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THE BRAZILIAN SCIENTIFIC AGRICULTURAL RESEARCH ECOSYSTEM: AN EVOLUTIONARY TRAJECTORY IN ST&I

O ECOSSISTEMA BRASILEIRO DE PESQUISA AGRÍCOLA: UMA TRAJETÓRIA EVOLUCIONÁRIA EM CT&I

Isabel Cristina dos Santos[1]
Váldeson Amaro Lima[2]
José Roberto de Souza Freire[3]

Abstract

The main objective of this work is to describe the historical trajectory of the Brazilian agricultural research as a conjugation of factors for Brazilian agricultural science. This is a qualitative and descriptive research outlined by historical-documentary analysis procedures. The results reveal the maturity of the Brazilian Science, Technology and Innovation System (ST&I) in agriculture, with strong interactions in international research networks, high technological service and international projects leadership. The continued support given by the Government and sectors of the private initiative created the conditions for the implementation of agricultural research results. Despite the considerable availability of written documents on the subject, they refer mostly to the successful aspects of the development of the ecosystem of the scientific research in the agricultural sector. There is a relative lack of evidence to collate the results of development with difficulties and obstacles found research throughout history. Similarly, the backstage about the political decisions on the creation of new institutions, have not been clearly documented. Specially to emerging economy countries in Latin America and other regions, the Brazilian experience can be a reference to the development and deployment of Agricultural Research, and also available to partnerships with institutes in different stages of development. The main contribution of this article is to present a synthesis of the research and development ecosystem in agriculture of Brazil, with a historical account of your evolution, which may support future decisions, public or private, on investments in research and development in this sector.

Keywords: Historical Trajectory. Agricultural Research. Research and Development. Scientific and Technological Development.

[1] PhD in Engineering (POLI-USP). Professor of the Postgraduate Program in Administration at the Municipal University of São Caetano do Sul (USCS), São Caetano do sul - SP, Brazil. Email: isa.santos.sjc@uscs.edu
[2] PhD in Administration (USCS). Professor at the Federal Institute of Education, Science and Technology of Rondônia. Porto Velho - RO, Brazil. E-mail: valdeson.lima@ifro.edu.br
[3] PhD in Administration (USCS). Analyst at the Brazilian Agricultural Research Corporation (Embrapa), Campo Grande - MS, Brazil. Email: jose.freire@embrapa.com.br

Resumo

O objetivo principal deste trabalho é descrever a trajetória histórica da pesquisa agropecuária brasileira como uma conjugação de fatores para a ciência agrícola brasileira. Trata-se de uma pesquisa qualitativa e descritiva, delineada por procedimentos de análise histórico-documental. Os resultados revelam a maturidade do Sistema Brasileiro de Ciência e Tecnologia (CT&I) na agricultura, com fortes interações nas redes internacionais de pesquisa, alta tecnologia de serviços e liderança de projetos internacionais. O contínuo apoio dado pelo Governo e setores da iniciativa privada criou as condições para a implementação dos resultados da pesquisa agrícola. Apesar da considerável disponibilidade de documentos escritos sobre o assunto, eles se referem principalmente aos aspectos bem-sucedidos do desenvolvimento do ecossistema da pesquisa científica no setor agrícola. Há uma relativa falta de evidências para confrontar os resultados do desenvolvimento com dificuldades e obstáculos encontrados na pesquisa ao longo da história. Da mesma forma, os bastidores das decisões políticas sobre a criação de novas instituições não foram claramente documentados. Especialmente para países de economia emergente na América Latina e outras regiões, a experiência brasileira pode ser uma referência para o desenvolvimento e implantação da Pesquisa Agropecuária, e disponível para parcerias com institutos em diferentes estágios de desenvolvimento. A principal contribuição deste artigo é apresentar uma síntese do ecossistema de pesquisa e desenvolvimento na agricultura do Brasil, com um relato histórico de sua evolução, que pode subsidiar futuras decisões, públicas ou privadas, sobre investimentos em pesquisa e desenvolvimento nesse setor.

Palavras-chave: Trajetória Histórica. Pesquisa Agrícola. Pesquisa e Desenvolvimento. Desenvolvimento Científico e Tecnológico.

