficiency, and externally, such as the formation of a brand positioning (Jung, 2017). Each new idea causes the generation of other new ideas (Fischer, 1989). Schumpeter (1997) emphasizes that the innovative agent breaks with the circular and stationary flow of economic life. When this agent brings new products to the market, either through new production combinations or the application of some invention or technology, consumers are encouraged to desire new things (which differs from the stationary habit of the past). Thus, the author also mentions that for this reason, innovation prescribes 'creative destruction', that is, the replacement of old patterns influences the process of economic development.

Bono (2003) identifies two elements that link innovation to the economy: production process and insertion of added value. The first refers to operations carried out in a new way, be it simpler or more economical. The second is related to the attribution of added value, which may be through a new product, the modification of an existing product, a new production operation or a new form of sale.

The Fourth Industrial Revolution has stimulated the development of new technologies and techniques that are changing the global production system. The Industry 4.0 is a concept that arose in 2011 as a part of German strategic initiative of high technological development in the manufacturing and it quickly spread throughout the world (Rojko, 2017). Industry 4.0 consists of a set of smart processes in production and management. Its results are digitization and integration of vertical and horizontal value chains, digitization of product and service offerings and digital business models and customer access. According to Salkin et al. (2018), a coordinated system following the 4.0 concept allows autonomy in the processes and real time decisions making. In addition, through the integration of supply chain, facilities, and service systems, it enables the establishment of added value networks.

Agriculture 4.0 (also known as farming 4.0) consists of employing cyber-physical characteristics in agriculture. It refers to a set of digital technologies integrated and connected by software, systems and equipment capable of optimizing agricultural production, upstream, midstream, and downstream.

Due to the deep transformation that is emerging in the agricultural way of production, the objective of this paper is to analyze the stream of innovation of Agriculture 4.0, as well as its origin and features, and describe a specific case, the Piracicaba Agtech Valley. This work has a descriptive and explained approach. Hence, the article is organized in 5 sections, including this introduction. The following section describes the methodology of this paper. The third section presents a literature review, which describes the origin and main characteristics of Agriculture 4.0, as well as the worldwide perspective. The fourth section describes the Brazilian main features of Agriculture 4.0 adoption and the Agtech Valley. The final remarks are in the last section of this paper.

Methodology

This article uses the theoretical framework of discourse analysis. We understand discourse as being a collection of texts that bring meaning to an object, as well as its distribution through the environment (Parker, 1992). In this sense, institutions produce discourses, which can be texts (reports, articles, interviews, etc.) that foster the field for the creation of new technologies (Munir and Phillips, 2005; Phillips et al., 2004).

Institutions can be defined as "historical accretions of past practices and understandings that set conditions on action", in which they "gradually acquire the moral and ontological status of taken-for-granted facts which, in turn, shape future interactions and negotiations" (Barley and Tolbert, 1997, p. 94; Meyer and Rowan, 1977). The construction of the Agriculture 4.0 is a mixture of different discourses, from teaching and research institutions, agribusiness multinationals, researchers, entrepreneurs, and other innovation players. In this environment, each one contributes with an isolated idea, by connecting these set of thoughts, we create the Agriculture 4.0 institution.

In symbiosis the methodology of discourse analysis for the Agriculture 4.0 institution, we use the practical case study of the Agtech valley. That is, we use a specific case as a sample of a larger process (Yin, 1986). In this attempt, we seek to show the movements and technological evolutions that have been occurring in Brazil, especially in the surroundings of the city of Piracicaba and Campinas in the process of construction of Agriculture 4.0.

Literature Review

In the early 2010s, a new stage in the agricultural evolution started, the Agriculture 4.0. In general, this revolution is related to the introduction of digital technologies, such as the employment of high-performance computational methods, machine-to-machine (M2M) communication, sensor networks, connectivity between mobile devices, automation and agricultural robotics, cloud computing and big data techniques, and Internet of Things (IoT) that combined with artificial intelligence and machine learning can generate better insights for the growers and specific recommendations regarding farm management, machineries performance, seeds and fertilizers scripts, diseases and bug scouting management and water management as some examples.

Moreover, it will contribute to raising productivity rates, efficiency in the use of inputs, reducing labor costs, improving the quality of work and the safety of workers and reducing impacts on the environment (Massruhá and Leite, 2017).

Agriculture 4.0, as a vision of agricultural development, is related to the increasing competitiveness, and implemented through the use of modern information technology (Piwowar, 2018). In addition, it has great potential for limiting harmful pollution of the natural environment, due the multidimensional transformation in agricultural activity, making the complete production chain more sustainable.

However, this digital model of agricultural production is guided by high-performance manufacturing and is a result of a long historical process of technological development. (Rapela, 2019) analyses the development of smart agricultural production into four stages, as follows below.

The Agriculture 1.0, up to the 1950 decade, was characterized by a relatively low energy intensity, low productivity (Rapela, 2019), labor intensive and land extensive. Zambon et al. (2019) giving ideas and considerations for the future. This paper analyses the specific challenges facing agriculture along the farming supply chain to permit the operative implementation of Industry 4.0 guidelines. The subsequent scientific value is an investigation of how Industry 4.0 approaches can be improved and be pertinent to the agricultural sector. However, industry is progressing at a much faster rate than agriculture. In fact, already today experts talk about Industry 5.0. On the other hand, the 4.0 revolution in agriculture is still limited to a few innovative firms. For this reason, this work deals with how technological development affects different sectors (industry and agriculture add the use of animal force in model 1.0 of agriculture). Moreover, given the low technological availability, hand tools were widely used both in land preparing for planting or for harvesting. The most used tools were the hoe, the manual plow, the pitchfork, the rake and the scythe (Gianezini et al., 2014).

The use of fossil energy (agrochemicals, machinery, fertilizers), and the first-generation genetics and hybridization emerged in the Agriculture 2.0 stage, in the 1960s, which resulted in a significant productivity increase (Rapela, 2019). According to Vieira Filho and Fishlow (2017), the tropicalization of soy allowed the expansion of this crop to the Cerrado biome in Brazil, that is, soy production became possible also in regions with a hot climate.

The biological nitrogen fixation was also an important advance in the second stage of agricultural evolution. Lantinga et al. (2013) and Whitmore (2000) describe the nitrogen effect in soil fertility maximization, as well as its benefits.

The expansion of the use of agricultural machinery also marked Agriculture 2.0 for the most diverse operations such as soil preparation, planting, cultivation, harvesting, threshing, and etc. Tractors with an explosion engine, which used gasoline or diesel oil as fuel, started to perform two main functions in rural work: i) served as stationary sources of energy, moving, for example, (by means of a belt transmission system), grain processors; and ii) they replaced animal traction in plows and other agricultural machines. Thus, combustion engine tractors have gained worldwide prominence for their versatility, as they can be coupled to the most diverse implements, such as the plow, planter, cultivator, harvester, among others (Gianezini et al., 2014).

