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Californian innovation ecosystem: emergence of agtechs and the new wave of agriculture

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Abstract

Purpose – In a context where the process of creation of technology and innovation for agriculture is being disrupted at a fast pace, the authors proposed to study one of the most prominent agtech innovation ecosystems. Therefore, this paper aims to identify key characteristics that make California's agtech innovation ecosystem remarkable.

Design/methodology/approach – The paper is an exploratory and descriptive research carried out in a twofold. First, data were collected through documental research focusing on actors such as universities, R&D centers and programs, business accelerators and venture capital platforms, agtechs, as well as multinational companies. Second, structured interviews were carried out to complement the secondary data collected and to obtain experts' perception on the relationships between actors of the ecosystem and on the characteristics that make this ecosystem remarkable.

Findings – The paper provides empirical insights about the relevance of California's agtech innovation ecosystem to creation of radical innovations in agriculture. It has a differentiated environment, where educational and research institutions play a key role in developing new knowledge. It also shows how important funding is to allow new business to succeed. Additionally, it shows that actors interact in a complex network, with multiple roles. All these key characteristics allow this agtech innovation ecosystem to be so remarkable.

Research limitations/implications – Because of the chosen research approach, the research results may lack generalizability. Therefore, researchers are encouraged to survey a larger number of actors of this and other agtech innovation ecosystems to test the identified key characteristics further.

Practical implications – The paper includes indication of characteristics necessary to develop a prominent agtech innovation ecosystem, which may contribute to decision makers to develop policies aiming to promote this type of ecosystem.

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Originality/value – This paper fulfils an identified need to open the "black-box" of agtech innovation ecosystems, which may then allow radical innovations within the sector to be developed and taken to the market.

Keywords Innovation, Innovation ecosystem, Agriculture, ICT, agtech

Paper type Research paper

1. Introduction

Agriculture is a millenarian activity that promotes food production and supplies to many other industries. Nowadays, technological improvements and innovations in agriculture are driven by agricultural firms' necessities of being competitive within national and international markets. The so called "third revolution in agriculture" (Mikhailov, Reichert, & Pivoto, 2018; Pham & Stack, 2018) got possible due to the existence of the innovation ecosystems around the globe, which offer an environment where different actors related to agricultural technology development and agricultural production and distribution interact to promote value creation through mass production of radical innovations.

In the past decade, the digital revolution has been transforming agribusiness worldwide (Bronson and Knezevic, 2016). These "new breed" of agricultural innovation, based more on information and communication technologies (ICT) rather than the traditional agricultural knowledge fields (Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017; Wolfert, Ge, Verdouw, & Bogaardt, 2017), are helping traditional agricultural firms to increase their productivity and efficiency, as well as their innovative performance toward a more sustainable activity (Dutia, 2014; Deichmann, Goyal, & Mishra, 2016; Wolfert et al., 2017).

In this context, many scholars have been studying the reasons why agribusiness firms adopt these new technologies and how they impact on their performance (Carrer, De Souza Filho, & Batalha, 2017; Pivoto et al., 2018). However, academic studies still did not open the "black-box" of agtech innovation ecosystems, which allow these radical innovations to be developed and to be commercialized in a large-scale.

The novelty of innovation ecosystem approach in studying innovation in agriculture relies on the fact that, historically, the innovation process in agricultural production and distribution took place within traditional value/supply chains (Boehlje, Roucan-Kane, & Bröring, 2011; Pham & Stack, 2018). In that time, all major innovations were introduced by large firms, where each large firm created innovations specifically within its main technological field (Pham & Stack, 2018).

However, the rise of ICT-based solutions in agriculture opened opportunities for smaller firms to create and promote radical innovation in agricultural production and distribution. These firms are new ventures, usually startups, which aim, by use of any kind of high technology, to improve the process of agricultural production and distribution, are called "agtechs" (Mikhailov et al., 2018).

New ventures usually lack physical, financial and knowledge resources (Kapoor & Furr, 2015; Paradkar, Knight, & Hansen, 2015), and therefore, it becomes particularly difficult for them to develop and commercialize innovations alone. Thus, innovation ecosystems can help new ventures to offer more value to the customers by providing them with valuable resources (Autio & Thomas, 2014; Gomes, Facin, Salerno, & Ikenami, 2018). Taking part of the innovation ecosystem may also help the new ventures to collectively manage market uncertainty, improve resource allocation for business growth (Adner, 2006) and be connected to potential clients or suppliers (Walrave, Talmar, Podoynitsyna, Romme, & Verbong, 2018).