Introduction

Recognized as an economic force, the Brazilian primary sector has gone through different economic cycles, since the 16th century with the exploitation of Pau-Brazil; sugar cane up to the 17th century; cotton plantation from the 18th to the 19th centuries; gold mining (19th century); livestock from the 18th century onwards; rubber, in the late 19th century up to the beginning of the 20th century and, finally, coffee plantation, from the second half of the 19th century up to the third decade of the 20th century (PRADO JR., 2012). Nowadays, Brazil is ranked as the world's second largest soybean producer.

The nature change of exploiting productive land to the embryo of planned agriculture was mainly due to the contribution of specialists in Botany and other natural sciences who visited the country in the 18th century and observed the damage caused in the environment throughout the country. The environmental degradation revealed the lack of appropriate techniques of both mining and crop planting. The relevant coffee international trade and the potential increase in production that could come from the adoption of the best planting practices, met both National Government and producers' expectations. In the context of the growing international demands on high quality coffee provision, inappropriate land use and pressure for improvements from rural producers, teaching and scientific research institutions in the agronomic sector were created (MARTINS, 2007).

In Agricultural Scientific and Technological Research, the investment must be continuously provided since food production is a strategic sector for national economic development (BRAZIL, 2016), what has unveiled a scenario of possibilities, strengthening an Ecosystem that combines innovation with technological transfer to producers.

This has therefore presented a trajectory for the innovation ecosystem´s creation regarding Brazilian agriculture, which is the main objective of this work. Hence, the historical panorama of the sector will be presented as well as principal agents and assigned roles, its progression to international projects and the mechanisms of governance that govern the research ecosystem in the Brazilian agricultural sector. This work was guided by the following central question: how is the agricultural research ecosystem set up in Brazil?

This research was conducted as qualitative and descriptive outlined by historical-documentary analysis procedures. For this reason, scientific articles available on the Web were analyzed, as well as the portals of Brazilian agricultural research institutes and the entities that congregate them (CONSEPA, EMBRAPA). Articles, reports and working papers available in other

official sources, such as IPEA, responsible for economic analysis, were also analyzed and appropriated to the content of this work.

The criterion for choosing data collection was established by these Institutions as centers of excellence in their field of action, bringing together the main agricultural transformations in agriculture in Brazilian scientific issues. Figure 5 summarizes the research findings and is inspired by Jackson´s (2011).

The article is organized in four parts. First is the introduction, which outlines the context from where the research problem and the objective came. The second part presents the literature related to the theoretical axes of the work; the third describes the research findings; the fourth presents the final considerations, limitations and contributions of the work.

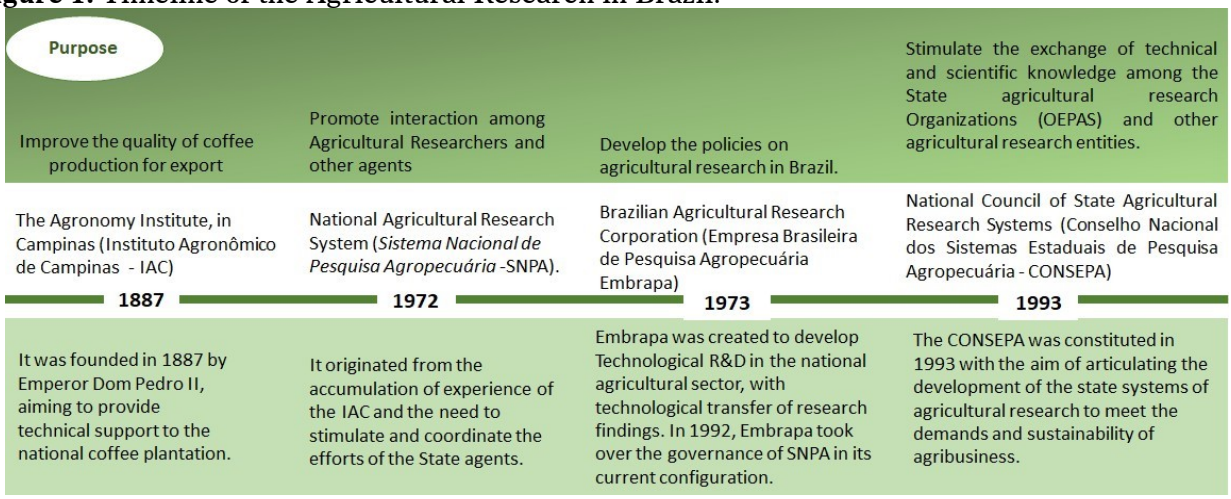
A historical perspective

Until the 19th century, the agricultural production system had as advantages the vast arable land and the high degree of sunshine, in favor of planting, but in sacrifice soil and productivity. With the arrival of the Royal family from Portugal to Brazil, some European practices related to planting were gradually introduced.