Then, Agriculture 3.0, which stretched from the end of the twentieth century to the beginning of the twenty first century, were essentially recognized by the development of knowledge in all areas, such as biology and various engineering disciplines. The convergence between digitalization and knowledge was the basis for the development of productive strategies that effectively combined the demands for higher productivity, efficiency, and sustainability (Rapela, 2019). Agricultural machinery gains a new innovation at this stage, as it is equipped with a hydraulic system by which the operator performs heavy tasks, such as displacing large volumes and blowing the straw from the seeds (Gianezini et al., 2014).

Agriculture 3.0 had a particular focus on the balance between high agricultural productivity and better environmental performance. The bioeconomy and sustainable development emerged in this stage (Rapela, 2019). McCormick and Kautto (2013) describes bioeconomy as an economy where the basic elements for energy, chemicals and other materials are derived from renewable biological resources. The authors also highlight the importance of a dialog between government, general public, and key stakeholders to develop a sustainable and competitive bioeconomy. Business innovation also plays an essential role. New biology-based value chains redefined the supply/product relations between agriculture and industry (Rapela, 2019). The main characteristics of Agriculture 1.0, 2.0, and 3.0 are summarized in Table 1.

Table 1. Agriculture 1.0 and 2.0 versus 3.0

Agriculture 1.0 and 2.0	Agriculture 3.0
Human resources	Human capital
Machinery	Information
Physical work	Intellectual work
Physical force	Emotional intelligence
Real and factual	Symbolic
What we produce	How we produce
Things	Concepts
Mechanical work	Creative work
Established and regulated	Experimenting
Rigid and hierarchical organizations	Flexible and horizontal organizations
Autarchy	Interrelated and open
Top-down decisions	Top-down, bottom-up decisions
Reactive decisions	Proactive decisions
Linear dynamics	Nonlinear dynamics
Fear of the unknown	Accepting the challenge
Controlled risk	Basic uncertainty

Source: Rapela (2019, p. 10)

Zambon et al. (2019) giving ideas and considerations for the future. This paper analyses the specific challenges facing agriculture along the farming supply chain to permit the operative implementation of Industry 4.0 guidelines. The subsequent scientific value is an investigation of how Industry 4.0 approaches can be improved and be pertinent to the agricultural sector. However, industry is progressing at a much faster rate than agriculture. In fact, already today experts talk about Industry 5.0. On the other hand, the 4.0 revolution in agriculture is still limited to a few innovative firms. For this reason, this work deals with how technological development affects different sectors (industry and agriculture describe that Agriculture 4.0 is correlated to the Industry 4.0 transformation, based on smart manufacturing). According to the authors, the Agriculture 4.0 offers digital information at all farm sectors and processes, as well as the combination of internal and external interactions of farming operations (upstream, midstream, and downstream). Due to the combination and integration of production technologies and devices, data and services in network infrastructures, and information and communication systems, the agricultural sector becomes smarter, more efficient, safer, and more environmentally sustainable. In order to remain competitive in the market, the smart farm must be able to adapt to this technological transformation, autonomously, and in real-time to these changes. In addition, an effective connection between all the actors, data-rich communication, as well as virtualization are elements that contribute to the development of Agriculture 4.0 (Zambon et al., 2019) giving ideas and considerations for the future. This paper analyses the specific challenges facing agriculture along the farming supply chain to permit the operative implementation of Industry 4.0 guidelines. The subsequent scientific value is an investigation of how Industry 4.0 approaches can be improved and be pertinent to the agricultural sector. However, industry is progressing at a much faster rate than agriculture. In fact, already today experts talk about Industry 5.0. On the other hand, the 4.0 revolution in agriculture is still limited to a few innovative firms. For this reason, this work deals with how technological development affects different sectors (industry and agriculture).

Smart farming technologies may contribute to agricultural sustainability and have a strong potential to enhance economic performance of farming as they may increase precision of inputs to soils and crops based on site-specific needs, and link these aspects to the farm management system (Knierim et al., 2019).

The exploratory literature review about extant social science by Klerkx et al. (2019) showed five thematic clusters on digitalization in agriculture, namely: i) adoption, adaptation and use of digital technologies on farm; ii) effects of digitalization on farmer identity, skills and work; iii) ethics, privacy, power and ownership in digitizing agricultural production systems, as well as the value chains; iv) innovation systems and agricultural and digitalization knowledge; and v) value chains and economics and management of digitalized agricultural production systems. In addition, digital agriculture socio-cyber-physical-ecological systems; digital agriculture policy processes; digitally enabled agricultural transition pathways; and global geography of digital agriculture development are also highlighted as a future research agenda by the authors.

Sponchioni et al. (2019) highlight that Agriculture 4.0 has multiple perspectives. The authors classify literature related to the 4.0 revolution in agriculture into six perspectives, such as: i) precision farming evolution; ii) industry 4.0 in agriculture; iii) digital technologies; iv) informed decision-making; v) beyond the farm boundaries; vi) ultimate goal (profitability and sustainability). In this way, the authors summarize the Agricultural 4.0 concept as an evolution of precision farming by the use of smart and digital technologies of Industry 4.0.

The generation of knowledge supports the farmer in the decision-making process not only in farm enterprise, but also when dealing with different players in the agricultural and food value chain. The Cyber-Physical System, as well as the automated collection, integration and analysis of data silos from farming, and equipment sensors, are technological tools that must boost the capability of farmer's decision-making. The main focus is to enhance profitability and economic-environmental-social sustainability of agriculture.

The Agriculture 4.0 concept of production is the data connection in real time, collected by digital technologies. It is the development of IoT in rural activities. Agriculture must be autonomous. The connected equipment, with the support of artificial intelligence and machine learning, will analyze the data in the production chain and make decisions. It will be up to the farmer to monitor and endorse the ongoing processes (Zaparolli, 2020).

The European Commission (2017) highlight three main points of Agriculture 4.0, that are: i) digitalization of agriculture; ii) connecting machines and farms; and iii) challenges to adoption; described as follows below.

Connected tractors, as well as connectivity and localization technologies (GPS), automation, which increases productivity and reduces the need for the human workforce, and new measurement tools (the ability to collect more data and measurement about the production through sensors, drones, and satellite imagery) are key instruments of agricultural digitalization. Thus, communication networks covering rural areas efficiently is an IoT requirement (European Commission, 2017).