Currently, one of the largest and greatest agtech innovation ecosystems is California's agtech innovation ecosystem. The past decade saw the rise of highly valuated agtechs (Mikhailov et al., 2018), agricultural technology business accelerators, venture capitalists focused on funding agricultural technologies development as well the whole package of different actors that focus exclusively on catalyzing the transformation of agricultural production and distribution worldwide. Given this context, the present article aims to *identify key characteristics that make California's agtech innovation ecosystem remarkable*.

To achieve this objective, an exploratory research with a qualitative approach was conducted in two stages. First, we mapped the main actors of California's agtech innovation ecosystem. Then, interviews with experts from the California's innovation ecosystem were conducted to shed light on the relationships among the actors, as well as benefits that the experts perceive the California's agtech innovation ecosystem promotes.

With this study, we expect to expand the knowledge about the characteristics of these innovation environments that help to promote creation, commercialization and large-scale diffusion of new sets of solutions and technologies, so important for making the third agricultural revolution to spread over the globe.

The upcoming sections are organized as follows. In Section 2, the phenomena of a new wave of innovations in agriculture is presented. Section 3 describes innovation ecosystem literature. Section 4 explains the methods used to answer the research problem. Results are presented in Section 5 followed by discussion in Section 6. Section 7 shows final remarks with some perspectives. Finally, references are listed.

2. Agribusiness innovation context

In its development, agriculture has experienced evolutions, innovations and revolutions "which have gone hand-in-hand with the innovations in the traditional industrial sector" (Pham & Stack, 2018; Zambon, Cecchini, Edigi, Saporito, & Colantoni, 2019). Similarly to the terminology adopted to characterize the technological revolutions that took place in the traditional industry in the 18th century onward, agriculture revolutions started with animal power (Agriculture 1.0), followed by adoption of combustion engines (Agriculture 2.0) and in recent decades of precision farming and GPS used in the agricultural production systems (Agriculture 3.0) (Zambon et al., 2019).

Due to the world population growth and the increasing food consumption in emerging economies (Dutia, 2014), agriculture and food production are facing bigger challenges than even before. By 2050, the world population may reach more than nine billion people (Alexandratos & Bruinsma, 2012). Global constraints such as arable land and available water resources may limit the agricultural expansion and output. Particularly in agriculture, external factors such as environmental restrictions (Van Der Veen, 2010), food security and consumer behavior are recognized as drivers of change. Therefore, constant innovation and a new set of technologies are essential to overcome these challenges.

In this context, application of ICT to the agricultural production and distribution and the rise of Big Data helps to promote the so-called agriculture 4.0 (Wolfert et al., 2017; Zambon et al., 2019). In this new agricultural era, physical and virtual integration has impacts on linking farmers to their suppliers and markets, increasing production efficiency, reducing the transaction costs, reducing uncertainties and stimulating the competitiveness within the sector (Deichmann et al., 2016; Kamilaris et al., 2017; Wolfert et al., 2017; Zambon et al., 2019).

However, perhaps, one of the most important transformations the agricultural production and distribution pushed through in the transition from agriculture 3.0 to agriculture 4.0 is not technological, but in the nature of how innovations were developed.

As shown in Figure 1, historically, innovation in agriculture occurred within the biological, chemical and mechanical technology fields (Evenson, 1974). Thus, during the second half of the 20th century, the farm's chemical and biological inputs were provided by large multinational companies (MNC) such as Dupont, Bayer and Syngenta (Pham & Stack, 2018). Particularly, the chemical input's market tended to be heavily olipolized (Pham & Stack, 2018).

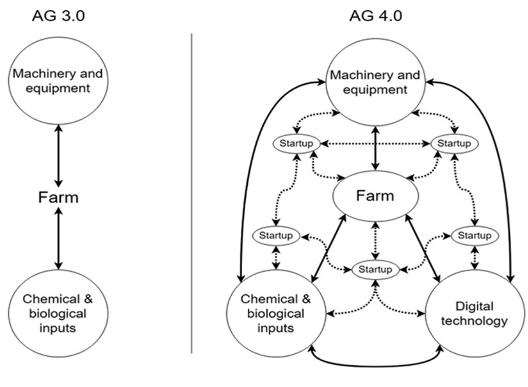
Companies focused on developing innovations only their own agricultural inputs markets, Thus, MNC such as John Deere produced only agricultural machinery and equipment solutions. Companies such as Bayer engaged in production of chemical inputs for agricultural production. As these companies developed products of radically different technological fields, it was also impossible for these companies to produce innovations outside of their main technological field (Pham & Stack, 2018).