The fall of export prices and the advance of the abolitionist movement would emerge the need for intervention to ensure agricultural production. In this context, five Imperial Institutes of Agriculture were set up in 1859, located in the state of Bahia, Rio de Janeiro, Pernambuco, Sergipe and Rio Grande do Sul (REIFSCHNEIDER et al., 2012). Three of them did not prosper, one located in Bahia, became the School of Agronomy of Bahia. Thus, on February 15, 1877, the Agronomy Course of the Imperial Agricultural School of Bahia was inaugurated, the first university-level course in agricultural sciences in Brazil (REIFSCHNEIDER et al., 2012).

The coffee crop revealed the need for a paradigm shift from resource exploitation to planned cultivation aiming to reach productivity (CASTRO, 2016). The first initiative includes creating a scientific organization in the field, as the timeline shown in Figure 1.

Figure 1: Timeline of the Agricultural Research in Brazil.



Source: Castro (2016); Pereira; Castro (2017); CONSEPA (2018).

The Agronomical Institute of Campinas (IAC) was implemented in 1887 by Franz Wilhelm Dafert, a German scientist in agricultural chemistry, who was hired to set up the foundations of agricultural research in Brazil. The German research model implemented has positioned the National Government as the financier of infrastructure for R&D including high skilled human resources. Since then, a considerable number of agricultural researchers have obtained a masters or PhD degree in first class institutions in Brazil and abroad.

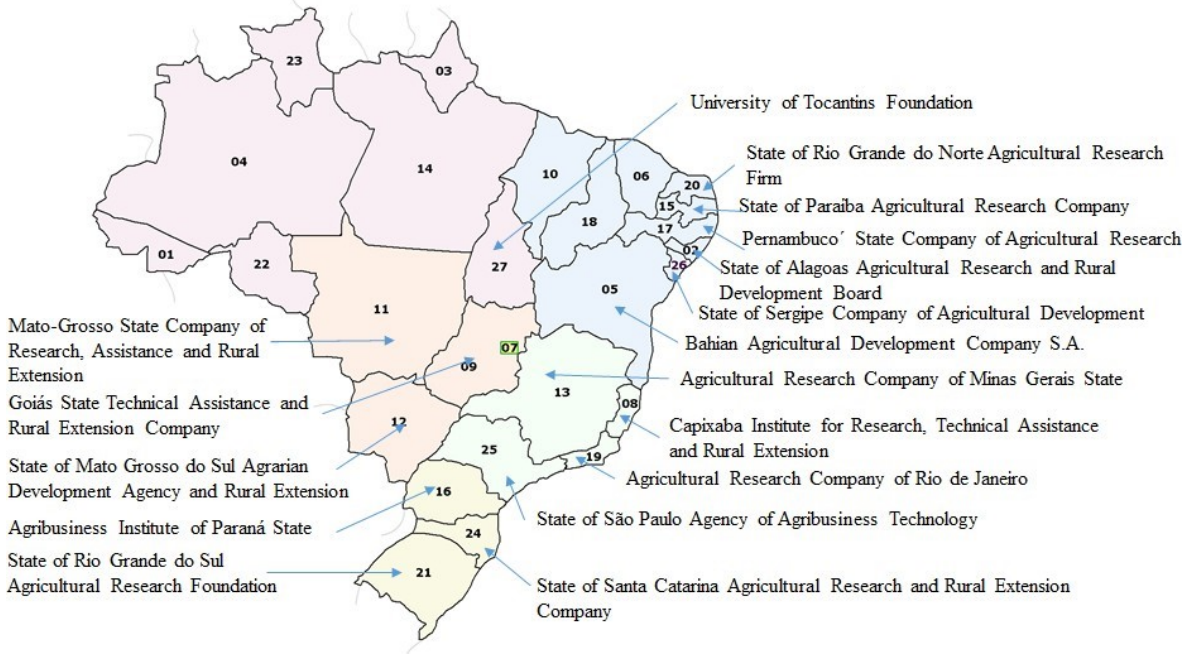
Aiming to improve agricultural production and implement best foreign techniques and practices, the IAC experience spilled over and other institutes such as State Agricultural Research Organizations, or simply OEPAS, were created since then.