Porter and Heppelmann (2014) exemplify the linking chain of Agriculture 4.0 in a tractor company, which may find itself competing in a broader farm automation industry. A simple product gets a system of systems through the inclusion of algorithms e connectivity. The connected products, besides increasing the smart farming, reshape competition within industries and expand industry boundaries (Porter and Heppelmann, 2014).

Transparency of product, preventive maintenance, and shared knowledge are consequences of the Agricultural 4.0 model of production, due to the ability to remotely collect, use and exchange data. These digital tools increased food traceability through the publication of detailed information on goods, origins, and quality (European Commission, 2017).

Thus, the digitalization and connectivity of agricultural tools enable the development of precision agriculture and increase the transparency of the sector (Jakku et al., 2019). However, they also face significant challenges in the key necessity to enable data exchanges in the business ecosystem and the need to invest in new infrastructure and tools. Among the challenges to adoption, there are the need for standards of technologies, the ability of farmers to invest in equipment modernization and supporting infrastructures (European Commission, 2017).

The Nayyar et al. (2018) highlight the need to transform food production systems. The need for industrialization and intensification of the agricultural sector has risen due to the increasing demand for food, both in terms of quantity and quality.

Among the new technologies that creates effective production systems following the 4.0 concept, Nayyar et al. (2018) cite the precision agriculture for input and water use optimization, gene-editing for multi-trait seed improvements, microbiome technologies to enhance crop resilience, biological-based crop protection and micronutrients for soil management, off-grid renewable energy generation and storage for access to electricity.

Tzounis et al. (2017) point out the main elements to modernize agricultural production and to improve its productivity, such as the IoT. Given the capability of IoT to offer many solutions to agriculture, research institutions and scientific groups as well as the industry, are in a race trying to deliver more and more connected products to supply the agricultural business stakeholders.

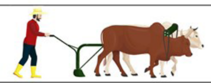
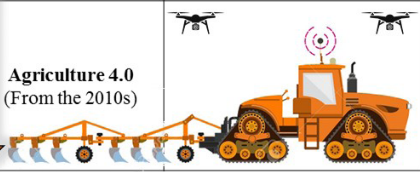
Thus, cloud computing gets also essential to sustain, store and analyze the huge amounts of data generated by IoT devices. The analysis and management of IoT data - Big Data - must be used to predict situations, automate processes, and improve many activities and productivity. In other words, by producing intuition, intelligence, and insights, the big data has the potential to reformat conventional process-driven agriculture to a smarter and data-driven farming (Lioutas et al., 2019). The example presented by (Tzounis et al., 2017) describes three IoT solutions for controlled environment, agriculture, and livestock.

Firstly, the controlled environment affects the productivity of plants. The IoT solution consists in climate monitoring and climate optimization based on cloud analytics services. The data come from sensors and weather stations, and the user can interact remotely through a wide variety of devices, such as laptops, smartphones, tablets, etc. (Tzounis et al., 2017).

The second is related to the monitoring in open field agriculture, the characteristics of the soil, how exactly, at different depths. Water is preserved through optimizing irrigation system control, due to the exact supply of water quantity to the plant. Moreover, optical sensors are used for mapping of the situation in the field, to provide additional information on crop reflectance or remote temperature sensing (Tzounis et al., 2017).

As a third example, IoT solutions for livestock includes animal and climate monitoring and control, as well as field monitoring for optimal feeding practices. In addition, it must include the instrumentation, animal tracking and behavioral analysis, as well as odor and hazardous gas monitoring (Tzounis et al., 2017).

In sum, Figure 1 presents the main features that determine the agricultural evolution. The plowing procedure transformation over time is a good example of agricultural stages from 1.0 to 4.0.

Stage	Example		Features
Agriculture 1.0 (Until the 1950s)		• Use of hand tools, such as the plow; • Labor intensive; • Land extensive.	• Animal force; • Low energy intensity; • Low productivity.
Agriculture 2.0 (From the 1960s to 1980s)		• 'Tropicalization' of soybean cultivation; • Biological nitrogen fixation. • Use of tractors; • Use of agrochemicals; • Use of fertilizers.	• Machinery force; • The first-generation of genetic manipulation and hybridization;
Agriculture 3.0 (From the 1990s to 2000s)		• Use of use of tractors, seeders, sprayers, and harvesters; • Integrated crop-livestock-forest systems; • No-till farming; • Genetic improvement in plants and animals.	• Development of knowledge; • Bioeconomy; • Sustainable development; • New biology-based value chains; • Nonlinear dynamics.
Agriculture 4.0 (From the 2010s)		• E-learning machines; • Artificial intelligence that supports decision-making; • Drones; • Plant/animal, soil, and weather sensors; • Geoprocessing; • Connected devices/machines.	• Digitalization; • Cloud computing and big data; • IoT and connectivity; • Localization technologies (GPS); • Precision farming; • Automation; • Cyber-Physical System.

EVOLUTION

Figure 1. Agricultural evolution over time
Source: Prepared by the authors

The technological change in agriculture works as a treadmill. That is, to remain competitive, the farmers must innovate agricultural operations. These innovations will result in a reduction cost and a displacement up the production frontier. That is the Treadmill Effect proposed by (Cochrane, 1958). Thus, the 4.0 model of production applied in agriculture must be a watershed.

To remain on the treadmill working, it is necessary to invest in innovation. AgFunder is a venture capital company whose mission is to invest in technologies to rapidly transform our food and agriculture system, such as agtech. Agtech, i.e., agricultural technology, consists in a set of tools ranging from machinery and implements to electronic data capturing devices, which supports the farming management systems, decision making, and to monitor the environmental footprint of agriculture (Rizzo et al., 2020). The connection, automation, mobile devices for augmented data-driven agriculture, use of cyber-physical interfaces and precision agriculture, provided by agtech, are the vanguard among modern elements currently available. Figure 2 shows the global farm tech funding from 2012 to 2019.