However, the advent of agriculture 4.0 and use of ICT in agriculture opened opportunities for new ventures that develop and commercialize new sets of innovation in agriculture. These ventures, usually startups, which develop high-tech solutions for agricultural production and distribution, are called "agtechs" (Mikhailov et al., 2018).

In the same period, large MNCs which previously developed solutions only within their main input market started to incorporate ICT into their solutions (Wolfert et al., 2017). Thus, currently, the chemical, biological, machinery and equipment companies, along with tech companies and agtechs, are engaged in development of ICT-based innovations in agricultural production and distribution.

Thus, the structure of the innovation process in agriculture, as well as roles of different players involved in this process, began to change. During the 20th century, the process of creation and diffusion of innovations in agriculture followed a traditional supply chain flow (Gunderson et al., 2014). The innovation processes in agriculture could be represented by a structured set of interconnected adding-value activities performed by different actors, where, ultimately, innovations were developed by large companies and supplied to the farmers (Dutia, 2014; Boehlje et al., 2011; Pham & Stack, 2018).

However, as argued by Boehlje et al. (2011), also due to industry convergence, the traditional supply chains no longer prevail in this new type of economy. Instead of that, a new set of actors engaged in value-added activities of innovation creation and diffusion process in agriculture. These set of actors include, for instance, venture capital firms



Source: Based on Pham and Stack (2018) and Wolfert *et al*. (2017)

Figure 1. Agricultural inputs landscape during the 20th century

(Wolfert et al., 2017), which engaged in financing innovations that could be too risky for the tenant firms to engage in.

There are also numerous agtech companies (Mikhailov et al., 2018; Wolfert et al., 2017), some of which are acquired by large firms. In turn, large firms also acquire agtechs to get access to the technologies they developed. In sum, the overall environment where agricultural innovation creation takes place seems to have changed. Therefore, to study this new innovation environment requires concepts that better adapt to agricultural innovation's new reality.

3. Innovation ecosystems

The innovation ecosystems approach has its roots on the business ecosystem (Moore, 1993), which have its origins on the ecology concept (Ferasso, Wunsch Takahashi, & Prado Gimenez, 2018), and on the national innovation system (NIS) concept (Freeman, 1988; Lundvall, 1992). In recent years, the use of innovation ecosystem approach to study innovation became increasingly popular, as the number of studies that use this approach enormously increased (Gomes et al., 2018; Granstrand & Holgersson, 2020).

There are a number of definitions for the innovation ecosystem concept. For instance, Autio and Thomas (2014) define it as a network of interconnected organizations, organized around a focal firm or platform, incorporating both production and consumer participants, focusing on new value development through innovation. Walrave et al. (2018) argues that the innovation ecosystem is a network of interdependent actors who combine specialized and complementary resources and/or capabilities to create overarching value propositions to end users, as well as to appropriate the gains received in the process.

However, as these ecosystem approaches are usually centered on a focal actor or firm, the definitions give room for the term "innovation ecosystem" to be mistaken by other concepts, such as those related to clusters or networks (Adner, 2017). To overcome this difficulty, Adner (2017) proposed a concept of "ecosystem as a construct", where the innovation ecosystem approach starts with a central value proposition and is defined as "alignment structure of multilateral set of actors that need to interact for a focal value proposition to materialize". This definition fits well highly advanced innovation ecosystems that are managed by collective collaboration rather than the focal firm or actor.

That may be the case of Massachusetts manufacturing innovation ecosystem, where the main players are original equipment manufacturers, universities, small and medium enterprises and startups (Reynolds & Uygun, 2018). Also, 3D printing innovation ecosystem is a good example of innovation ecosystem where a set of actors is organized around a common structure, as this ecosystem functions through a number of complementary platforms (Kwak, Kim, & Park, 2018).

Adner's (2017) concept seems to fit well with California's agtech innovation ecosystem reality, which comprises a number of different actors, none of which concentrate considerable part of the innovation ecosystem activities on its own. Thus, CA's agtech innovation ecosystem comprises a large number of big players, such as multinational corporations, venture capitalists, agtechs and top universities, all of which have their own role and make their unique contribution to create and diffuse radical agricultural technology innovations.