OEPAS reduced the gap between Scientific Research and the agricultural producers' needs. And when, in 1930, there was an effort to create the industrial park in Brazil, agriculture, in addition to other export products, also came to be seen as a supplier of raw material in the supply chain of

the food industry. Diversification of planting with adoption of new cultivars to meet the demand of the urban population was another reason that has justified the growth in the agricultural economy. The current distribution of agricultural research centers in the country is shown in Figure 2.

The Amazon region looks to be an empty space in the agricultural field research institutes. Nevertheless, there is an important economic exploitation of the natural resources beyond agricultural production. Still, in the region, the intensive fishery, wood extraction and mining coexist with extensive areas occupied with livestock breeding and herds. An exception is the state of Roraima, unit 23 in the map, which is one of the major producers of rice in the country. Farmers and livestock breeders in the region receive technical assistance from Embrapa (COSTA et al., 2013; ARAÚJO; DOS SANTOS; PEREIRA, 2016).

Figure 2: Agricultural R&D in Brazil



Source: The Authors

The National Agronomical Teaching and Research Center (CNEPA), created by the Getulio Vargas Government, in 1938, is probably the most remarkable event to emphasize the interventionism policy to underline the role of Science and Technology. According to Reifschneider et al. (2012), CNEPA consolidated the sunflower plantation process in the Butantan Institute in the beginning of the 20th century. Agricultural research, experimentation and the teaching of agriculture in various levels of specialization would now be coordinated by a single organization. Five years later, CNEPA became a core organization, surrounded by the state institutions of Research and Development in order to set up the National Agronomical Research Service that, in turn, would form the National System of Agricultural Research - SNPA. In 1992, the SNPA governance was legally transferred to Embrapa, which was established in 1973, and would eventually become one of the most respected research institutions in the agricultural field worldwide.

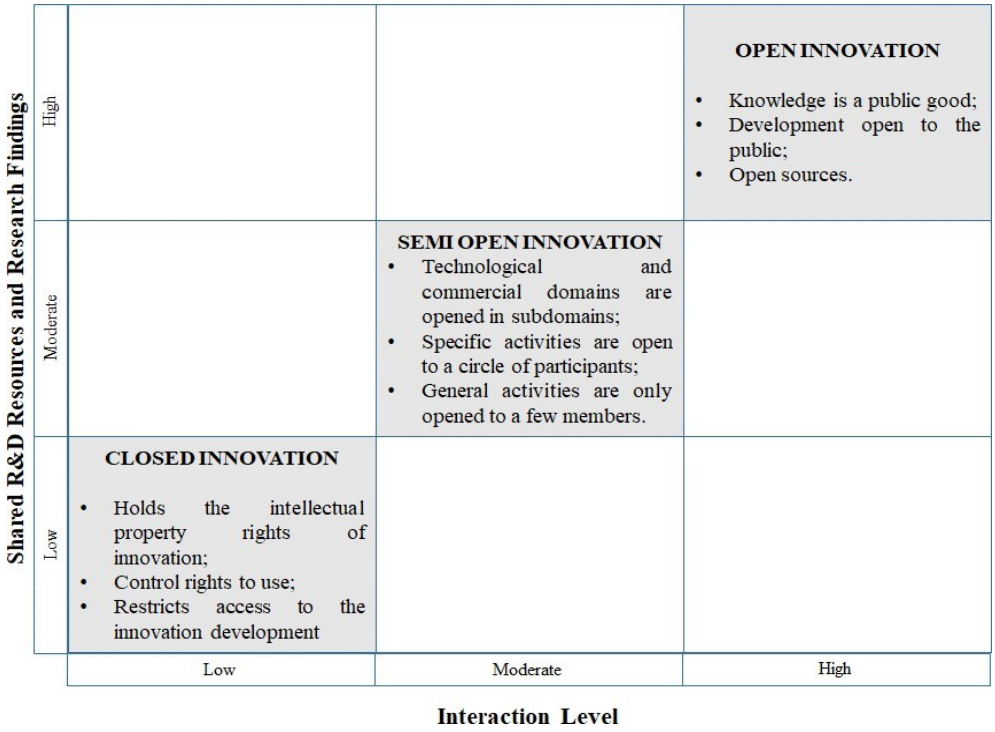
The most relevant effort to organize research institutions arose after 1960, based on the purpose of exchanging knowledge and providing support, in the sphere of a national agricultural research system, which would eventually be led by Embrapa and would include OEPAS, which are agricultural research organizations based on the characteristics of climate, culture, breeding and soil of each state. These institutions constitute the National Council of State Entities for Agricultural and Livestock Research – CONSEPA (2018).