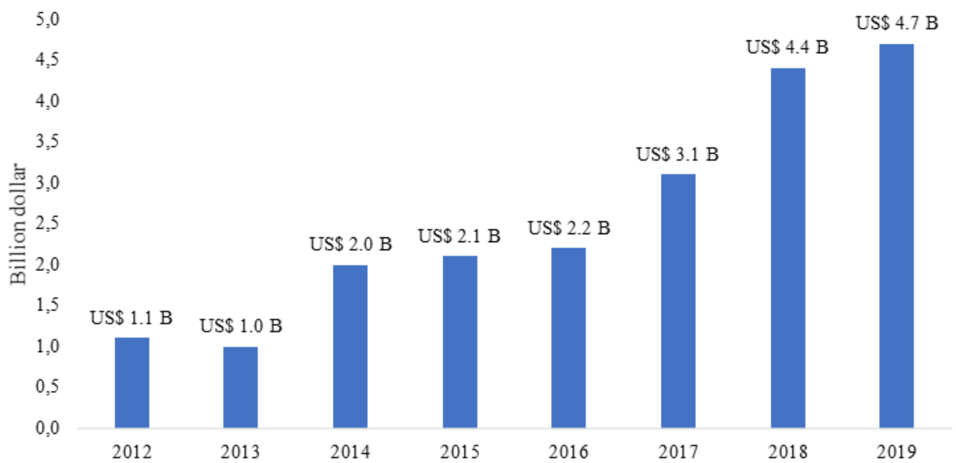


Figure 2. Global farm tech funding from 2012 to 2019 (US$)
Source: Pepared by the authors; adapted AgFunder (2020)

The growth in agtech financing has been consistent over the years, with big leaps in 2017 and 2018, and reaching US$ 4.7 billion in 2019, due to the increase in venture capital in various economic sectors. Biotechnology, novel farming systems and farm management software, sensing and IoT were the main focus of these investments when analyzing agtech categories (Agfunder, 2020), as shown in Figure 3.

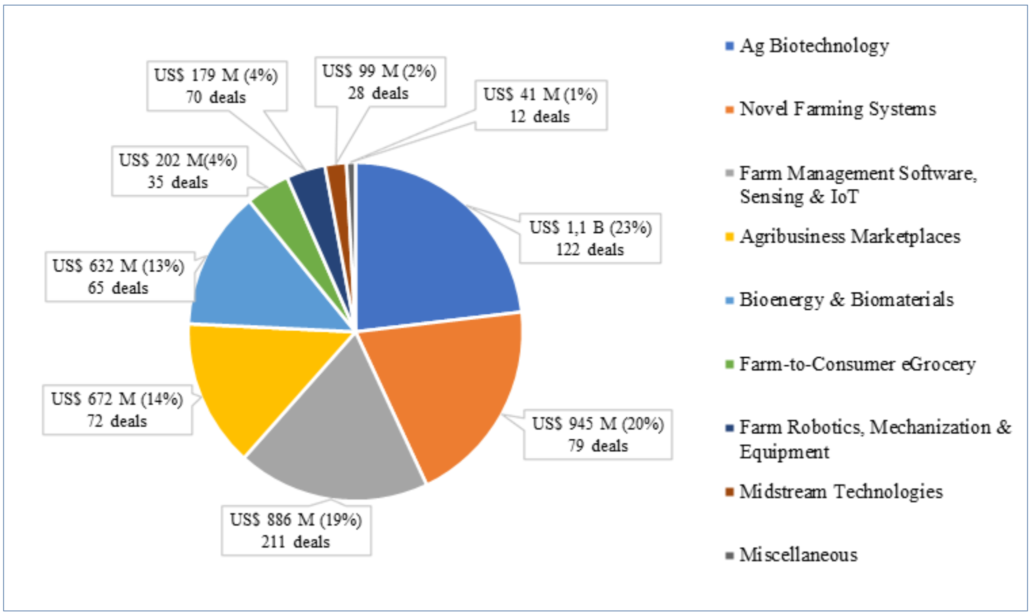


Figure 3. Agtech categories investments (2019)
Source: Pepared by the authors; adapted AgFunder (2020)

Ag (agricultural) biotechnology is all the operations related to on-farm inputs for crop and animal ag including genetics, microbiome, breeding, animal health. The investment in ag biotechnology exceeded US$ 1 billion distributed into 122 deals. The average of each deal is about US$ 9 million.

When analyzing the indoor farms, aquaculture, insect, and algae production, that is, novel farming systems, the average of each deal is almost US$ 12 million, i.e., the highest verified according to the data. In 2019, one fifth of the agtech investments were applied in this category.

Farm management software, sensing and IoT is the category which received US$ 886 million into 211 deals, in order to apply and improve the usage of agricultural data capturing devices, decision support software, big data analytics.

Agribusiness marketplaces (commodities trading platforms, online input procurement, equipment leasing), and bioenergy and biomaterials (on-farm ag waste processing, biomaterials production, anaerobic digesters) received more than US$ 600 million each one. The average of investment per deal was about US$ 9 million.

Farm-to-consumer eGrocery (online platforms for farmers to market and deliver their produce direct to consumers), farm robotics, mechanization and equipment (on-farm machinery, automation, drone manufacturers, grow equipment), midstream technologies (food safety and traceability tech, logistics and transport services used by farmers), and miscellaneous (e.g. fintech for farmers) received altogether more than US$ 500 million of the agtech investments in 2019 distributed into 145 deals.

Brazil and the Agtech Valley

Until the 1980s, Brazil was a net food importer. The intensive use of science and technology has resulted in significant productivity gains (Vieira Filho and Fishlow, 2017) . The trajectory of Brazilian agriculture is marked by productivity gains (Gasques et al., 2012).

Gasques et al. (2012) analyze the main sources of agricultural growth of Brazilian agriculture from 1975 to 2016. In this period, many transformations have occurred, e.g. the creation of the Brazilian Agricultural Research Corporation (Embrapa) in 1973; the boom and bust of agricultural subsidy policy; the economic opening from the 1980s; and the economic stabilization plans from 1986 to 1994 (Gasques et al., 2012, 2014, 2018). The reduction of government participation in rural credit and price policies resulted in the loss of importance of public financing for agriculture. In this way, the participation of the private sector in financing and marketing increased (Gasques et al., 2018; Schimidt and Cançado, 2019).

As a consequence of these transformations, significant increases in productivity placed Brazil among the most competitive countries in the world in the agricultural sector. (Gasques et al., 2018) highlight those investments in research, development and innovation (RD&I) – public and private – are the main source for productivity growth in the Brazilian agriculture between 1975 and 2016. The increase in agribusiness R&D expenditure is directly related to the increase in TFP (Dias Avila and Evenson, 2010; Fuglie et al., 2020) we incorporate schooling capital to yield two new indexes: Invention-Innovation Capital and Technology Mastery. We find that TFP performance is strongly related to technological capital and that technological capital is required for TFP and cost reduction growth. Investments in technological capital require long-term (20-to 40-year). Araújo et al. (2003) have found that every real invested in research generates nearly twelve reais in return in the agricultural production value.

The trajectory of Brazilian agriculture is marked by deep transformations, which have made Brazil stop being a net food importer and become one of the world leaders in agro-exports. The country has become one of the main players in global agribusiness. Several events stimulated the advancement of science and technology and, as a result, expressive gain in productivity was verified, as well as the offer of labor to other dynamic sectors of the economy (Santos and Spolador, 2018). Embrapa played a crucial role in this process, being considered a success case of induced innovation. Agricultural activities are decisive for the economic performance of several Brazilian municipalities stimulated by exports. In short, the trajectory of agriculture contributes to understanding the dynamization of the Brazilian economy and space (Alcantara, 2020).

