THE STATE IN THE
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Ana Célia Castro
Fernando Filgueiras
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The State in the 21st Century

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From catching-up to the technological frontier: challenges for knowledge governance

Ana Célia Castro and Silvia Zimmermann

> *"Perhaps a crux of success or failure as a society is to know which core values to hold on to, and which ones to discard and replace with new values, when times change."*
> *Diamond, J. COLLAPSE. How societies choose to fail or succeed. 2005.*

Theoretical and conceptual framework

The first challenge to this reflection regards the updating *(aggiornamento)* of the concept of technological *catching-up*[1],

[1] Convergence or *catching-up* is defined as technological parity or equivalence to state-of-the-art international standards. It is a process that tends to occur in a concentrated form within a given time range, and it is accompanied by high rates of economic growth, with increased productivity and international competitiveness for the sectors and companies involved. In addition to the concept of historical *catching-up,* there is the concept of technological *catching-up,* with which we will work in this paper. The most important reference texts for studies on catching-up are: Gerschenkron (1962); Abramovitz (1986); and Hikino & Amsden (1994). See also Nelson, Mazzoleni, Cantwell, Bell, Hobday, Von Tunzelmann, Metcalfe, Henry & Odagiri (2005). Two recent theses on the subject can also be cited: Bastian (2008) and Rego (2014). Antonio Barros de Castro was the author responsible for the introduction of this approach to interpret Brazilian industrial development as a process of *catching-up,* instead of the prevailing interpretation in the ECLAC tradition, synthesized in Tavares (1973), who describes Latin American industrialization as an import substitution process. On this topic, see Castro and Proença (2001) and Castro (2003). The collection of papers presented by Castro at the National Forum can be seen in Velloso *(Antonio Barros de Castro. O Desenvolvimento Brasileiro da Era Geisel ao Nosso Tempo)*. The article *Renegade Development: Rise and Demise of State-led Development in Brazil*, in Smith *et al*. (1993), takes a step forward and discusses the role of conventions and shared beliefs in the interpretation of the most recent period in Brazilian economy. The latest version of this article is in Castro and Castro (2012).

given the new context of the 21st century. In synthesis, the following reflections could be suggested.

As opposed to the recent past, there does not seem to be a single technological path while a higher standard is not established. The concept of secondary innovation[2], which describes how countries test and pursue different technological trajectories, following their vocations and capabilities[3], makes the concept of catching-up indefinite – catching-up with what? It seems that a roadmap to be followed by sectors and countries is no longer available. If there were such a path, it would not necessarily be up to the countries with higher *per capita* income to hold up to the "less developed" "the mirror of their own future".[4]

The so-called "superior" technologies must also meet objectives outside the traditional universe of technology. Considerations on sustainability, saving/not wasting resources, not harming human and

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[2] Based on Dosi's (1982) notion of technological paradigm and technological trajectories, secondary innovation sheds new light on the topic. Before the technological standards of an industry/ product/process are consolidated, developing countries may explore alternative routes according to their capabilities. A company may purchase a technology from a developed country, absorb knowledge gained via technology transfer agreements with companies from developed countries and enhance it, thus exploring new trajectory possibilities. See Wu, Ma and Xu (2011).

[3] The concept of dynamic capabilities was introduced by Teece (1998), but its roots lie in the literature of the Resource-Based View. Dynamic capabilities translate into market sensing and sizing abilities, alluding to the Schumpeterian sources of competitive advantage, which may be considered a consequence of unique innovations. Innovations, in turn, help understand other organizational and business processes of integration, learning, reshaping and transformation, positioning (location), enforcement capability ("assessment"), reproducibility and imitability of the organizational process. The Resource-Based View has its precursors in Penrose (1959) and Chandler (1977) and emphasizes the competitive advantage related to the ownership of scarce, but relevant and difficult to imitate, assets, such as knowledge. See Foss (1997), *Resources, Firms, and Strategies: a reader in the Resource-Based Perspective,* which concentrates the main contributions of this literature.

