# Innovation ecosystem in agriculture
## Embrapa's evolution and contributions

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## Introduction

There are several challenges facing digital transformation of agriculture, and according to Simões et al. (2017, p. 52),

> [...] implementing an adapted and less expensive digital agriculture model using national technology could be the great revolution in the field, as small farmers and large grain producers search for innovation, thus making their crops more efficient and sustainable.

The concept of open innovation reflects the collaboration scenario, which is important to operate in a context as dynamic as that of digital innovation (Chesborough et al., 2003), in which knowledge, experience and capabilities are dispersed among various organizations. Gomes et al. (2018) consider the perspective of joint value creation and innovation in an ecosystem, with cooperation and competition processes.

The work of Teixeira et al. (2017) highlights that acting in innovation ecosystems involves reciprocity between public and private actors (from corporations to technological startups), organizations that support the creation of enterprises (such as incubators, business accelerators, associations, coworkings, hubs innovation), investors, services such as the Brazilian Micro and Small Business Support Service (SEBRAE) and entrepreneurship support organizations such as Endeavor.

The "ecosystem" concept was developed in the 1930s with the intention of creating a clearer and simpler nomenclature for biological systems in the field of ecology (Golley, 1991), and was later used in other

study areas. Bambini and Bonacelli (2019) highlight other uses of the term "ecosystem" in the social sciences, referring to the entrepreneurial environment. Some approaches emphasize the entrepreneurial ecosystem developed around large universities (Fetters et al., 2010), while others emphasize the role of entrepreneurs in influencing their ecosystem (Feld, 2012). Malecki's (2018) approach considers that the entrepreneur is a central actor in an innovation ecosystem, always integrated with other equally important organizations and institutions, with a role of interdependence and complementarity.

One of the origins of the innovation ecosystem concept is precisely the systemic approach to innovation (Suominen et al., 2019), developed in the early 1990s by authors such as Lundvall (1992) and Nelson (1993), who consider that innovation is the result of relationships established between various actors to produce, disseminate and implement new knowledge, economically useful, within a nation.

The innovation systems approach quickly spread in the academic environment, as well as in regional and sectoral perspectives (Edquist, 2006). The focus of sectoral innovation systems considers the specificities of each economic sector in relation to innovation processes, based on their sources of scientific knowledge and technological opportunities, the research fields involved, actors, relationships, performance of institutions and policies, market, and others (Malerba, 2006).

The analysis of innovative processes in agriculture has been developed with a systemic focus and, more recently, also under the innovation ecosystem approach, according to Pigford et al. (2018). The difference of this approach is that the ecosystem actors interact with each other and with the ecosystem as a whole, creating a value that would not be generated without the relationships and complementarity of the other actors involved. The ecosystem concept is associated with a shared environment of evolution for the creation of value and innovation, with different roles and competences, marked by the sharing and mutual strengthening of the dynamic capabilities of the participating actors (Teece, 2009; Suominen et al., 2019).

There are several categories of actors involved in agricultural innovation, namely: a) agricultural producers; b) education and training system; c) agricultural research system; d) research and innovation agencies; e) credit agencies; f) rural extension and technical assistance system; g) companies supplying inputs, equipment and services; h) producer and business organizations; i) agroprocessors; j) exporters; k) government institutions; and l) end consumers (Rajalahti, 2012). Also part of the "enterprise generation mechanisms", such as business incubators, accelerators, coworkings and open laboratories (Audy; Piqué, 2016), and, with a central role are the agricultural technology-based startups, called agtechs, agritechs or agrifoodtechs (AgFunder, 2020). It is understood that agtechs have more agility, knowledge and audacity so that the new technologies reach the field, as they have a more agile and disruptive modus operandi and mentality (Cook, 2020).

In this new innovative context, Embrapa Digital Agriculture, a research unit of the Brazilian Agricultural Research Corporation (Embrapa) that works in digital technologies, has been contacted by companies from different segments, with emphasis on information technology, bank insurance, communication technologies, investors and accelerators, and also by Non-Governmental Organizations (NGOs). Researchers at Embrapa Digital Agriculture have offered technical mentoring in several startup development programs, strengthening companies and the sector's human capital.

This chapter reports the performance of Embrapa Digital Agriculture in terms of strengthening the Brazilian agricultural innovation ecosystem. The next section describes the Brazilian contextual characteristics and the actions developed by Embrapa nationwide. Section 3 details initiatives developed in the state of São Paulo, considering the type of actor involved and the type of relationship established. Section 4 describes the AgroAPI initiative, an example of an innovative public-private partnership model for digital agriculture. At the end of the chapter, the final remarks are presented.

# Embrapa's performance record in agricultural innovation ecosystems

## Agricultural innovation ecosystem in Brazil: actors, resources and regional differences

Economic geography is a field that seeks to understand dynamics and competitiveness, analyzing the spatial agglomeration of economic activity as a source of growing benefits. Feldman and Kogler (2010) point out that innovation is geographically concentrated, with differences between locations depending on their innovation capacities and configuration, defined by historical, cumulative and evolutionary processes developed over time. The evolutionary perspective[1] of economic geography also considers the influence of historical events, whether close or remote, random or not, on the trajectory and results of economic changes that occur over time (Davi, 1985; Arthur, 1994).

Sotarauta's (2004) work analyzes the capabilities of each region to use and create resources, developing a strategic regional development model based on dynamic capabilities, a concept originally established by Teece et al. (1997) to understand the process of acquisition of new competitive advantages y the firm, inserted in fast-changing environments.

Agricultural technology-based startups (agtechs) play a central role in offering and disseminating technologies and innovations to producers, using new business models, and in interacting with educational institutions, research centers, investors, large corporations and other innovation support organizations.

Bambini and Bonacelli (2019) identified several Brazilian organizations that have a relevant role in agricultural innovation with national capillarity: Brazilian Micro and Small Business Support Service (SEBRAE); SENAI-SESI-IEL System, formed by the National Service for Industrial Training (SENAI), the Social Service of Industry (SESI) and the Euvaldo Lodi Institute (IEL); Federal Institutes of Education, Science and Technology; Research Centers of the Brazilian Agricultural Research Corporation (Embrapa), with strong regional influence; National Service for Rural Learning; and the Public Rural Extension Network, linked to state governments and present throughout Brazil.

Oliveira Junior et al. (2019) highlight that both technology-based entrepreneurship and innovation environments and leading Brazilian universities are located in the Southeast and South regions of the country, which are more industrialized and account for about 75% of the Brazilian Gross Domestic Product (GDP). Table 1 corroborates this information, based on the analysis of recent reports on the distribution of innovation environments, such as technology parks, and mechanisms for generating enterprises, as defined by Audy and Piqué (2016).