The Brazilian agribusiness is the main foreign currency generator for the country . Between 1997 and 2018, when verifying the Brazilian agribusiness trade balance, an increasing growth can be noticed. In 1997, this balance was US$ 15.2 billion, passing to US$ 87.2 billion in 2018 (MAPA, 2019). In other words, the value of exports has grown considerably over time, while imports have remained relatively stable.

The use of Information and Technology (IT) tools is increasing in Brazilian agricultural sector mainly among commodity producers, such as soybean, maize, cotton, sugarcane, fruits, coffee and meat. However, the sector still needs to take a new step toward Agriculture 4.0 (Zaparolli, 2020).

Besides the growth of 1.900% in internet accessibility in rural establishments in the last between 2006 and 2017 (according to agricultural census), the digitization process and the telecommunication infrastructure is still restricted in Brazil. Just 5% of agricultural lands are connected to the internet. To expand coverage to about 90% of Brazilian territory, it would be necessary to install about 16 thousand of transmission antennas, that is, an estimated investment of over R$ 8 billion. Hence, the lack of connectivity is the biggest bottleneck for the advancement of Agriculture 4.0 in Brazil (Zaparolli, 2020).

In Brazil, new agtechs are founded each year (Vasconcelos, 2019). When analyzing its location, 35% are in their own headquarters, 21% in incubators, 15% in coworking locations, 13% are not yet headquartered, 9% in technological centers and 7% in company-sponsored hubs. The main role of a startup is related to giving support for decision making, IoT and hardware, agricultural management software and precision agriculture. More than a half of

Brazilian agtech startups have a relationship with educational centers. The startup agtech focused on soy production is predominant in Brazil (46%), followed by corn production (41%), sugar cane production (35%) and livestock (30%) (AgTech Garage, 2018). Figure 4 presents the ideas to create the agribusiness startups in Brazil from (Start Agro, 2016).

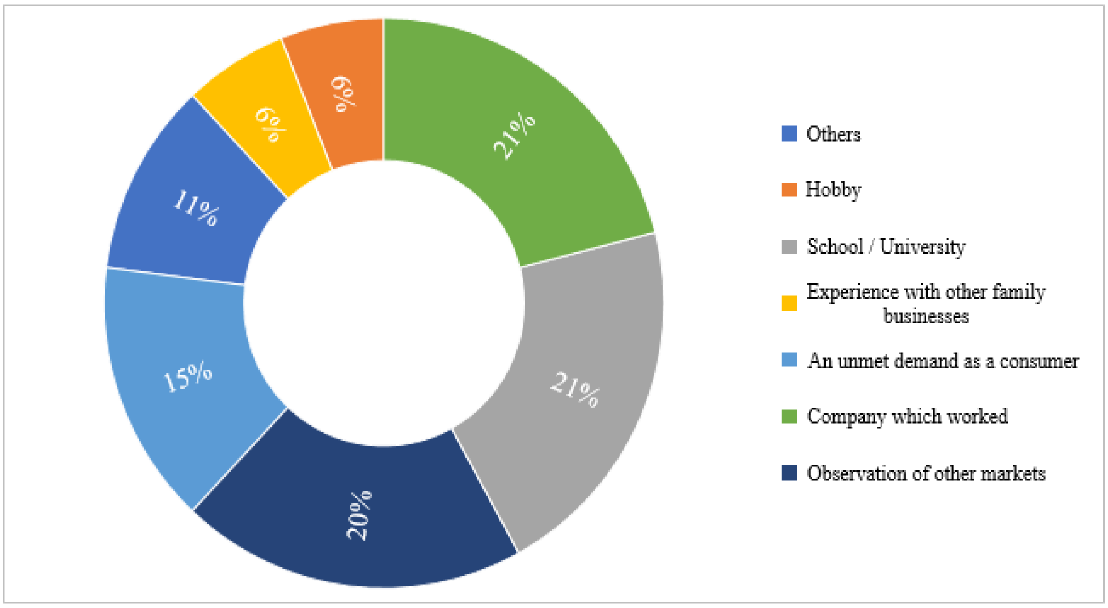


Figure 4. Ideas to create startups
Source: Start Agro (2016), adapted

The company in which one or some founders worked, school and/or universities, and observation of other markets were the main core to development of new ideas for agribusiness startups in Brazil. The innovation in Brazil happens through a decentralized network between researches, investors - public and private. Figure 5 shows the main centers of Research, Development and Innovation (RD&I) in Brazil.

Figure 5. Educational and Research Institutions in Agricultural Technology in Brazil
Source: Dias et al. (2019)

The innovation does not happen exclusively in the research laboratories of multinationals, but in a complex system of partnerships in new ideas in different ways, that is, the open innovation (Araújo and NiColella, 2018; Chesbrough and Appleyard, 2007). The ESALQ (Luiz de Queiroz College of Agriculture), FAPESP (São Paulo Research Foundation), and Embrapa (Brazilian Agricultural Research Corporation) can be highlighted due the range of this institutions in the agricultural production (Chesbrough and Appleyard, 2007).

Agtech are technology companies applied to agribusiness. The venture capital investment in Agtech startups has grown, from US$ 6 billion in 2015 to US$ 80 billion in 2018 (Chesbrough and Appleyard, 2007; Dias, Cleidson Nogueira; Jardim, Francisco; Sakuda, 2019).

In Brazil, there is a chain of development and investment which form an ecosystem (AgTech Garage, 2018; Distrito, 2018; Finistere Ventures, 2018; Startse, 2017). There are 1574 Agtech startups in Brazil. Most of them, 45,6%, are downstream, while 41,6% are midstream and just 12,6% are upstream (Figueiredo et al., 2021). Hence, there are challenges inside farms as much as outside farms (Dias et al., 2019). Figure 6 presents the distribution of Agtech startups by region and federative units.