[4] Marx (1867), *Capital*, cited in this paper according to the Marx (1968) edition: "Los países industrialmente más desarollados no hacen más que poner delante de los países menos progresivos el espejo de su proprio porvenir" (Prologue to the First German Edition, 1867, p. xiv). China is perhaps the greatest example of *leapfrogging.* On this theme, see Proenca, Habert, Aredes, Camargo Jr. (2011).

animal health/life, fulfilling social inclusion objectives, respecting/ taking into account traditional knowledge of cosmologies rooted in tradition are involved in the definition of which technologies a society will reckon superior in the present or near future[5].

Another important line of thought recognizes a change in the way of doing science which impacts knowledge governance, in that it redefines the forms of coordination within and outside companies, thus far a privileged locus for innovation[6]. Concepts such as open innovation[7], user innovation[8] and the existence of innovation

[5] If this is taken to be true for certain industries, in the case of agriculture, such requirements or demands become even more compelling. The outlook on agriculture seems to mirror the existence of at least three tensions currently present in Brazil: a perspective of the social movements – which is markedly ideological – on the agrarian restructuring movements, in which the issue of unequal access to resources is more important than its use; a productivist point of view – related to agribusiness – emphasizing average income of farming operations; and an understanding derived from sustainability, environmental protection, low use of fossil fuels, agroecology, which may or may not be accompanied by cosmologies which emphasize religious and spiritual dimensions, present, for example, in movements like Pachamama (Mother Earth, divinity related to the earth, fertility, the mother, and the feminine) or in shamanic traditions which have been valued and studied by traditional science itself.

[6] In *Capitalism, Socialism and Democracy,* Schumpeter (1947) identified the "domestication" of innovation within enterprises – subordinating the introduction of innovations in the economy to a reduction in the differential rents of technologies still in use – as one of the causes for the overcoming of capitalism: not for its failures, but precisely for its successes.

[7] "We propose the following definition of open innovation, in hopes of unifying future work in this area: open innovation is a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with each organization's business model. These flows of knowledge may involve knowledge inflows to the focal organization (leveraging external knowledge sources through internal processes), knowledge outflows from a focal organization (leveraging internal knowledge through external commercialization processes) or both (coupling external knowledge sources and commercialization activities)" (Chesbourough, 2006, p.xxiv). The latest publication on the advances of the "open innovation" approach is Chesbrough, Vanhaverbeke and West (2015).

[8] Baldwin and Von Hippel, 2011:1400 and Von Hippel, E. Democratizing Innovation. MIT Press. 2005. The concept of "user innovation" was proposed by Von Hippel (1988, 2005, 2010) and has had increasing adherence in the business world, especially in the development of applications launched by mobile and information technology

platforms, knowledge networks and markets[9] have been absorbed by the literature on innovation but need to be reconsidered in the assessment of technological catching-up process. In fact, processes that involve knowledge, learning and innovation have been deeply renewed.[10] Such changes take place not only happen in companies, universities and research institutions responsible for innovation.

> New types of organizations, hybrids composed of markets and corporate networks – knowledge networks and markets – are emerging. In these new types of organizations, knowledge is both the intellectual property of a company and fragmented across multiple entities in the network. It is also incorporated in intangible assets,[11] whose value is commodified in different forms and in emerging market structures[12] (Burlamaqui; Castro; Kattel, 2013, p.xiv).

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companies. A case in point is Shaumi, a Chinese company adopting a business model that relies on followers ("fans") to test the launching of new applications/products, which engenders its own market of potential customers. A more recent publication can be cited on the advances of the "user innovation" approach: Chesbrough, Vanhaverbeke and West (2015).

[9] The OECD has circulated a document entitled Knowledge Networks and Markets for discussion by experts. For more information, see http://www.oecd.org/innovation/inno/knm.htm.

“Knowledge networks and markets are arrangements which govern the transfer of various types of knowledge, such as intellectual property, know-how, software code or databases, between independent parties across the economy. The OECD's KNM project studies existing and emerging knowledge allocation mechanisms and their impact on knowledge creation, dissemination and use. The assessment of the economic significance of KNMs informs an evidence-based approach to science and innovation policy making” (OCDE, 2013, p. 2).