In innovation ecosystems, unlike in, for instance, traditional value chains or supply chains, the positions of actors are not necessarily fixed all the time (Adner, 2017). Also, the multiparty interdependence within innovation ecosystems is crucial, that is, the same actor maintains relations with more than one actor (Adner, 2017).

Another important characteristic that differentiates innovation ecosystems from other approaches is control. Even when an innovation ecosystem is organized around a hub firm, the level of control that it exercises on other actors is much lower within this context than it would in a traditional supply chain or value chain. For instance, concentration of content providers and advertisers among a common platform was crucial for Google's innovation ecosystem to function. Still, the company did not exert direct control over these actors, so fundamental for its success (Iyer & Davenport, 2008).

Taking part of an innovation ecosystem brings advantages for its actors, as they gain access to complementary resources and capabilities (Ferasso et al., 2018; Kwak et al., 2018). For instance, for the new ventures, the availability of complementary resources is crucial to achieve market and financial success (Adner, 2006; Adner & Kapoor, 2010; Paradkar et al., 2015). Being part of an innovation ecosystem favors firms' and new ventures' fundraising (Henton & Held, 2013), as well as provides access to specific resources and facilitates partnerships with business-supporting organizations (Ferasso et al., 2018). Innovation ecosystems tend to increase new products' creation and to promote growth of entities related to technology and innovation issues (Ferasso et al., 2018; Shaw & Allen, 2016).

Previous studies have identified that the access to the innovation ecosystem benefits may have huge effects on the pace of technological substitutions and rates of new technologies adoption (Adner & Kapoor, 2016; Granstrand & Holgersson, 2020). Hence, given the magnitude of the transformation that agricultural production and distribution is undergoing, the role of innovation ecosystems in pushing through a third agricultural revolution may be enormous.

The next section describes the method used to conduct the present study.

4. Methods

An exploratory and descriptive research was performed to achieve the objective of this work, which is to identify key-characteristics that make California's agtech innovation ecosystem remarkable. The advantage of using a qualitative approach is that it also allows a deep analysis of the idiosyncratic characteristics of studied object or phenomena (Yin, 2015), which is the case of the California's agtech innovation ecosystem.

To collect data, first, we carried out a documental research concerning the following actors: universities, R&D centers and programs, business accelerators and venture capital platforms, agtechs, multinational companies, as well as California's institutional environment.

To collect data on agtechs and multinational companies, researchers used CB Insights database (CB Insights, 2017a), specialized database which provides free and publicly available information about agtech companies and Agfunder (2017) agtech report. Both databases were chosen as they represent reputed data source on agtech investment. QS World University Ranking (2020) were used to collect data on the quality of universities within California's agtech innovation ecosystem for agricultural technology and computer science knowledge fields. The information on R&D centers, programs as well as business accelerators and venture capitalists were gathered through websites as well as specialized reports. Additionally, to collect data on all actors cited at Table 1, we looked into annual reports, governmental data sources, organizations and firm websites.

Type of organization	Position	Age	Highest academic degree	Other organizations that interviewed person take part of
Agtech company (AG1)	CTO	38	Msc in Computer Engineering	Private organization
Private organization (PO1)	COO	38	Msc in Business Management	–
Private organization (PO2)	Partner	34	Msc in Computer Science	University
Venture capital firm (VCF)	Partner	40	Bsc in Communication Science	University

Table 1. General description of interviewed innovation ecosystem's actors

To collect data on the relationships between actors of California's agtech innovation ecosystem, as well as to obtain experts' perception on the characteristics that make this ecosystem remarkable, we performed structured interviews. We applied structured interview script with agtech business experts from the ecosystem, as presented at Table 1, and we have observed that some of the interviewed experts took part in more than one organization within the ecosystem.

During the study, researchers also visited the facilities of some actors of California's agtech innovation ecosystem, to engage in informal contacts with innovation ecosystem's actors, such, among others, entrepreneurs, investors and researchers.

Completed all stages of data collection, first, the analysis was concentrated in actors established within California's agtech innovation ecosystem. Second, the relationships between different actors are presented (based on the interviews with agtech experts).

5. Results

To present the obtained results, this section is divided in two parts. First, data on each actor are described. Then, a set of relationships according to expert's perception is presented.