a. INTERACTIVE MODELS IN SCIENCE, TECHNOLOGY AND INNOVATION

Interaction is an important asset for reducing cycles in Scientific Research and Technological Development, especially due to the fact that “most innovation involves more than one person, often many individuals specializing in different domains” (CARLILE; LAKHANI, 2011). It

is more than reasonable to assume that innovation almost always results from a multidisciplinary and interactive action, as shown in Figure 3.

Figure 3: Closed, semi open and open innovation framework.



Source: Hirsch-Kreinsen e Jacobson (2008); Chesbrough (2012).

With rare exceptions, for instance within the innovation in Critical Military Technologies which calls for a restricted level of interaction outside the members of the project, innovative artifacts, even in Defense, can generate breakthrough that will end up being transferred to the civil industry. Technology advances could respond to about 90% of the economic growth in an industrialized country (SOLOW, 1957). However, from the very beginning of the neo-Keynesian thinking up to nowadays, at least, six models of innovation have been introduced from 1950 onwards:

i. The Black Box Model: innovation related to the basic research and Scientific Knowledge Creation.

ii. The Linear Model: Linear model consisted of researching from knowledge creation up to commercializing new products and services.

iii. The Interactive Model: Highlighted the value of interaction and networking as a key element to develop new knowledge and new artifacts.

iv. Systems Model: The strengths rely on a large spectrum of agents that provides solutions to reach the complexity that developing innovation has become.

v. Evolutionary Model of Innovation: This model focuses on the variety of changes and the speed they occur and redefine the innovation and organizational capabilities.

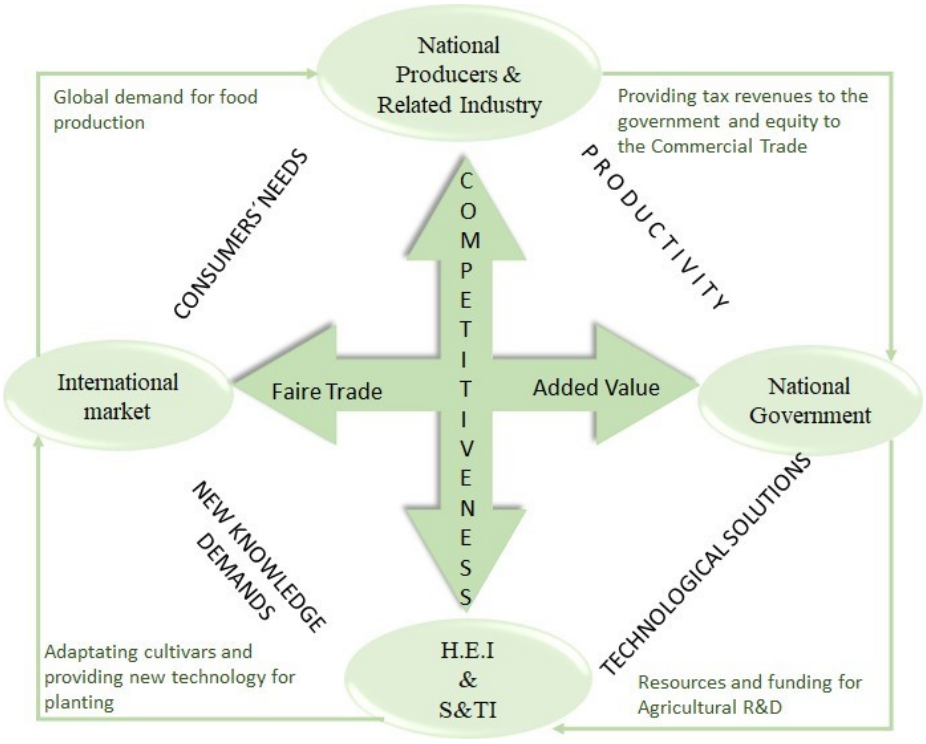
vi. *Milieu Innovateur*: Emerged from the first debates regarding regional growth around the technological clusters.