Table 2 presents the main cities that concentrate agtechs in Brazil, totaling 55% agtechs. The São Paulo cities listed represent 36.4% of the agtechs mapped. This concentration corresponds to the new dynamic region of the state of São Paulo, identified by Marighetti and Sposito (2009). The state of São Paulo concentrates 58% of startups mapped by Dias et al (2019).

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[1] Evolutionary economics, developed in the 1980s based on the seminal works of Nelson and Winter (1977, 1982), was adopted by economic geography to better understand the geography of technical progress; the dynamics of competitive advantage; economic restructuring; and economic growth, according to Boschma and Martin (2010).

In terms of resources and innovation capabilities, the regions of Campinas, São José dos Campos, São Carlos and Ribeirão Preto stand out as development hubs related to Information and Communication Technologies (ICT) and Telecommunications. In relation to agrarian sciences, a recent study identified 154 Research and Education organizations of the state of São Paulo operating in this area, including agricultural Research Center (50%), public colleges (30%), technology colleges (15%) and private colleges (7%), with 30% of these institutions concentrated in the cities of Campinas, Piracicaba and São Paulo (Firetti et al., 2016).

**Table 1.** Percentage of technology parks, mechanisms for generating new enterprises and agtechs in the Brazilian regions.

| Region | Technology park (%) | Incubator (%) | Accelerator (%) | Agtech (%) |
|---|---|---|---|---|
| Midwest | 9.7 | 10.7 | 6.9 | 6.5 |
| Northeast | 8.7 | 16.8 | 12.0 | 3.4 |
| North | 5.8 | 8.5 | 1.7 | 1.1 |
| Southeast | 39.9 | 36.4 | 57.0 | 66.0 |
| South | 35.9 | 27.6 | 22.4 | 23.0 |

Source: Brasil (2019), Dias et al. (2019) and National Association of Entities Promoting Innovative Enterprises (2019).

The city of São Paulo concentrates 23% of agtechs. Even though it is a large urban metropolis, the concentration of agrarian technology-based startups is justified by the resources and innovation capabilities offered by the state capital, considered the largest center of innovation and entrepreneurship in Latin America. The culture of startups and entrepreneurship in the capital is rapidly emerging, according to Oliveira Júnior et al. (2019). A 2019 startup ecosystems ranking (StartupBlink, 2019) classified the city of São Paulo as the 23rd startup ecosystem in the world, the only one in Latin America ranked in the list of the 25 most relevant ecosystems, taking into consideration the number of startups, quality ecosystem and business environment. Table 3 presents an international classification of entrepreneurial ecosystems based on the survey by StartupBlink (2019).

The United States is emphasized in this ranking with several relevant ecosystems. The country is an important agricultural producer, and the sector aggregates more than two million companies, generating

**Table 2.** Main Brazilian cities where agtechs are located.

| | City | Number of agtechs | State | Participation percentage (%) | Accumulated percentage (%) |
|---|---|---|---|---|---|
| 1 | São Paulo | 262 | SP | 23.3 | 23.3 |
| 2 | Piracicaba | 41 | SP | 3.6 | 26.9 |
| 3 | Campinas | 38 | SP | 3.4 | 30.3 |
| 4 | Ribeirão Preto | 37 | SP | 3.3 | 33.6 |
| 5 | Curitiba | 36 | PR | 3.2 | 36.8 |
| 6 | Rio de Janeiro | 35 | RJ | 3.1 | 39.9 |
| 7 | Porto Alegre | 29 | RS | 2.6 | 42.5 |
| 8 | Belo Horizonte | 24 | MG | 2.1 | 44.6 |
| 9 | Florianópolis | 21 | SC | 1.9 | 46.5 |
| 10 | Uberlândia | 19 | MG | 1.7 | 48.2 |
| 11 | Goiânia | 17 | GO | 1.5 | 49.7 |
| 12 | São José Dos Campos | 17 | SP | 1.5 | 51.2 |
| 13 | Londrina | 15 | PR | 1.3 | 52.5 |
| 14 | Campo Grande | 14 | MS | 1.2 | 53.8 |
| 15 | São Carlos | 14 | SP | 1.2 | 55.0 |

Source: Dias et al. (2019).

significant income and around 11% of the country's jobs (Australian Trade and Investment Commission, 2018). The Land Grant Colleges had the role of working with communities, developing new agricultural technologies with experimental stations and rural extension services. Lyons et al. (2018) consider that the transfer of technologies generated in universities and the sharing of resources, such as extension services and experimental stations, can contribute to develop the opportunities identified with agtech entrepreneurs, in addition to supporting the capture of investments.

The United States is responsible for 35% of the volume of venture capital for the agtech sector, according to AgFunder (2020). The Austrade report (Australian Trade and Investment Commission, 2018) highlights the following American states as important agtech clusters: California, North Carolina, Missouri, Colorado, and Illinois. The document also mentions emerging clusters: Minnesota, Indiana, and Wisconsin.

It is worth noting, in California, the ecosystem of Salinas, a city located in Monterey County, on the central coast of the state, approximately 100 km from Silicon Valley. The city acts as an important economic hub in the region, which has a relevant agricultural industry both in terms of production (with horticulture, production of strawberries and wines) as well as the presence of large agricultural production enterprises (Myrick; Deloffre, 2017). The resources established in the locality to support this project were: a) startup acceleration program; b) a business incubator, with work and collaboration spaces, as well as research initiatives applied to real cases; c) programs to encourage young entrepreneurs; and d) partnerships between secondary schools in the region to strengthen the training of young people.

Another prominent country in agricultural innovation is the United Kingdom, which ranks fourth in risk investments in agtechs, according to AgFunder (2020). The British innovation ecosystem attracts many entrepreneurs and investors and accounts for 45% of European venture investment in the agtech sector (AgFunder, 2019). Another important region in terms of agtech venture investment is Israel, the 5th country in terms of invested resources (AgFunder, 2020). Known as the "startup nation", Israel is a global innovation center with a culture based on interdisciplinary capabilities, technological skills and entrepreneurial spirit (Israel Innovation Authority, 2019).

Brazil has attracted the interest of investors and fostered its agricultural innovation ecosystem, based on the actions of several actors. As identified in the study by Dias et al. (2019), Brazil has 1125 agtech startups headquartered in its territory. Operating in various technological areas, startups play an important role in disseminating new technologies to agricultural producers, especially new digital tools.