5.1 Universities

California is the hometown for a number of the world's top-tier universities, including in agricultural sciences and computer sciences. Table 2 positions some of them in international rankings. Thus, overall, Stanford (2nd) and California Institute of Technology are the best universities with top ranked California's agtech innovation ecosystem universities. The Berkeley university is the world's 6th and USA's 3rd best university in agriculture. Likewise, the UC Davis agribusiness school is the highest rated agribusiness school in the USA. In turn, the UCLA is world's 15th and USA's 7th best university in computer science field.

Hence, it can be supposed that, in general, CA's agtech innovation ecosystem possesses state-of-art scientific and technological knowledge in both traditional agricultural knowledge fields, as well as in new emerging technologies in agriculture, that is, ICT. In turn, these top-tier universities contribute to the formation of high-profile qualified professionals, some of which may become entrepreneurs.

5.2 R&D centers and programs

Along with universities, CA's agtech ecosystem comprises a number of R&D facilities and hubs. Among them, Kearney Agricultural Research and Extension Center (KARE), founded in its official dedication in 1965, can be highlighted. It has international acclaim for leadership in the development of new fruit, nut and grape varieties, innovative

Table 2. US and World ranking of Californian universities in IT and AG knowledge fields

	WR	AG WR	IT WR	AGUSA	ITUSA
California Institute of Technology	5	–	29	–	13
Stanford	2	–	2	–	2
UC Berkeley	28	6	4	3	4
UC Davis	104	2	201	1	51
UCLA	35	–	15	–	7

Notes: WR – World Ranking; AG WR – Agricultural World Ranking; IT WR – Information Technology World Ranking; AGUSR – Agricultural US Ranking; ITUSR – Information Technology US Ranking. The missing camps represent that the institution has no graduate or undergraduate courses in the field, or it is not rated
Source: QS [1] World University Rankings (2020)

cultural and irrigation practices, pest and disease management techniques and postharvest biology. Likewise, the center is involved in programs related to air and water quality (KARE, 2020).

Another R&D center the ecosystem is The San Joaquin Valley Agricultural Sciences Center (SJVASC) that is part of the Agricultural Research Service, which is the research branch of the United States Department of Agriculture (USDA). The facility was completed in 2000 on a 130-acre tract of land which includes 100 acres of agricultural land that is used for research.

The California State University (CSU) has the Agricultural Research Institute (ARI) that is responsible for applied scientific research in, among others, the agtech sector, to ensure sustainability of California's agricultural production (CSU-ARI – The Agricultural Research Institute [ARI] of California State University, 2020). The research grants for in agricultural technology are also granted by National Science Foundation (NSF). As a matter fact, in 2019 California received 13.36% of the total amount of research grants granted by NSF (National Science Foundation [NSF], 2019).

It is important to add that California's agtech R&D centers and programs are concerned not only with technological issues but also with sustainable ones. For instance, FAO (2020) points out the University of California Sustainable Agricultural Research and Education Center (UC-SAREP) as an important world research center for sustainable food and agricultural production techniques.

Within California's agtech ecosystem, it can also be highlighted the Center for Agroecology and Sustainable Food Systems (CASFS). It is a research, education and public service program at the University of California, Santa Cruz, dedicated to increasing ecological sustainability and social justice in the food and agriculture system. CASFS offers practical as well as academic training in the techniques of agroecology and organic farming for domestic and international students, researchers and farmers (FAO, 2020).

5.3 Business accelerators and venture capital platforms

The California's agtech innovation ecosystem comprises a number of large agtech business accelerators and venture capital platforms. One of these business accelerators is Radicle Growth Accelerator, located in San Diego, which is an acceleration fund run by a large Multinational Corporation (MNC), such as Du Pont and Bayer. It stands out from other acceleration funds by the amount of initial investment, which correspond to US $500.000,00 (Radicle gworth, 2020).

The "Better Food Ventures" is another venture capital platform dedicated to agricultural technology, in the words of its own, it "connects innovators in Food, Ag and IT" (Better Food Ventures, 2020). The venture capital firm was established in 2013 and is located in Menlo Park. The technologies that the company argues to be most important for food and agricultural applications are mobile and cloud-based computing, sensor technologies, IoT, robotics, artificial intelligence, location-identification and image recognition, real-time data analytics, collaborative production and consumption and social marketing (Better Food Ventures, 2020).