[10] “The changes alluded to are the products not only of new technological regimes, such as described in Coriat and Weinstein (2002), but, especially, the result of changes in institutions, organizations, and governance structures that accompany them” (Burlamaqui; Castro; Kattel, 2012, p. xvi).

[11] Possas (1999) draws attention to "the presence of intangible assets, based on experience, knowledge, relationships established, image created" (Possas, 1999, p. 120).

[12] “New types of organizations, hybrids composed of markets and corporate networks – knowledge networks and markets – are emerging. In these new types of organizations, knowledge is both proprietary and fragmented across multiple entities. It is also incorporated into intangibles assets, whose value they seek to seize. (Teece 2002) These intangible assets are marketed under different forms in emerging market structures" (Burlamaqui; Castro; Kattel, 2013, p.).

However, not all knowledge can be appropriated – it can also move freely in research networks and innovation cooperatives, such as open databases, genetic code mappings, *wikipedias*, and under agreements based on *"creative commons"* and "*science commons*", which seek alternative intellectual property regimes, with major implications for knowledge governance. In this sense, knowledge creation and diffusion are ahead of policy and regulation, which have not kept pace with changes in the fast-paced real and virtual world of innovation. The implications for the catching-up process seem to not have been enough discussed or clarified.[13] An unforeseen result, one might suggest, is that technological catching-up is in fact a never-ending process, in which innovation may arise from changing architectures in denser institutional arrangements, and therefore may not constitute a clear goal to be achieved, while *leapfrogging* is always a possibility that collaborative innovation may or may not reveal.

R&D activities are thus increasing the connectivity and development of technology platforms that facilitate management activities dispersed in firms and more distributed innovation networks[14], therefore involving a larger number of different entities. This new organization of innovation, it seems, would have advantages and could prove more efficient than centralized/ hierarchical alternatives, as it can mobilize more substantial and more dispersed resources for innovation. In this sense, competition between alternative technology routes – adopted by countries when conducting the so-called secondary innovation – may be enabled due to a reduction in the bureaucratic costs associated with centralized research and development processes. Such alternatives, as suggested by the OECD document, need a "strong glue" that allows for denser

[13] Emphasis on this point is justified by the fact that innovation platforms coordinated by Embrapa are the object of this work.

[14] Eric Von Hippel was the first to propose the term "distributed innovation" to describe a system in which innovation is the result of interaction between producers, users, and even rivals.

knowledge flows among players. This knowledge governance structure, the document suggests, would be the so-called knowledge networks and markets, as widely discussed above.

Knowledge networks and markets could be defined as (not necessarily) soft infrastructures and instruments/mechanisms that facilitate the development of innovation clusters, based on the concepts of open innovation and marketing of inventions by universities (in the Brazilian case, these would be the Technology Innovation Centers – NITs – under the Innovation Law)[15]. These are arrangements governing the transfer of various types of codified knowledge, such as patents, know-how, code and databases, among others, which flows among independent parties and facilitates accessibility, usability and marketing. Participants in knowledge networks and markets are universities, firms (particularly start-ups), government agencies, and even individual researchers or innovators (using a very broad concept of innovation).[16]

Knowledge networks and markets - KNM may be characterized, first, by their objectives: circulate (share and negotiate) intellectual property rights, whether on patents, databases, research results from virtually connected teams, proprietary material in general, knowledge, secrets, among others; arrange the joint production of new knowledge, as such contracts are complex and difficult to monitor; circulate (share, negotiate) existing knowledge, which may depend on setting up the markets in which these negotiations will take place.

[15] / See Lei de Inovação, Lei nº 10.973, of 2 December 2004. Available at http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/lei/l10.973.htm.