**Table 3.** Startup Ecosystem Ranking in the year of 2019.

| Ranking | Country |
|---------|---------|
| 1 | United States |
| 2 | United Kingdom |
| 3 | Canada |
| 4 | Israel |
| 5 | Australia |
| 6 | Netherlands |
| 7 | Sweden |
| 8 | Switzerland |
| 9 | Germany |
| 10 | Spain |

Source: StartupBlink (2019).

# Relationships established by Embrapa with ecosystem actors

Focusing on open innovation, Embrapa's innovation model seeks partnerships for the different stages of creating technological assets. In all types of partnerships, those carried out with agtechs, technology companies applied to agriculture at the initial or medium stage of maturity, have gained increasing prominence. The agtech ecosystem is considered fundamentally important, as it uses new operating concepts that have contributed to developing technological solutions capable of increasing the sustainability and competitiveness of Brazilian agribusiness, such as agile management; lean startup; gamification; self-managing teams; and others.

In several agricultural chains, the interaction between actors from science and technology institutions (STI), private companies, rural producers and consumers is still incipient, therefore each link operates individually. Ideally, each part could interact with the others, so that rural producers and consumers present their needs to the ICTs, related to technological research, and to private companies, in relation to its capacity to complement the development of solutions and the process of making them available to the producer and/or consumer market.

Thus, it is noticeable that the Brazilian innovation and entrepreneurship environment has changed rapidly in recent years, especially the strengthening of joint initiatives between private companies, startups, development agencies and risk fund managers (Venture Capital). When it comes to entrepreneurship and rapid growth of technology-intensive companies, Silicon Valley, California (USA), is the reference, and one of the key points in this process is the existence of financing sources for venture capital. The allocation of financial resources of this nature – venture capital – is essential for these companies to have the financial conditions to operate in the early stages of their innovation and development process.

The approach of entrepreneurs and research centers is enhanced with the inclusion of the financial link in the process of building innovative companies. Therefore, Embrapa interacts with Venture Capital companies in the agribusiness startup segment (AgriTechs), such as Cedro Capital, SP Ventures and NTagro, so that companies with Embrapa technology receive financial resources to accelerate their business.

One of the ways to expand this interaction and promote innovation ecosystems can be through actions aimed at the development and strengthening of startups. Some of the actions with the greatest impact are the innovation challenges, such as hackathons, demodays, business rounds, matchmaking events and bootcamps.

Interacting with different sources of knowledge is a fundamental condition for a company to innovate and incorporate new solutions. This movement in favor of innovation, exploring disruptive technologies, was also intensively supported at Embrapa, which has actively followed the initiatives developed by its Decentralized Units (UDs) and by its partners.

Some of the possibilities that Embrapa has accessed external knowledge and created new partnerships to implement its open innovation model, are the initiatives presented in Table 4.

During the events presented above, startups received mentoring from experts in agribusiness, technology and business; had opportunities to present their ideas to representatives of the production sector and investors, receiving feedback on their strengths and weaknesses; participated in awards and matchmaking actions with large companies in the production sector, innovation hubs, accelerators and seed and venture capital investors.

As a result, Embrapa and key companies in the agricultural sector had opportunities for growth, and contributed to increase the effect of technologies generated by institutions in the agricultural research sector, co-developed, adopted or in phase of adoption by the private companies installed in the country. In each innovation initiative, Embrapa established cooperation agreements for the development of technological solutions and assets, catalyzing open innovation and getting financial returns for the federal government, through royalty payments or profit sharing in the commercialization of the solutions created.

The open innovation actions undertaken by Embrapa supported the consolidation of the Brazilian agricultural innovation ecosystem through the interaction between companies, universities, agricultural research institutes and the productive sector, through the presentation of new technological solutions for the promotion of technology-based entrepreneurship in agriculture. In addition, in its 2019–2023

**Table 4.** Embrapa's open innovation initiatives.

| Event | Objective |
|---|---|
| Avança Café | Avança Café is a pre-acceleration program for startups that aims to encourage the development of technological solutions for the coffee sector. |
| Caminho Startups Seminar | Seminar to discuss opportunities and challenges for startups in São Carlos, with the presentation of startups linked to Embrapa Instrumentation to the companies AgroRobótica and Fine Instrument Technology (FIT). |
| Soja Open Innovation | Open Innovation Soybean is a public call for the selection of startups interested in developing open innovation projects having Embrapa Soybean as a technical partner for the development or improvement of solutions in areas that adhere to priority research lines indicated in the guidelines of the call. |
| TechStart AgroDigital | TechStart Agro Digital is an acceleration program created by Embrapa Digital Agriculture and Venture Hub®, with support from the National Association of Entities Promoting Innovative Enterprises (Anprotec), to help startups, large companies and institutions to accelerate businesses and technologies for the agribusiness. |
| Ideas for Farm | Ideas for Farm is an innovation challenge that seeks technological solutions for Brazilian agribusiness, focusing on the Mid-North region of Brazil. |
| Pitch Deck AgTechs | The Pitch Deck refers to a quick and visual presentation used to attract the attention of investors and show the public the main differentials in the food, environment, waste management, pest control, phenotyping and livestock solutions segment. |
| Ideas for Milk | Ideas for Milk is a startup challenge that creates opportunities for young entrepreneurs to validate and present their ideas and solutions, connecting investments from large corporations that value innovation and that boost incorporating digital technology into the world of milk. The objective is to increase the level of innovation in the milk chain, increasing efficiency from the farm to the relationship with the final consumer, with respect for animals, the environment and society in general. |
| Vacathon | It is a hackathon whose objective is to debate ideas for the development of software and hardware aimed at solving problems in the milk production chain. |
| InovaPork | InovaPork is the first challenge of ideas in pig farming. The objective is to foster meaningful innovation in pig farming and attract innovative individuals with ideas at any stage of maturity, helping them to become businesses and solutions for the swine production chain. |
| InovaAvi | InovaAvi is the first ideas challenge in poultry farming. The proposal is to foster meaningful innovation in poultry farming and attract innovative individuals with ideas at any stage of maturity, helping them to become businesses and solutions in the poultry production chain. |
| Camp de EcoInovação Agrotech | It is a challenge of ideas/startups focused on eco-innovation, promoted by the UN Environment, SEBRAE and Embrapa, which seek eco-innovative solutions for agribusiness. In the first edition, the challenge was for the grain chain; for the next edition, the theme will be "food waste". |
| Gado de Corte 4.0 | The Beef Cattle Event 4.0 was an innovative action for the beef cattle chain in Brazil. Based on real demands identified together with companies in the chain, it promoted a call for proposals, open to startups and Science and Technology Institutes interested in working for the chain. |
| Pontes para Inovação | Pontes para Inovação is a public call developed in partnership between Embrapa and Cedro Capital, which aims to connect agritechs with investors, partners and customers, in order to allow them to have access to resources that could accelerate their business. |
| Hackathon Embrapa | The National academic Hackathon Embrapa is a contest for the participation of teams of students and graduates, with the objective of choosing the best technological solutions in the development of mobile applications, hardware solutions, Internet of Things (IoT) solutions, educational pieces or games, with a focus on technological innovation of agricultural interest. |