Together with traditional business accelerators, CA's agtech ecosystem counts with a new type of venture capital firm, called AgFunder. Founded in 2013 and based in Silicon Valley, it is one of the most active agri-food tech venture capitalists, which counts with more than 75,000 members and subscribers, and proprietary technology to support the investment team (Agfunder, 2020). The AgFunder is responsible for creating a number of reports and providing state-of-the-art information on agri-food technology.

5.4 Agtechs and multinational companies

The CBinsights report database (2017) database contains 81 invested agtechs distributed among 28 countries. The USA has the highest number of invested agtechs – 36, and California's agtech innovation ecosystem alone comprises six invested agtechs, as shown in Table 3.

Thus, according to Table 3, the received investments by the Californian agtech companies varied from US$1.1m up to US$93.46m. All six companies are diverse in terms of offered solutions.

Materra farming, with investment of US$93.46m aims to produce animal feed. The Green Earth Greens, with US$23.75m of funding is a company which produces fresh vegetables year-round in organically certified farms. The company's practices and processes set new standards of sustainability, food safety and conservation of critical resources.

Hollandia Produce Group received investments of US$22.28m and develops solutions in terms of greenhouse-grown vegetables. Uncommon Cacao, a firm that received US$1.96m in investments, focuses on work with cacao farmers and responsible exporters, aiming to be a trusted supply chain partner. Aquarius Cannabis, with US$1.16m of investment is a branding company in the legal medical and recreational cannabis industry in the USA. The Aquaria Cannabis has a mission to professionalize the legal cannabis industry by creating a portfolio of consistent, pesticide-free cannabis brands.

Stelagenomics, originally a Mexican company that moved to California's agtech innovation ecosystem, received investment of US$1.1m. It seeks to enable a rational, eco-friendly control of weeds and use of fertilizers in modern high-yield agriculture. It developed a solution based on a platform for weed control based on the use of phosphite that achieves sustainable high-yield agriculture for any transformable crop without the use of herbicides. The total amount of investment occurring inside California's agtech ecosystem was US $143.71m. According to CBInsights database (2017), CA state alone corresponds to more than half (50.3%) of all funds received by US agtech companies.

In addition to data from CB Insights (2017b) report, there are some other famous investments received by agtechs from California's agtech ecosystem. For instance, Agfunder (2017) report points out the Climate Corporation, one of the first agtechs ever was founded in 2006 in California. Later, in 2013, the company was acquired by Monsanto Corporation per value of US$1.1bn. Another agtech founded in California's agtech ecosystem was Blue River Technology, which is specialized in smart agricultural machinery and equipment. The company was founded by two Stanford graduate students in 2013, and in 2017, it was acquired by John Deere for the price of US$305m. Through this acquisition, John Deere, by that time, intended to enhance its artificial intelligence capabilities (Agfunder, 2017). The *Granular,* a farm management software company, was acquired by Du Pont by US$300m (Agfunder, 2017).

Thus, all above mentioned data show that California's agtech ecosystem is able to act as a marketplace world largest agricultural technology acquisition.

Table 3. California Agtech companies received investment according to total funding

Company	Total investment US$m	City and state
Materra Farming	93.46	Escondido
Green Earth Greens	23.75	Campbell
Hollandia Produce Group	22.28	Carpinteria
Uncommon Cacao	1.96	Berkeley
Aquarius Cannabis	1.16	Woodland Hills
Stelagenomics	1.1	Santa Clara

Source: CB Insights (2017a)

5.5 Farms and farmers

Currently, CA is the far biggest agricultural GDP among 50 states of the USA, with almost US$50.0bn in crop cash receipts from raw agricultural products (USDA, 2018). It has 69.900 farms operating within a total cultivated area of 24.3 million acres of land. Moreover, it focuses on the production of high value-added agricultural products. Among them, those that bring the highest income are milk (US$6.37bn), grapes (US$6.25bn), almonds (US $5.47bn), pistachios (US$2.62bn) and strawberries (US$2.34bn).

In general, the higher the value added of a particular agricultural product, the higher the technological demand required by the producer for the production activities. Therefore, together with a production scale and number of the farms, having this high value-added commodities production creates favorable conditions for testing or purchasing of new high value-added technologies, which is essential for future scalability of new solutions.