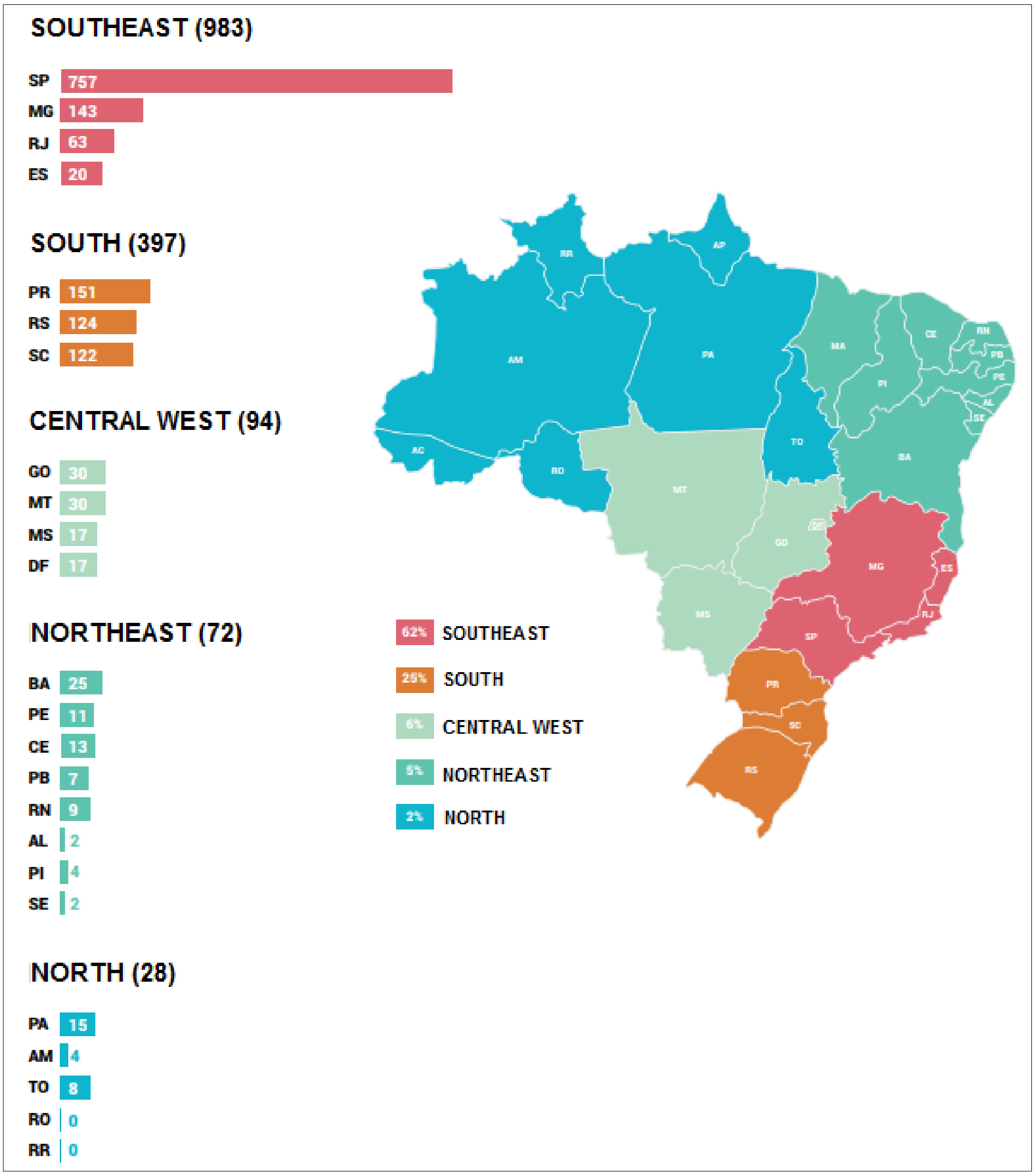


Figure 6. Distribution of Agtech startups by region and federative units
Source: adapted Figueiredo et al. (2021),

The Agtech startups are predominantly located in the Southeast, in state of São Paulo, specifically. This phenomenon must be related to the proximity to RD&I centers, as noticed in Figure 6. But it's important to remember that new Agtech Hubs are growing in new regions such as the South and Central West due to the strong agriculture industry and proximity to growers. These initiatives bring new ideas and startups into the region, where it's easier to validate the MVP's (minimum viable product) and reach the market faster.

The Piracicaba Agtech Valley is considered as the agribusiness center of innovation (Barbosa and Pinheiro, 2020). It received this name because the agricultural technologies developed in Piracicaba (São Paulo – Brazil) are compared to the Silicon Valley (California – USA) of computing. Beyond innovation, the essence of Piracicaba Agtech Valley is related to entrepreneurship and cooperation supported by the private sector, universities and society (Canciani, 2016).

Final Remarks

Since the objective of this paper, that was to analyze the stream of innovation of Agriculture 4.0, such as its origin, features, and consequences, it was noticeable that innovation and technology is essential for the maintenance of competitiveness in the agricultural sector. Agriculture 4.0 is a new concept of production which includes the connectivity among remote devices (through IoT), and artificial intelligence helps the control, management, and decision-making based on big data available in Cloud. The interconnection among these elements drives productivity increases in a sustainable way.

The productivity increase through innovation and technology is essential to nourish the world in a sustainable way. The evolution from 1.0 to 4.0 significantly contributed to this challenge. Agriculture 4.0 is a result of a historical process of technological development. This concept of production has become a reality for several production systems worldwide.

In the agriculture 4.0 revolution, a new development pattern for farms has emerged: the idea of creating platforms that can communicate. Farmers are aware of the innovation storm. The more integrated and connected are the farms, the greater the chances of success. The new vision for agriculture must simultaneously deliver food security, environmental sustainability, and economic opportunity.

In Brazil agribusiness environment, there is a symbiosis between universities (ESALQ, UNICAMP, etc.), development agencies (FAPESP, FINEP, EMBRAPA, CNPQ, etc.), research institutes (IPecege, IAC, etc.), multinationals (Corteva, etc.) and startups. In general, this transformation process comes from research centers, oriented by master's, doctoral and postdoctoral studies.

The financing of Agriculture 4.0 innovation is made up of a mix of state and private funds. There are postgraduate scholarships for researchers within universities, such as scholarships from FAPESP, CAPES (Coordination for the Improvement of Higher Education Personnel) and CNPq (National Council for Scientific and Technological Development). Moreover, there are funds for entrepreneurship projects, such as FAPESP's Innovative Research in Small Companies (PIPE), Studies and Projects Financing (FINEP), and Brazilian Industrial Research and Innovation Company (EMBRAPII). When there is an already proven technical viability, the venture capital resources are also investment funds from Institutes and Multinationals.

Thus, the innovation in the agricultural sector in Brazil is essential to the maintenance of its competitiveness. However, the 4.0 concept is still a challenge the country needs to overcome. Agtech startups are working as a solution for technology diffusion. The Piracicaba Valley Agtech, in the state of São Paulo, is a successful case of Agriculture 4.0 concept development.

This study is limited to focusing on innovation startups located in Brazil. As suggestions for future research, it is recommended to explore the determinants of the foundation of agtech hubs, as well as the regional characteristics that encourage the generation and diffusion of 4.0 technologies.

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References

Agfunder, 2020. 2020 Farm Tech Investing report. Available in: <https://agfunder.com/research/2020-farm-tech-investment-report/>. Accessed in: oct. 20, 2020.