**Table 4.** Continuation.

| Event | Objective |
|---|---|
| Agritech Semiárido | It is an innovation challenge conducted in order to promote the development of innovative solutions through startups for agribusiness problems facing the Brazilian semiarid region, promoting mentoring with experts in agriculture, technology and business and enabling the connection with the production sector. |
| Inova AgroBrasília | Inova AgroBrasília is the first challenge of technological solutions carried out by the Department of Agriculture of the Federal District (DF), Emater-DF, Embrapa, AgroBrasília and Coopa-DF. Its objective is to attract business men, academics or entrepreneurs with innovative ideas at any stage of maturity and collaborate for these ideas to become businesses with the potential to solve problems experienced by the sector. |
| InoveAqua | The purpose of InoveAqua is to provide a favorable environment for transferring knowledge to university students, to the community and to the professionals in the areas that are related to the many segments of the aquaculture chain. It aims to develop skills and promote innovations for the development of Brazilian aquaculture, contributing to increase the production and provide enhanced competitiveness, sustainability and innovation in the production chain. |
| Horta & Escola | The purpose of this contest is to promote a competition between elementary, secondary and technical education students from schools in the Federal District and surrounding cities of the state of Goias, inspiring them to work as a team and to create businesses, processes, products, services and innovative solutions, with social and economic impact. Therefore, it seeks to promote the practice of innovation and the dissemination of an entrepreneurial culture. |

Source: Embrapa (2020).

business plan, Embrapa continues to prioritize the goal of implementing 25 innovation initiatives, nine of which have already been carried out in 2019.

It is noteworthy that the actions carried out by Embrapa were recognized within the federal government, with led to the inclusion of an Embrapa representative in the National Committee of Support Initiatives for Startups, created by Decree No. 10,122/2019, to articulate the Executive Power actions for innovative startups.

# Relationships of Embrapa Digital Agriculture with the innovation ecosystem

Embrapa Digital Agriculture, one of Embrapa's Decentralized Unit, has the mission of enabling research, development and innovation solutions in digital agriculture, which has been heavily demanded in the last five years by various actors in the agricultural innovation ecosystem. Thus, in order to disseminate and potentialize its research, development and innovation initiatives in the production sector, this Research Unit has traditionally established collaborative research contracts with educational and research institutions and private companies. Figure 1 presents two graphs with the percentage of agreements, licensing and non-disclosure terms with public and private institutions over the last five years. Forty four technical cooperation agreements were signed with public institutions and 28 software licenses were granted, in particular the Ainfo software for library management. With a greater insertion of Embrapa Digital Agriculture in the innovation ecosystem, through different initiatives such as hackathons, participation in innovation programs, organization of workshops and fairs, among others, and consequently larger exposure of its research lines, there was an increase of private companies' interest in
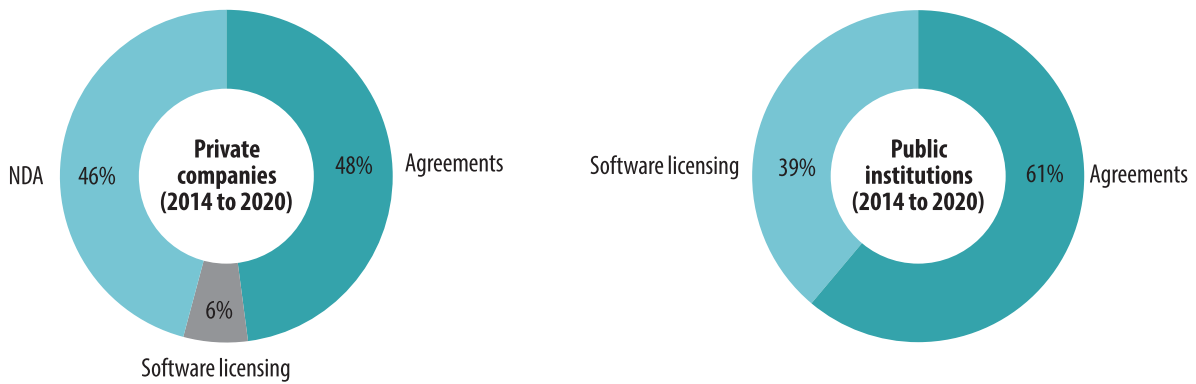
**Figure 1.** Percentage of legal instruments signed between Embrapa Digital Agriculture and public institutions and companies over the last 5 years.

partnerships. Negotiations with private institutions are usually preceded by Confidentiality Contracts or Non-Disclosure Agreement (NDA). Over the past few years, 22 NDAs were signed, many of which led to an Agreement, totaling 23 at the beginning of 2020.

As shown in Figure 2, the number of agreements, NDAs and software licensing has increased over the past few years as a result of the Unit's insertion into the innovation ecosystem. As 2020 could not be fully accounted for, it was not included in the graph shown in Figure 2. However, until May 2020, six cooperation agreements, five NDAs and one software licensing were signed.