vii. Habitats of Innovation: Following the contributions of Natural Sciences, the interdependency among individuals and their environment and entities, such as universities, research institutions, and industries and other businesses agents and Government in terms of knowledge, information and resource sharing to stimulate innovation was perceived. Thus, innovation habitats are fundamentally an interactive space - physical or virtual – based on knowledge sharing.

A "Biological Systems is a complex set of relationships among living resources, habitats, and residents of an area, whose functional goal is to maintain an equilibrium sustaining state", according to Jackson (2011, pp. 1). In agricultural production, innovation is obtained by combining different and complementary knowledge. It can also be obtained by combining support from different actors, such as agricultural producers and related industries, institutions that provide qualified personnel for industry and for research. The national government sees this activity sector as a strategic asset, and international market whose needs can be attended by this interactive model, as shown in Figure 4.

As part of an interactive model, innovation habitats are part of a complex and energetic system, formed by different actors and entities "whose functional goal is to enable technology development and innovation", according to Jackson (2011, pp. 1-2). A multidimensional innovation ecosystem is a possible means to represent the model since one can see different habitats of innovation operating in such different directions but having, in common, the interest of combining innovation and production systems to reach productivity and capacity to attend greater markets. Jackson (2011, p. 2) detached the agents that take part in an innovation ecosystem, which include: the material resources (funds, equipment, facilities, etc.) and the human capital (students, faculty, staff, industry researchers, industry representatives, etc.) that make up the institutional entities participating in the ecosystem (universities, colleges of engineering, business schools, business firms, venture capitalists, industry university research institutes, federal or industrial supported Centers of Excellence, and state and/or local economic development and business assistance organizations, funding agencies, policy makers, etc.).

Figure 4: Valid Exchange among actors



Source: The Authors

Despite being classified as Low Intensity of Technology, according to OECD (2011), it is clear that Agricultural Innovation Ecosystem comprises both knowledge economy and commercial economy which are anchored by international trade affaire and follow government orientation. They also attend to the market food needs, with Science and Technology serving as a guide to reach productivity.

b. INTERACTIVE MODELS UNDER AGENTS' INTERACTIONS PERSPECTIVE

It is a consensus that, no one can develop and implement huge innovations on their own. There are changes in several levels and issues that depend on widely environmental scanning and,

at the end, have to be implemented by several agents within an innovation ecosystem with changes that would affect everyone (ADNER, 2006; ADNER; KAPOOR, 2010). Cooperation may convert from a difficulty to a less complex implementation process.

Studies on collaboration between different agents in the R&D environment point to the shared advantages of this interaction. Reducing costs and R&D cycles and increasing the intensity of knowledge application are some of them. The interaction process based on triple helix - government, research centers and industry (ETZKOWITZ; LEYDESDORFF, 2000) – has evolved towards the innovation ecosystems which includes the combination of a varied spectrum of agents, as also listed by Jackson (2011).