AgTech Garage. 2018. 2º Censo Agtech Startups Brasil. Available in: <https://www.agtechgarage.com/censo/>. Accessed in: oct. 20, 2020.

Alcantara, I.R. 2020. Production factors, agriculture and regional economic development in Brazil. Western Paraná State University – UNIOESTE. Available in: http://tede.unioeste.br/handle/tede/4780. Accessed in: may 8, 2020.

Araújo, P.F.C.; NiColella, A.C. 2018. Evolução recente da economia paulista. p. 47-116. In: Contribuição da FAPESP ao Desenvolvimento da Agricultura no Estado de São Paulo. FAPESP, São Paulo, SP, Brasil.

Araújo, P.F.C. de; Schuh, G.E.; Barros, A.L.M. de; Shirota, R.; Nicolella, A.C. 2003. O crescimento da agricultura paulista e as instituições de ensino, pesquisa e extensão numa perspectiva de longo prazo. FAPESP, São Paulo, SP, Brasil.

Barbosa, S.; Pinheiro, A.C. 2020. Sobre o Vale do Piracicaba. Available in: <http://www.valedopiracicaba.org/sobre-o-vale-do-piracicaba/>. Accessed in: may 18, 2020.

Barley, S.R.; Tolbert, P.S. 1997. Institutionalization and Structuration: Studying the Links between Action and Institution. Organ. Stud., 18: 93-117. <https://doi.org/10.1177/017084069701800106>.

Bono, E. 2003. O modelo atual pede inovação. HSM Manag. 7: 1-5.

Canciani, A. 2016. O Vale do Piracicaba: um caso de inovação para o setor agropecuário brasileiro. Fundação Getulio Vargas, São Paulo, SP, Brasil.

Chesbrough, H.W.; Appleyard, M.M. 2007. Open Innovation and Strategy. Calif. Manage. Rev., 50: 57-76. https://doi.org/10.2307/41166416.

Cochrane, W.W. 1958. Farm Prices: Myth and Reality. University of Minnesota Press, Minneapolis, Minnesota, USA.

Dias, C.N.; Jardim, F.; Sakuda, L.O. 2019. Radar AgTech Brasil 2019: Mapeamento das Startups do Setor Agro Brasileiro. Embrapa, SP Ventures e Homo Ludens, São Paulo, SP, Brasil.

Dias Avila, A.F.; Evenson, R.E. 2010. Total Factor Productivity Growth in Agriculture: The Role of Technological Capita. Handbook of Agricultural Economics. 4: 3769-3822. https://doi.org/10.1016/S1574-0072(09)04072-9.

Distrito, 2018. Agtech mining report. Sao Paulo, SP, Brasil. Available in: <https://materiais.distrito.me/data-miner-agtech>. Accessed in: may 8, 2021.

European Commission. 2017. Industry 4.0 in agriculture: focus on IoT aspects. Available in: <https://ati.ec.europa.eu/reports/technology-watch/industry-40-agriculture-focus-iot-aspects>. Accessed in: may 12, 2021.

Figueiredo, S.S.S.; Jardim, F.; Sakuda, L.O. (Coords.). 2021. Relatório do Radar Agtech Brasil 2020/2021: Mapeamento das Startups do Setor Agro Brasileiro. SP Ventures e Homo Ludens, Brasília, DF, Brasil.

Finistere Ventures. 2018. 2018 agtech investment review. Available in:<https://finistere.com/wp-content/uploads/2018/12/Finistere_Ventures_2018_Agtech_Investment_Review.pdf> Accessed in: may 20, 2021.

Fischer, J.S. 1989. Geography and development: a world regional approach. 3ed. Merril Publishing Company, Columbus, Ohio, USA.

Fuglie, K.; Gautam, M.; Goyal, A.; Maloney, W.F. 2020. Harvesting Prosperity: Technology and Productivity Growth in Agriculture. World Bank, Washington, DC, USA. https://doi.org/10.1596/978-1-4648-1393-1.

Gasques, J.; Bastos, E.; Valdes, C.; Bacci, M.R.P. 2014. Produtividade da agricultura: resultados para o Brasil e estados selecionados. Revista de Política Agrícola, 23(3): 87-98.

Gasques, J.G.; Bacchi, M.R.P.; Bastos, E.T. 2018. Crescimento e Produtividade da Agricultura Brasileira de 1975 a 2016. Carta de Conjuntura, 38: 1-9.

Gasques, J.G.; Bastos, E.T.; Valdes, C.; Bacchi, M.R.P. 2012. Total factor productivity in Brazilian agriculture. p. 145-161. In: Fuglie, K.O.; Wang, S.L.; Ball, V.E. Productivity Growth in Agriculture: An International Perspective. CABI, Wallingford, Oxfordshire, UK. https://doi.org/10.1079/9781845939212.0145.

Gianezini, M.; Ruviaro, C.F.; Santos Júnior, S.; Watanabe, M. 2014. Notes on the evolution of agricultural machinery. Ambiência, 10: 381-388. Supl. 1. https://doi.org/10.5935/ambiencia.2014.supl.11nt.

Jakku, E.; Taylor, B.; Fleming, A. Mason, C.; Fielke, S.; Sounness, C.; Thorburn, P. 2019. “If they don’t tell us what they do with it, why would we trust them?” Trust, transparency and benefit-sharing in Smart Farming. NJAS - Wageningen Journal of Life Sciences, 90-91, 100285. https://doi.org/10.1016/j.njas.2018.11.002.

Jung, C.F. 2017. Inovação. In: Griebeler, M.P.D.; RIEDL, M. (Eds.) Dicionário de Desenvolvimento Regional e Temas Correlatos. Conceito, Porto Alegre, RS, Brasil.

Klerkx, L.; Jakku, E.; Labarthe, P. 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS - Wageningen Journal of Life Sciences, 90–91, 100315. https://doi.org/10.1016/j.njas.2019.100315.

Knierim, A.; Kernecker, M.; Erdle, K.; Kraus, T.; Borges, F.; Wurbs, A. 2019. Smart farming technology innovations – Insights and reflections from the German Smart-AKIS hub. NJAS - Wageningen Journal of Life Sciences, 90-91, 100314. https://doi.org/10.1016/j.njas.2019.100314.

Lantinga, E.A.; Boele, E.; Rabbinge, R. 2013. Maximizing the nitrogen efficiency of a prototype mixed crop-livestock farm in The Netherlands. NJAS - Wageningen Journal of Life Sciences, 66: 15-22. https://doi.org/10.1016/j.njas.2013.07.001.