Embrapa Digital Agriculture has established partnerships with institutions throughout the national territory, with emphasis on the Southeast and Midwest regions, as shown in Figure 3.
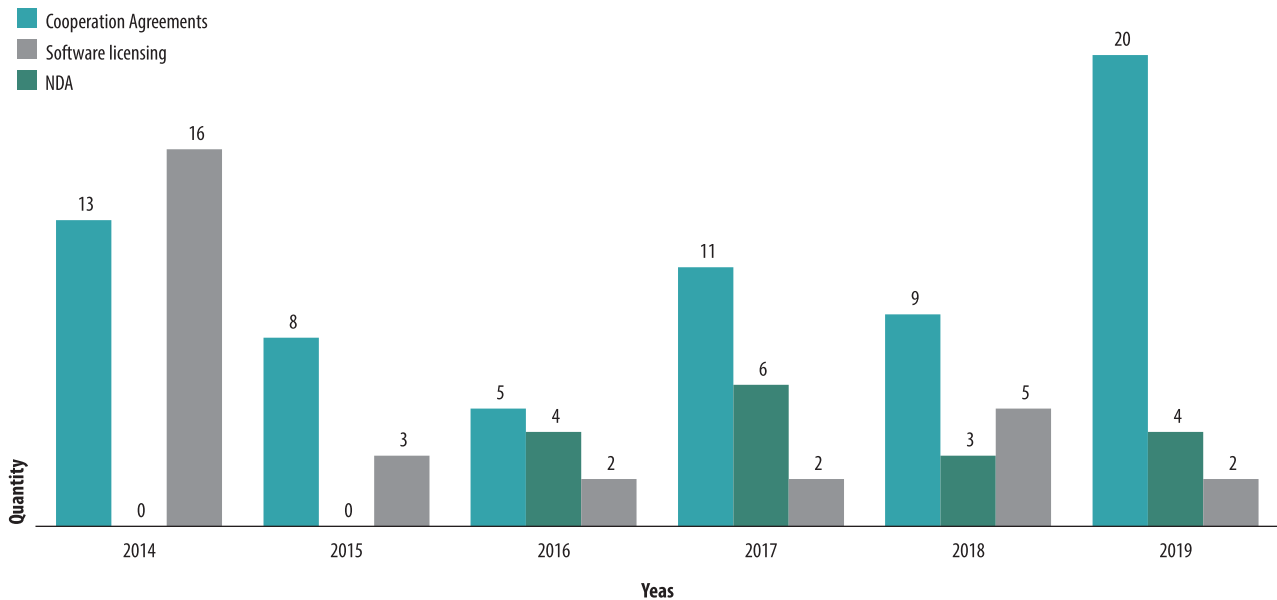


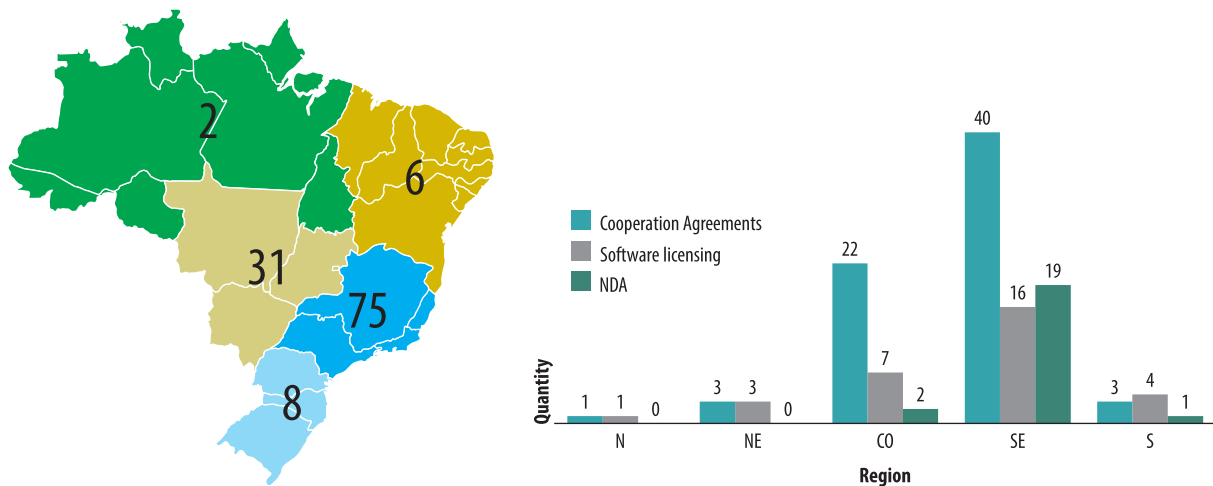**Figure 2.** Legal instruments signed by Embrapa Digital Agriculture from 2014 to 2019.

**Figure 3.** Research Center partnerships in the national territory.

# Embrapa's contribution to adopting and evaluating the effect of technologies in agriculture

As a public agricultural research institution with a mandate for the entire Brazilian territory, Embrapa receives most of its resources from the federal government. Every year the Company evaluates the adoption rates and effects of the technologies and innovations generated, considering its various stakeholders.

The concern regarding the availability of systematized information about the adoption and impacts of technologies generated by Embrapa, mainly in the economic and social dimensions, dates back to the first edition of the Company's Social Balance, published in 1997. In its introduction, Alberto Duque Portugal, the president at the time, believed that the various experiences of rural development carried out by Embrapa, many of them in partnership, led to positive social impacts through the adoption of technologies developed and transferred to society, benefiting the entire country, which he called social profit.

This process was developed with the y training the Company's technical staff associated to methodological developments. In 2008, a reference methodology called Evaluating the Effects of Technologies Generated by Embrapa was published. Currently, all the Company's Decentralized Research Centers follow the same impact assessment model, based on the one proposed in 2008, but with the necessary adjustments to the present context. The dimensions currently analyzed are: a) economic; b) socio-environmental; c) employment; and d) institutional development.

Every year, all of Embrapa's Research Units report the impacts of their main technologies, and this effort to systematize information is consolidated in a Social Balance, which is published in digital media (internet) and printed as mechanism for accountability and transparency. From these data, the relationship between social profit and operating income is calculated, which generates an index that shows the return that each Brazilian Real invested in the Company offer to society. Over the last 2 years, according to data reported in the 2018 and 2019 in Embrapa´s Social Balance Reports, these rates were higher than USD 12.00 returned for each dollar invested. This data gains importance as the federal government invests billions of dollars in the Company, that is, this large capital contribution is remunerated by a counterpart

12 times greater than the amount invested. Thus, social profits in 2018 and 2019 were USD 8,44[2] billion and USD 9,02 billion, respectively.

In terms of the federal administration, the Impact Assessment Reports measure the Company's effectiveness, since the disclosure of its results contributes to promoting its accountability for control organizations, becoming an important indicator of Embrapa's operational viability.

As one of the 42 Decentralized Units of the Company, Embrapa Digital Agriculture is also involved in the preparation of impact assessment reports. As a reference center in agroinformatics for the entire Company, it develops digital technologies applied to various problems in Brazilian agriculture and livestock. This variety of themes is reflected in the impact reports of the technologies generated by this research center over the last ten years. Table 5 presents each reported technological asset, its respective evaluation period and the theme related to the initiative.