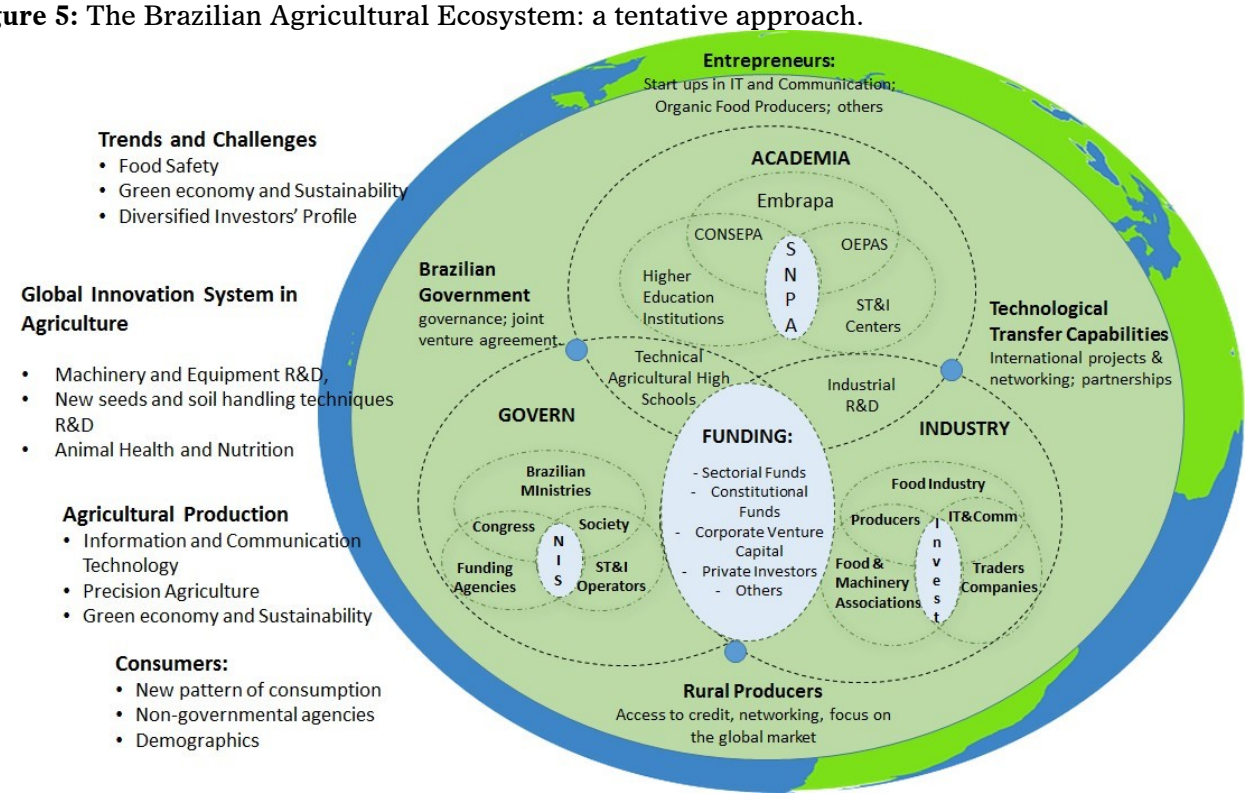
The nature of an innovation ecosystem is the interaction between different actors, entities, institutions and firms, with different attributes, knowledge and beliefs and roles that are played towards the better ecosystem functionality to reach its purpose consisted by innovative products, processes, technologies and organizations.

The Brazilian results

In summary, the development of agriculture in Brazil was promoted by the strong presence of specialists, photographers and foreign scientists, responsible for the first surveys of the territory, flora, fauna and soil use. The agricultural research came to add to the interests of increasing production of the international market, under the expectations of sugar cane producers in the Northeast, coffee and livestock breeders in the south and southeast (ALVES; CONTINI; GASQUES, 2008). Nevertheless, the Brazilian Research in agriculture was born to enhance international techniques, practices and interactions.

Firstly, IAC was implemented in several states to help rural producers and regional governments to provide support to obtain better results from the land. The interaction started internally, among state institutes in order to establish knowledge exchange specially referring to the potential of adaptation of new cultivars and planting areas. With Embrapa, in the 1970s, other successful experiences were implemented such soybean planting in the before arid and inhospitable, Brazilian Cerrado Region. Nowadays, the sector presents an extensive and diversified production chain that includes the equipment industry, export agencies, producers of varied sizes that, through production cooperatives, have constituted an important productive network for the food industry, as is summarized, but not exhaustive, in Figure 5.

Figure 5: The Brazilian Agricultural Ecosystem: a tentative approach.