Lioutas, E.D.; Charatsari, C.; La Rocca, G.; De Rosa, M. 2019. Key questions on the use of big data in farming: An activity theory approach. NJAS - Wageningen Journal of Life Sciences, 90-91, 100297. https://doi.org/10.1016/j.njas.2019.04.003.

Massruhá, S.M.F.S.; Leite, M.A. de A. 2017. Agro 4 . 0 – rumo à agricultura digital. pp. 28-35. In: JC Na Escola Ciência, Tecnologia e Sociedade: Mobilizar o Conhecimento Para Alimentar o Brasil. Centro Paula Souza, São Paulo, SP, Brasil.

McCormick, K.; Kautto, N. 2013. The Bioeconomy in Europe: An Overview. Sustainability, 5(6): 2589-2608. https://doi.org/10.3390/su5062589.

Meyer, J.W.; Rowan, B. 1977. Institutionalized Organizations: Formal Structure as Myth and Ceremony. Am. J. Sociol., 83: 340-363.

Ministério da Agricultura Pecuária e Abastecimento (MAPA). 2019. Saldo da balança do agronegócio foi de U$ 8,6 bilhões em 2019. Available in: <https://www.gov.br/agricultura/pt-br/assuntos/noticias/saldo-da-balanca-do-

agronegocio-em-maio-soma-us-8-6-bilhoes>. Accessed in: may 21, 2020.

Munir, K.A.; Phillips, N. 2005. The birth of the "Kodak moment": Institutional entrepreneurship and the adoption of new technologies. Organ. Stud., 26: 1665-1687. https://doi.org/10.1177/0170840605056395.

Nayyar, S.; de Cleene, S.; Dreier, L. 2018. Innovation with a Purpose: The role of technology innovation. World Economic Forum, 1-42.

Parker, I. 1992. Discourse dynamics: Critical analysis for social and individual psychology. Routledge, London, UK.

Phillips, N.; Lawrence, T.B.; Hardy, C. 2004. Discourse and Institutions. Academy of Management Review, 29(4): 635-652. https://doi.org/10.5465/amr.2004.14497617.

Piwowar, A. 2018. Opportunities and Barriers to the Development of Agriculture 4.0 in the Context of Low Carbon Agriculture in Poland. In: Jedlicka, P.; Maresova, P.; Soukal, I. Hradec Economic Days 2018. Available in: <https://wir.ue.wroc.pl/info/article/WUT5c244c9fe2ea4b4a97bbe1ed45394731/Publication+%E2%80%93+Opportunities+and+Barriers+to+the+Development+of+Agriculture+4.0+in+the+Context+of+Low+Carbon+Agriculture+in+Poland+%E2%80%93+Wroclaw+University+of+Economics+and+Business>. Accessed in: aug. 15, 2021.

Porter, M.E.; Heppelmann, J.E. 2014. How Smart, Connected Products Are Transforming Competition. Harvard Business Review, 92: 64-88.

Rapela, M.A. 2019. Fostering Innovation for Agriculture 4.0. Springer International Publishing, Switzerland. https://doi.org/10.1007/978-3-030-32493-3.

Rizzo, D.; Ritz, S.; Combaud, A. 2020. Mastering Agtech again: emerging of new training offers and intermediate players. Rural Dev., 2019: 57-61. https://doi.org/10.15544/RD.2019.044.

Rojko, A. 2017. Industry 4.0 Concept: Background and Overview. International Journal of Interactive Mobile Technologies (iJIM), 11(5): 77-90. https://doi.org/10.3991/ijim.v11i5.7072.

Salkin, C.; Oner, M.; Ustundag, A.; Cevikcan, E. 2018. A Conceptual Framework for Industry 4.0. p. 3-23. In: Ustundag, A.; Cevikcan, E. Industry 4.0: Managing The Digital Transformation. Springer International Publishing, Switzerland. https://doi.org/10.1007/978-3-319-57870-5_1.

Santos, P.F.A.; Spolador, H.F.S. 2018. Produtividade setorial e mudança estrutural no Brasil: Uma análise para o período 1981 a 2013. Revista Brasileira de Economia, 72(2): 217–248. https://doi.org/10.5935/0034-7140.20180011.

Schimidt, J.G.A.; Cançado, M.P. 2019. Exploração pela complexidade: um modelo teórico para analisar como se dá a extração de valor no complexo agroindustrial da soja. p. 314-330. In: Rodrigues, J.F. (Org.). Inovação, Gestão e Sustentabilidade. Atena Editora, Ponta Grossa, PR, Brasil. https://doi.org/10.22533/at.ed.04719180619.

Schumpeter, J.A. 1997. Teoria do desenvolvimento econômico: uma investigação sobre lucros, capital, crédito, juro e o ciclo econômico. Nova Cultural, São Paulo, SP, Brasil.

Sponchioni, G.; Vezzoni, M.; Bacchetti, A.; Pavesi, M.; Renga, F. 2019. The 4.0 revolution in agriculture: A multi-perspective definition. Proc. Summer Sch. Fr. Turco, 1: 143-149.

Start Agro. 2016. Confira o infográfico completo do 1º Censo Agtech Startups Brasil (em primeira mão). Available in: <http://www.startagro.agr.br/confira-o-infografico-completo-do-1o-censo-agtech-startups-brasil-em-primeira-mao/>. Accessed in: may 5, 2020.

StartSe. 2017. Agrotechs: como as Startups estão revolucionando o agronegócio. StartSe, São Paulo, SP, Brasil.

Tzounis, A.; Katsoulas, N.; Bartzanas, T.; Kittas, C. 2017. Internet of Things in agriculture, recent advances and future challenges. Biosystems Engineering, 164: 31-48. https://doi.org/10.1016/j.biosystemseng.2017.09.007.

Vasconcelos, Y. 2019. A força Agtechs. Pesquisa FAPESP, 287: 21-23.

Vieira Filho, J.E.R.; Fishlow, A. (Eds.). 2017. Agricultura e indústria no Brasil: inovação e competitividade. IPEA, Brasília, DF, Brasil.

Whitmore, A.P. 2000. The biological management of soil fertility project. NJAS - Wageningen Journal of Life Sciences, 48(1): 115-122. https://doi.org/10.1016/S1573-5214(00)80009-3.

Yin, R.K. 1986. Case Study Research. Organization Studies 7: 95-95. https://doi.org/10.1177/017084068600700114.

Zambon, I.; Cecchini, M.; Egidi, G.; Saporito, M.G.; Colantoni, A. 2019. Revolution 4.0: Industry vs. agriculture in a future development for SMEs. Processes, 7(1): 1-16. https://doi.org/10.3390/pr7010036.

Zaparolli, D. 2020. Agricultura 4.0. Pesquisa FAPESP, 287: 12-20.