**Table 5.** Technologies analyzed by Embrapa Digital Agriculture through impact assessment reports over the last 10 years.

| Technology | Period analyzed | Site | Theme associated with technology | Economic impact (BRL[1]) base year 2019 |
|---|---|---|---|---|
| Computerized System for the Management of Printed and Digital Library Collections (Ainfo) | 2012–2019 | www.ainfo.cnptia. embrapa.br | Library management and knowledge availability | 15,054,680.91 |
| Embrapa Information Agency (Ageitec) | 2010–2019 | www.agencia. cnptia.embrapa.br | Availability of knowledge | 6,279,104.22 |
| Vegetation Temporal Analysis System (SATVeg) | 2019 | www.satveg. cnptia.embrapa.br | Geotechnologies | 1,057,989.27 |
| Interactive Environmental Licensing Support System (SISLA) | 2013–2018 | www.sisla.imasul. ms.gov.br | Geotechnologies | 1,564,350.84 (data from 2018) |
| Agrometeorological Monitoring System (Agritempo) | 2014–2019 | www.agritempo. gov.br | Agrometeorology | 2,491,920.01 |
| Agricultural Climate Risk Zoning (ZARC) | 2017–2019 | - | Methodology applied to public policy | 4,661,047,163.73 |
| Virtual Diagnosis | 2010–2012 | www.diagnose. cnptia.embrapa.br | Remote diagnosis of plant diseases | 332,941.00 (2012 data) |
| Free Software Network for Agriculture (Agrolivre) | 2010–2011 | www.agrolivre. gov.br | Free software repository | 118,156.02 (2011 data) |

[1] Average dollar exchange rate for 2019: USD 1 = BRL 3.9233.

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[2]  Average dollar exchange rate for 2020: USD 1 = BRL 5.1575.

# Developing the agricultural innovation ecosystem in the state of São Paulo

Embrapa Digital Agriculture has been developing important actions in its surroundings in order to strengthen the local and state agricultural innovation ecosystem. This section details the initiatives developed in the state of São Paulo, considering the type of actor involved and the form of relationship established.

The state of São Paulo is responsible for about 32% of the Brazilian Gross Domestic Product (GDP). In 2019, agribusiness represented 12% of the state's GDP. The city of São Paulo stands out for being the largest innovation and entrepreneurship center in Latin America, concentrating a large amount of resources and innovation capabilities, such as research centers, universities, technology parks, business incubators, open laboratories, innovation hubs, coworkings and various events dedicated to technology, entrepreneurship and innovation. Furthermore, it concentrates the headquarters of numerous corporations, financial institutions and risk investors.

In addition to the capital, several cities in the state have important innovation ecosystems, especially Campinas, the third city in São Paulo in terms of population and GDP, where Embrapa Digital Agriculture is located. The Metropolitan Region of Campinas, which includes the city of Campinas and 20 surrounding municipalities, corresponds to 18% of the state's GDP and about 7% of its population (Sistema Estadual de Análise de Dados, 2020). In recent years, the region has gained and consolidated an important economic position in the state and national scenarios, concentrating many technological industries, technological and scientific research centers, as well as private universities and colleges, an important structure for agricultural research and a significant agro-industrial production (Agência Metropolitana de Campinas, 2020).

The strengthening of an agricultural innovation ecosystem involves relationships, partnerships and interactions established with new technology-based companies, such as the acceleration program for agricultural technology-based startups called TechStart AgroDigital (TSAD). Created in partnership with Venture Hub, accelerator and creator of new businesses, and the National Association of Entities Promoting Innovative Enterprises (Anprotec), the program is based on processes for identifying, selecting and offering support to innovative agribusiness ventures (startups) for a period of 6 months, offering them various development activities. The program had eight topics of interest a) biotech; b) precision livestock; c) field automation and robotization; d) nutrition and animal health; e) identification and detection of pests and diseases; f) agricultural risk management; g) fruit and vegetable chain; and h) management and monitoring of water, soil and plants. During the program, which took place in the 2nd semester of 2019, technical and business mentoring were conducted to support the development and validation of selected technologies. In the first cycle of the TSAD, more than 90 startups signed up and went through a process that selected 13 startups to participate in the program, 11 of which graduated in early 2020. The program contributes to solving several problems in the agribusiness production chain, meeting the expectations of customers, beneficiaries and users in the program's eight themes.

It is understood that the TSAD, due to its closer relationship with the selected startups, enabled Embrapa to gain greater knowledge and agility to interact with this new type of actors (startups), as well as with an accelerator for new business. In addition, the program represented an institutional strengthening opportunity for Embrapa, making it better known in the Brazilian agricultural innovation ecosystem and increasing its role in the agricultural digital transformation scenario. In this program, colleagues from other Embrapa Research Centers actively participated in mentoring or in the suggestion of content and lectures.

They are: a) Secretariat for Innovation and Business (SIN); b) Embrapa Agricultural Instrumentation (São Carlos); c) Embrapa Maize & Sorghum (Sete Lagoas); and d) Embrapa Soybean (Londrina).

Other recent actions related to the interaction with startups were:

- In 2017, at the *Open Innovation Business Round – 100 Open Startups and 100 Open Techs* – the Embrapa Digital Agriculture´s evaluation team was recognized as one of the most demanded by participating startups, helping 14 startups in a single day of the round, held in Campinas.

- Embrapa Digital Agriculture has contributed with ongoing mentoring offered by the São Paulo Research Foundation (FAPESP) to companies in its Small Businesses Innovative Research program, called PIPE. Some of PIPE's objectives are: a) to support research in science and technology as an instrument for technological innovation, development and business competitiveness of small companies; and b) enable the association between companies and academic researchers in research projects aimed at technological innovation. FAPESP offers training to the participating companies to improve their business models and therefore counts on the mentors' support. Embrapa Digital Agriculture employees have been mentoring the program since 2018.

- The Unit has supported, since 2018, the pre-acceleration program for digital startups (Startup SP) carried out by the SEBRAE-SP, which supports the development of innovative companies that use software or information technology services as the central point of its business model. In Piracicaba, the program's focus has been on startups linked to the agribusiness value chain. During the program, companies participate in workshops, seminars, individual and collective mentoring, and have the opportunity to interact with investors and accelerators – activities that help validate the product or service developed and its arrival on the market. The program takes place over four months, from April to July, and Embrapa Digital Agriculture participates in the mentoring stages with a team composed of researchers and analysts in the areas of Technology Transfer (TT) and Research and Development (R&D).