Source: The Authors

The first step of the Brazilian Agricultural Research organization was aimed to fulfill the rural producers' demands, driven by the need to enhance better production volume in accordance to the exploitation of the natural wealth logic. Natural conditions, such as soil, water, solar radiation and the extension of the farmable lands contributed to this logic so far. At the same time, the efforts seen at this trajectory, in its very beginning, made it possible to attain one of the most valuable experiences in Agriculture Research ecosystem formation, as seen today, in accordance to the Jackson (2011) contribution, shown in Fig. 5:

- Government: The National Brazilian Government is the main agent in the regulation, financing and coordination of efforts in the consolidation of the National Agricultural Research Ecosystem. The Brazilian Government is also responsible for supporting R&D infrastructure in Agriculture; the implementation of distribution logistics and export of agricultural products; the orchestration of public policies of the states; and trade and cooperation agreements among countries.
- Material resources: The Brazilian National Innovation System is constituted by an infrastructure organized at three levels:
  - The political sphere: that defines and organizes the set of resources necessary to promote innovation, combining legislative, executive and social organizations;
  - The funding agencies: responsible for organizing and distributing the financial resources for Research and Development activity, such as; installation of research laboratory; acquisition of materials and research equipment. Specifically, for agricultural research, there is a sectorial fund named ST – Agro, i.e, Science and Technology Fund for Agricultural Research and Development initiatives;
  - The Operators of Science, Technology and Innovation that include universities, technological institutes, science parks, business incubators, and innovative companies.
- The human capital: The educational system in the agricultural area comprises practically the whole cycle of the training of qualified human resources, both for field practice and scientific research.
- One particular note must be given to technical schools, implemented in 1930, which form field technicians; institutes of higher education in the field of agronomy, veterinary medicine and agronomic engineering; and in food production, educational institutions in food engineering, nutrition and more recently, in environmental management with strong guidance for preservation of the natural environment, to emphasize a few.
- The Brazilian National Agricultural Innovation Ecosystem concentrates centers of excellence in R&D, led by Embrapa, with wide coverage in the national territory and boasts of a bunch of highly qualified professionals, also mobilizes a global network of researchers in the agricultural research sector and has as it focus, the supply of technological solutions to rural producers.

The nature of the relations observed in the innovation ecosystem in agricultural research, due to the purpose and variety of agents, can be better explained by the interaction between different propellers, mobilized to complete the chain of innovation and national agricultural production. Thus, the system combines forces of a political nature, responsible for the research infrastructure and financial resources; economic nature responsible for the commercialization of production; of technological nature, which offers resources not only arising from scientific research, but also from the progress made by other areas such as Information and Communication Technology, applied to Precision Agriculture, and innovation in the field of agricultural implements. The socio-cultural force imposes not only the increase of food production to meet the demographic dynamics, but also in compliance with the new patterns of consumption, inserted in the field of food security, as well as the production of organic foods and oriented production to follow the precepts of sustainability.

Conclusions

The first efforts for the exploration of Brazilian lands responded by the movement of exploring the territory, with purpose of taking advantage of natural resource wealth, following the interests of international commerce promoted by the Portuguese metropolis. However, after the

installation of the Portuguese Crown, a mere colonial exploitation became a secondary cause. Under the Dom Pedro II Government, questions such as improving productivity were imposed on the agricultural *modus operandi*. The breakdown of the gold cycle was an important milestone for the expansion of the Brazilian agricultural potential.

The rupture of the model of agrarian exploitation would take on a more modernization after the creation of the first agrarian schools, still on the regency of Dom Pedro II and, under the pressure of the great agricultural producers, the first research institutions, directed to the best use of the soil and plantations, with the national government as the basic source of financing.

The Government is still an important agent for financing the ST&I structure expenses and institutionally support the agreements for cooperative R&D international projects with ST&I institutes or between foreign governs. However, it is important to highlight the effect of international trade on the strategies for creating Scientific Research in Brazilian Agriculture. Added to this element is the pressure by producers both to identify solutions to improve productivity and to finance the resources needed to obtain it, which is seen by historians as a fragility in the growth project of the Brazilian industry. This can be confirmed in future research regarding technological nationalization in the machine and equipment production sector, which is part of the same project that generated the present work.

In terms of models, observing agents' diversity points to the integration of system effort. The nature of relationship among entities suggests a hybrid model which combines both the Interactive and Systemic Models.

The limitations of this research refer to the need to deepen the historical research and the delineation of path dependence related to the evolutionary process of the Brazilian agricultural research, as well as a more explicit relationship among the agents. But being an initial work, it is concluded that this is an opportunity to be explored by this work in an expanded version. The present research's next step will be to validate the interpretative and historic model.

As contributions to the research, it is considered that the delineation of the tentative model of the agricultural research ecosystem, is an initial step and that offers the conditions for advances in the debate.

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