5.6 Set of relationships

In the present subsection, the main results of the interviews with the agtech experts from California's agtech innovation ecosystem are presented. The first expert, called VCF, holds a Bsc degree in Communication science and is a partner of a venture capital firm. The firm was founded in 2015 with a proposal of focusing on early-stage funding of startups. According to VCF, his organization is considered very important to interact with business incubators, startups, universities and other private organizations.

PO1 holds an Msc degree in Business Management, he is COO of a private organization that works with training in courses in business management and innovation issues. He considers to be very important for the organization he represent to interact with Science and Technology parks, startups, universities as well as private associations.

PO2 holds Msc degree in Computer Science and he is one of the owners of a private organization that works with training in courses in business management and innovation issues. He considers to be very important for the organization he represents to interact with Science and technology parks, business incubators, startups, private associations and organizations.

Finally, AG1 holds Msc degree in Computer Engineering, and he is the CTO of agtech which develops insurance-based solutions for agriculture. He considers it to be very important for the organization he represents to interact with Business incubators, Science and technology parks, startups as well as private organizations and associations.

When asked about the most important benefits that California's agtech innovation ecosystem offers to the organizations that the agtech experts take part of, all four experts highlighted networking and access to clients. Likewise, the interviewed stated to be very important the following benefits from the California's agtech innovation ecosystem: scientific and technological knowledge (VCF, PO1, PO2), conferences and workshops (VCF, PO1, PO2), cooperative R&D projects (VCF, PO1), innovation environment in general (AG1, VCF, PO1).

The perceptions of interviewed experts concerning the most important actors were different. For instance, AG1 argued that Climate Corporation, which was the first agtech ever and also a first agtech unicorn, was one of the main actors within California's agtech innovation ecosystem. VCF argued that the most important actors were the entrepreneurs: "because they have the vision and gut to make changes happen". In contrast, PO1 argued that large Ag Corporations represented the main players in the ecosystem.

Even that results cannot be generalized to the whole population of California's agtech innovation ecosystem actors, it can be supposed that many different types of actors of the ecosystem do represent quite a large importance for the innovation ecosystem to be remarkable.

Concerning the strengths of California's agtech innovation ecosystems, agtech experts argued that they are diversity of people (PO2), mindset (PO1), availability of venture capital (AG1), as well as the Silicon Valley region itself (VCF, PO2).

5.7 Summary

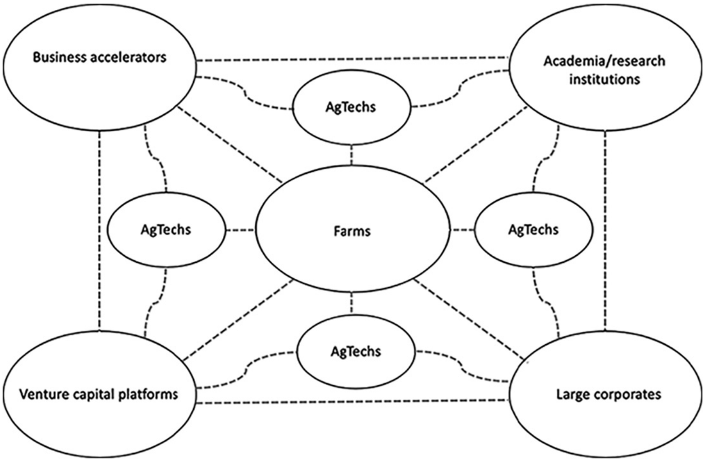
Figure 2 is created according to the results of the documental research and the answers obtained in the interviews with the experts. In the Californian agtech innovation ecosystem, financial actors, the academic and applied knowledge base, together with large corporations and consultants, interact with farmers and entrepreneurs who seek to offer solutions based on specific knowledge and digital tools.

Thus, we can argue that some of the characteristics that make California's agtech innovation ecosystem remarkable are world's best universities and research centers; state-of-the-art scientific and technological knowledge; availability of venture capital; also, the presence of a set of actors which are engaged exclusively in promoting innovations in agriculture (i.e. agtech business accelerators); least but not last, large and tech-savvy agricultural technology internal consumer market, which makes turns possible to test new developed technologies directly in the farms of California state.

6. Discussion

The purpose of this study was to identify key characteristics that make California's agtech innovation ecosystem remarkable. The results presented above demonstrate the limitations of a single organization in having the full set of resources necessary to implement innovations. It means that to innovate, it is necessary the articulation and cooperation of different ecosystem's actors among common value propositions. According to Yoo, Lyytinen, and Boland (2008), this reality promotes incentives for organizations to share knowledge and joint development in the condition of ecosystems.