- Embrapa and its partners organized and carried out, during the *XI and XII Brazilian Congress of Agroinformatics* (SBIAgro), in 2017 and 2019, the SBIAgroConect@, in order to promote interaction and the formation of qualified market networking between institutions, ICT companies, users, accelerators, investors and developers related to the subject of data science and digital agriculture. The dynamics involved lectures by institutions and companies, presenting innovation initiative programs and relationship conversations, in order to enable integrated, advanced or differentiated solutions to be offered to the market. In 2017, the event had 100 participants and achieved the objective of promoting an environment for connections and networking qualified in technological solutions for agribusiness.

- In 2017, Embrapa Digital Agriculture promoted the XI SBIAgro Innovation Challenge, held at the State University of Campinas (UNICAMP). The challenge included encouraging young students and professionals to develop innovative technological solutions, in the form of mobile apps, aimed at solving problems faced by Brazilian agriculture. Teams of up to five members submitted proposals within the theme "Data Science in the Age of Digital Agriculture," the same as the conference. Each proposal involved a technology solution implemented in a mobile app, a one-page article describing it, and a video of up to 120 seconds.

The following criteria were considered by the evaluation committee: a) relevance of the problem to be solved; b) design quality; and c) correct functioning of the application. At the end of the event, seven proposals were classified to participate in the final stage, the Pitch Competition. It can be said that the SBIAgro 2017 Innovation Challenge promoted the approximation of agroinformatics research with real

problems in agriculture, providing the teams' interaction with a judging panel composed of professionals, and raising the interest of investors in the presented technological solutions, which involved the following themes: a) classification of pests that attack crops; b) agroclimatic zoning; c) forecast of banana harvest and crop profitability; d) evaluation of the environments thermal conditions; e) monitoring wild boar spotting; f) identification of fruit fly species; and g) assessment of animal welfare during beef cattle transport. The articles presented by the teams were published in the annals of the event.

Embrapa Digital Agriculture has participated in Agropolo Campinas-Brasil, an initiative that started in 2015, to carry out projects in order to promote the development of the bioeconomy in the region of Campinas, enabling the proximity of other research institutions with the production sector. The following participated in Agropolo Campinas-Brasil: a) Secretariat of Agriculture and Supply (SAA) of the state of São Paulo, through the Agronomic Institute of Campinas (IAC); b) Institute of Food Technology (ITAL); c) Biological Institute (IB); d) Institute of Animal Science (IZ); e) State Secretariat for Economic Development, Science, Technology and Innovation; f) UNICAMP; g) Municipal Government of Campinas; h) Associtech Techno Park Campinas; and i) Agropolis International Association, mediated by Embrapa. Based on the concept of "collaborative innovation", as an inter-institutional platform, Agropolo Campinas-Brasil started its activities by promoting a series of work meetings, through workshops and events, for the selection of thematic areas that are the focus of actions, with the participation of representatives of Embrapa Digital Agriculture. With the approval of the project Agropolo Campinas-Brasil: Roadmap for Identification of Strategic Research Areas for the Creation of a World Class Bioeconomic Ecosystem, financed by FAPESP, a new plan of activities was started, with the promotion of workshops on several topics related to bioeconomy and agriculture, between 2016 and 2018.

Another important relationship and communication initiative in the Metropolitan Region of Campinas is the participation of Embrapa Digital Agriculture in the Inova Campinas (Tradeshow) event, occurring more intensively in 2017. The InovaCampinas event is promoted by the Campinas Forum Innovative Foundation (FFCi) during 2 days, bringing together companies, startups, research institutions, universities, incubators, accelerators and science and technology parks in the same space. The goal of the event is to present the technological potential of the region and new trends and initiatives of the ecosystem to the public, as well as promoting interactions with business roundtables and networking among the participants. Embrapa Digital Agriculture participated in 2018, with its own stand at the event, promoting presentations of its own technologies, AgTech pitches and a meeting of Biotech Hacking Campinas, a professional group for exchanging information on biotechnology, an initiative of the Venture Hub accelerator. In 2019, there was a shared stand called Inova#Agro, with the participation of partners such as Bayer and Venture Hub. Several accelerated startups in the TechStart Agro Digital Program participated by speaking about their solutions and technologies and interacting with the entrepreneurs, investors and researchers present at the event. Participating in InovaCampinas became a way to create an opportunity to connect Embrapa Digital Agriculture with startups from various areas, small and medium-sized companies, investors and other professionals, in order to communicate their activities and to establish new relationships.

# Innovative public-private partnership models for digital innovation in agriculture

Faced with a scenario of digital transformation, including in agriculture, there is an urgent need to propose new business models. In this context, the AgroAPI initiative was created by Embrapa Digital Agriculture to boost value creation in agriculture by offering data and services via APIs. The acronym

API stands for "Application Programming Interface" and is often translated as "application programming interface," defined as specifications that govern the interoperability between applications and services (Vukovic et al., 2016). Therefore, they are deemed fundamental in the process of digital transformation in organizations, as they facilitate the integration of information systems, reducing cost and time.

APIs represent a set of patterns and programming languages that allow, in an automated way, the communication between different systems. Although invisible to the common user, they are responsible for the operation of several resources in mobile applications, e-commerce sites and social networks, among other market niches.

Due to the great demand for Embrapa's technologies and intelligence by public and private partners, the AgroAPI platform was conceived as an innovation and business strategy focused on the market of technologies in digital agriculture, enabling information and models generated by Embrapa to be accessed through APIs, in an agile, reliable and wide-ranging way, given that the same API can be useful for numerous purposes and customers, thus allowing the creation of solutions to support decision-making in the field, in real time.

The WSO2 API Manager tool has been used for the management of AgroAPI APIs (Vaz et al., 2017). The main components of the tool are: a) API publisher: user interface for API creators to develop, document and version APIs; b) API store or developer portal: collaborative interface for developers to host and publish APIs for consumers to use in a secure, protected and authenticated way. The portal is used for users to register, discover and evaluate the APIs, as well as to register to use them; c) API gateway: protects, manages and schedules calls to APIs; and d) other components for key management, traffic management and data analysis (WSO2 Inc., 2017). The AgroAPI Platform was launched in 2019 with two APIs initially published for use by external partners: API Agritec and API SATVeg.

The Agritec API arranges useful information for managing the production of agricultural crops and is based on the web version of the service called WebAgritec (Massruhá et al., 2008). The API includes the offer of data and models about the ideal planting time for dozens of crops, based on agricultural zoning of climatic risk; the list of the most suitable cultivars, for 12 different crops; the indication of fertilization and soil correction, for five crops, according to the previous soil analysis result; the yield forecast, also for five crops; and about the climatic conditions before and during harvest (water balance). The information provided by API Agritec can be used in solutions to support decision-making in the planning, monitoring and management stages of agricultural production. The distinct data made available by API can benefit farmers, cooperatives, representatives of technical assistance and rural extension and other agents, such as banks and insurance companies (Embrapa, 2020a).