[16] This concept does not apply only to innovations in the "more conventional" sectors. An application which may not have yet been considered for the concept of KNM in creative economy could be the business model introduced by the YouTube platform to "monetize" the uploads of videos and other products made available on the web. See the excellent presentation of this business model by Pedro Misukami, from the Center for Technology and Society, Fundação Getulio Vargas, Cultura Digital e Novos Processos de Intermediação. There is a presentation by the same author on the new Brazilian Internet legal framework at https://www.youtube.com/watch?v=qiOd_owiv6w

On the supply side, KNM include monetary incentives (including public funding), reciprocal access, reputation or contacts, public interest. On the demand side, KNM enable different conditions of access: restricted (like clubs, or research networks); open access, but through payment; open and free access, like in Wikipedias and Scielo, for example.[17] Governance can take place at the micro level (of companies and organizations participating in consortia), the meso level (of network and market-type structures), and at the macro level (mechanisms/instruments governing the production, use, circulation and appropriation (rights, protection) of knowledge).[18]

Industrial and technological policies (favoring innovation); regulation of competition; intellectual property regimes – resulting from the activities of patent offices –; the Judiciary, which deals with the litigation of intellectual property; and the diplomatic corps of a country that operates in global governance organizations with some degree of influence or freedom to modify the international legal apparatus of intellectual property (IP) and/or competition regulation are institutions involved in the new ecology of innovation and its governance.

Thus, the concept of knowledge management was impoverished by this tangle of dimensions, actors and policies. The term knowledge

[17] Other relevant criteria to think of a KNM typology would be: who are its members and how they interact, what are the governance mechanisms or how coordination takes place within the KNM.

[18] It seems convenient to distinguish two more recent concepts of knowledge governance. The first, focusing on the company, may be attributed to Nicolai Foss and other researchers following this line, and is described in Foss and Michailova (2009). Another consideration was explored in the abovementioned book by Burlamaqui, Castro and Kattel, where knowledge governance refers to policies and regulations that encourage the production, circulation, diffusion/use and protection of knowledge. Thus, it is a concept located in the macro dimension. In this regard, the very judgment on knowledge benefits from a distinction between general – restless, ungovernable – knowledge, as described in Metcalfe, and organizational knowledge, which, even when uncoded, is shared by the company/organization and may thus be coordinated. See also Tsoukas (2005) and Tsoukas and Mylonopoulos (2004).

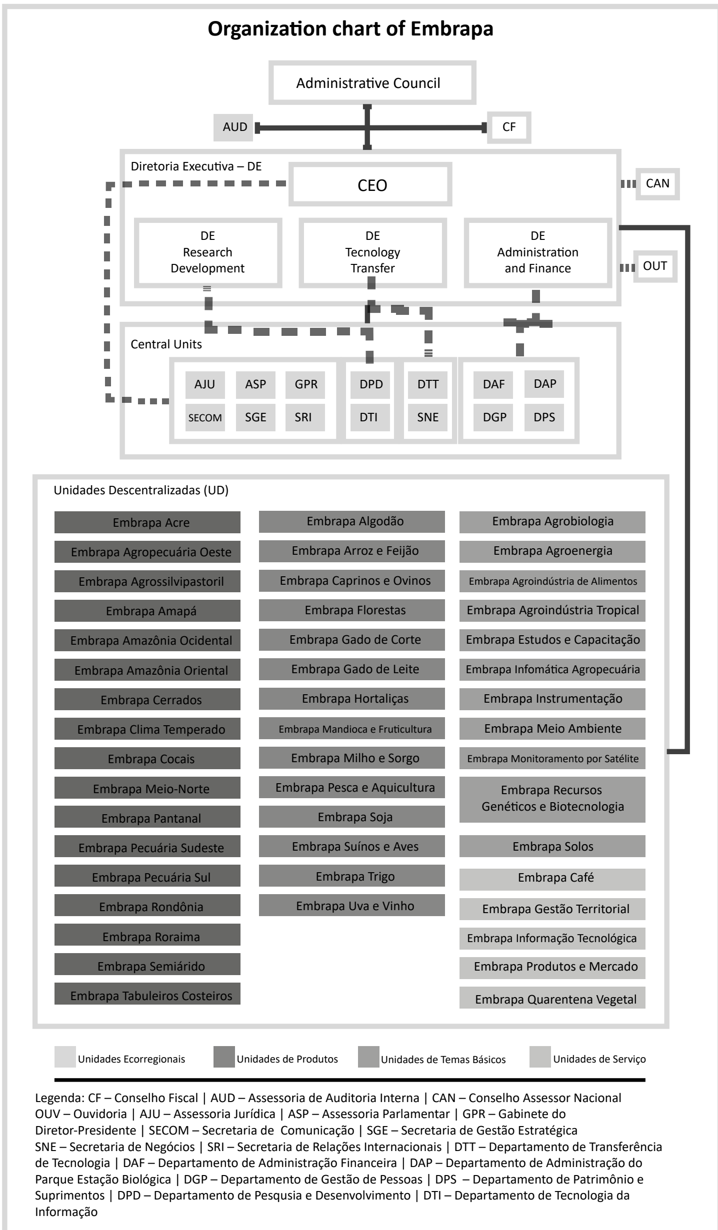
governance seems more adherent to the multiple realities of the knowledge economy, including not only its scientific and technological frontier, but also the subtleties and complexities of creative economy, for example. Similarly, organizational knowledge cannot be strictly managed, because dynamic capabilities may lead technological trajectories to different paths, which were not necessarily expected. In this sense, although fundamental for envisaging frontiers, paths and trends, technology prospecting cannot comprehend windows of opportunity that companies seek and will seek to take advantage of, and which appear unexpectedly.