California's agtech innovation ecosystem has its essence partly in line with that state's overall innovation ecosystem. The appreciation of the innovation environment in general



Source: Elaborated by authors

Figure 2.
California's agtech innovation ecosystem

was highlighted by three of the experts interviewed. However, Su, Zheng, and Chen (2018) highlight that when looking inside an innovation ecosystem, it is possible to observe that not all ecosystems have the same architecture and models of internal collaboration. An element highlighted by experts as a strength of the California agtech innovation ecosystem is the positive coexistence in diversity. In the study of Yoo et al. (2008), the ability to overcome heterogeneity among ecosystem players, such as differences in governance, value, knowledge and communication resources is a key characteristic.

As showed by the study, the rise of ICT and agtechs impacted on model of creation and diffusion of agricultural innovations. Thus, it has been changing from the simplified model perceived in Agriculture 3.0 (supply chain), to a more complex configuration in Agriculture 4.0 (innovation ecosystem). It is important to stress that relationships within an innovation ecosystem transcend a traditional value chain due to interactions between suppliers, partners and customers, with tangible (monetary) and intangible (cultural and social) elements (Su et al., 2018).

Still in this line, the analysis of main innovation ecosystem' actors showed that some actors perform more than one role within the ecosystem. That is the case of MNC, as frequently they not only act like innovators or investors but also help to support business accelerators. It means that MNCs are also involved in providing a number of complementary resources to both technological and business innovation, which are crucial for new ventures' growth and consequently for scalability (Freeman & Engel, 2007).

Finally, it is interesting to highlight that the current transformations in agriculture suggests a relation between technological aspects and the process of creation and diffusion of innovations: the rise of ICT in agriculture lowered barriers to new entries, in the present case agtechs. This happened because, first, it was created a whole new market and second, possibly the cost of developing a new software program for agriculture was much lower than the cost of implementing traditional agricultural innovations, such as new chemicals, fertilizers, machinery and equipment. Similarly, venture capital for agtechs became available. In turn, these events contribute to a transformation of the process of creation and diffusion of innovations in agriculture from a traditional supply chain flow to innovation ecosystem structure.

7. Final remarks

The results showed that what makes the California's agtech innovation ecosystems are top universities and R&D centers, which create state of art scientific knowledge. Also, the availability of venture capital and the presence of a set of actors that are engaged exclusively in promoting innovations in agriculture (i.e. agtech business accelerators); agricultural technology internal consumer market, which makes turns possible to test new developed technologies directly in the farms of California state. This paper fulfils an identified need to open the "black-box" of agtech innovation ecosystems, which may then allow radical innovations within the sector to be developed and taken to the market.

As a policy implication of the present study, it is suggested here that to enhance agricultural technology and production development, traditional agricultural and industrial policies focused exclusively on a given supply chains may not be sufficient anymore. Instead, the governments and local authorities need to think about the whole set of actors involved in a given activity when attempting to bring changes to the given sector or region. Also, the paper includes indication of characteristics necessary to develop a prominent agtech innovation ecosystem, which may contribute to decision makers to develop policies aiming to promote this type of ecosystem.

The practical implications of the study are that actors within ecosystem can improve their performances only through interaction and communication with each other. In addition, public policies can be shaped to the notion of innovation ecosystem as *locus* of interference. This strategy can promote benefits broadly comparatively if directed only at a specific industry. This notion is desirable in an economic activity such as agriculture, in addition to promoting economic development the production of food with less cost and more efficiency can benefit society more broadly.

This papers also presents some limitations. First, because of the idiosyncratic aspects of innovation ecosystems, the research results may lack generalizability. Therefore, researchers are encouraged to survey a larger number of actors of this and other agtech innovation ecosystems to test the identified key characteristics further.

For future research, the authors suggest to conduct in-depth case study of California's agtech innovation ecosystem, with a primary focus on relationships among actors. Also, innovation ecosystem's strategies used by the actors, particularly agtechs, to innovate represents another possibility. Finally, it would be interesting to conduct multiple case study to compare the California's agtech innovation ecosystem with other agtech innovation ecosystems around the globe.

Note

1. The researchers chose to use QS World University Rankings instead of Times Higher Education (THE) World University Rankings because QS World University Rankings is the only that offers specific ranking for subject "agriculture".

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