However, SATVeg API is derived from the Temporal Analysis of Vegetation System (SATVeg) (Esquerdo et al., 2016), a web tool developed by Embrapa Digital Agriculture for generating and displaying temporal profiles of vegetation indexes of the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) for Brazil and all of South America, with the objective of supporting territorial management and agricultural and environmental monitoring activities. The vegetative indices are provided by the MODIS sensor coupled to NASA's Terra and Aqua satellites, and include data produced from 2000 until the last date made available by its official repository. The NDVI and EVI indices are correlated with biophysical variables, such as leaf area and biomass that can indicate the presence and vigor of vegetation in a given area of interest. The time series of these indices allow monitoring, over time, the behavior of vegetation in these locations. Thus, it is possible to identify what is an urban area, annual planting, sugar cane, pasture or forest, for example, in addition to monitoring the cycle of an agricultural crop and deforestation and reforestation processes. The data made available can be used for activities

related to environmental mapping and monitoring and for evaluating agricultural production, as well as verifying losses (Embrapa, 2020a).

As of May 2020, the Agritec API has been signed by 274 customers, and more than 111,300 requests were made, while the SatVeg API was signed by 118 customers and more than 1,700 requests made. To enable conducting business with commercial exploitation of APIs with a monetization profile, a marketing plan and business model were elaborated for the provision of services through the AgroAPI platform. This model comprises some legal instruments that also involve a research support foundation.

The AgroAPI platform facilitates integrating information systems, with cost and time reduction, improves the interface with mobile devices, expands the ability to obtain and disseminate agricultural data and information, enables savings in computational resources and sharing data and services, facilitates establishing agreements with other organizations and enables greater reach of the results of the company and its partners (Vaz et al., 2017). The currently available APIs and the partnerships signed so far have demonstrated that this strategy benefits numerous partners and, consequently, the end customers, contributing to the solution of real agricultural problems. The platform's expansion plan is under development, with new APIs to be published based on prospecting demands.

# Final considerations

This chapter describes the characteristics of the new ecosystem of Brazilian agricultural innovation, specifically presenting the case of the state of São Paulo, emphasizing Embrapa's performance in this scenario. The actions developed by Embrapa Digital Agriculture to consolidate this ecosystem were described in the chapter, highlighting the actions developed in Campinas.

This chapter emphasized the strategies carried out to establish and strengthen relationships with the actors in the segment. The promotion of events has been important to externally present to Embrapa the challenges identified in the Brazilian agricultural sector and to promote the search for results together with students and entrepreneurs.

In this regard, the promotion of business roundtables with companies and startups is relevant to the innovation challenges. Organizing longer programs, aimed at AgTech startups, is another very important line of action in order to insert Embrapa in this context. These programs – focused on various agricultural production chains – offer startups several possibilities such as pre-acceleration, acceleration, establishing partnerships and greater exposure and dissemination of their projects to relevant actors. In these programs, Embrapa has partnered with venture capital companies, startup accelerators, government agencies, and others.

It is noteworthy that, as regards relationships, Embrapa Digital Agriculture has a tradition of establishing technical cooperation agreements, NDAs and technology licenses, legal instruments in order to regulate signed partnership initiatives regarding confidentiality, objectives, stages, duration, resources and expected results. These are partnerships with various actors in the agricultural innovation ecosystem, with emphasis on organizations located in the Southeast and Midwest regions.

The Unit has also worked to strengthen the ecosystem of agricultural innovation in its surroundings, within the state of São Paulo and, in particular, in the region of Campinas. With regard to partnerships with scientific research institutions, more traditional in the context of Embrapa, the scientific partnership to promote the innovation ecosystem in the Metropolitan Region of Campinas, Agropolo Campinas-Brasil, which started in 2015, stands out. The action was led by the Department of Agriculture and Supply

(SAA) of the state of São Paulo, through various agricultural research institutes in the state, such as the Agronomic Institute of Campinas (IAC), mediated by Embrapa, with the participation of local actors such as the Municipality of Campinas; the UNICAMP, Associtech Techno Park Campinas; and the Agropolis International Association. Several events on topics related to bioeconomy and agriculture were promoted between 2016 and 2018. This action enabled establishing relationships between Embrapa Digital Agriculture and municipal actors, promoting the relationship of the agricultural innovation ecosystem in Campinas.

A highlight in 2019 was the promotion of the TechStart AgroDigital (TSAD) program, in partnership with Venture Hub and Anprotec, aimed at accelerating the startups registered, which received more than 90 applications. It is worth pointing out that the closer interaction of Embrapa Digital Agriculture´s team with the universe of agtechs, investors and the acceleration environment enabled greater knowledge in this context, requiring more interactive flexibility with this type of actor and with the acceleration process of startups. Other actions involving mentoring for startups, both under FAPESP's PIPE and SEBRAE-Piracicaba programs, and business roundtables established at the 100 Open-Startups (2017) and SBIAgroConect@ (2017 and 2019) were also instrumental to bring the Embrapa Digital Agriculture teams closer to the business environment and, in particular, to startups.

Participation in the *Inova Campinas* event (Tradeshow), since 2017, proved to be very important to strengthen the image of Embrapa Digital Agriculture in the context of the Metropolitan Region of Campinas, presenting the Company and its technological potential, as well as providing opportunities for interactions with companies, organizations, investors and the press. All these events and local programs offered a new perspective on the startup environment for Embrapa teams, influencing culture and behavior, contributing towards strengthening the presence of the Unit in the agricultural innovation ecosystem of Campinas and São Paulo, as well as increasing its leading role in the area of digital agriculture, which is a technological driver of the Campinas ecosystem.

In this context, it is noteworthy that Embrapa Digital Agriculture has been demanded by companies from different segments, with emphasis on information technology, in order to establish partnerships for collaborative development and product validation. The AgroAPI platform is an example of technology designed to promote value creation in agriculture by offering data and services via APIs. The business model is based on the use of this technology (API) to make Embrapa data, information and models available to its partners with an agile, reliable and comprehensive approach.

Embrapa's actions aimed at strengthening the Brazilian agricultural innovation ecosystem are expected to continue, which were prioritized in its 2019–2023 Business Plan, the organization's medium-term strategy.

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