Before examining the knowledge platforms coordinated by Embrapa, one should mention the following research results from the years 2012 and 2013, when interviews with Embrapa's directors were conducted.

It could be said that there was a shared belief or structured consensus: Embrapa believed to be at the technological frontier of low-carbon tropical agriculture; besides, the corporation believed it was able to set that frontier. In this sense, internal, national and international institutional arrangements, strategic design, research infrastructure, new research units that had recently been inaugurated, virtual laboratories abroad (LABEX), organization in macro programs, the whole governance of internal knowledge, reinforced that very understanding, that very intelligence. The research evaluation methodology itself required new metrics which would be able to reveal the dynamics of such an agriculture. Tensions between social inclusion, productivist (high -yield farming), and sustainability objectives, seemed to be entangled under the same strategic direction: low-carbon tropical agriculture. Embrapa performed technology prospecting and trusted its leadership over countries with similar agriculture.[19] The organizational structure was as shown in Figures 1 and 2.

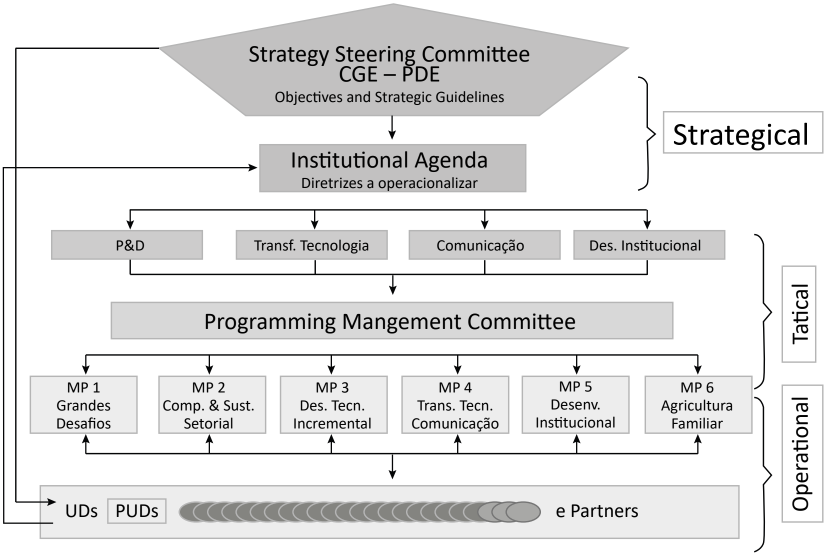
[19] The same cannot be stated today, but there is not enough evidence to say otherwise.

Figure 1 – Embrapa's organizational chart, 2012



Source: Embrapa, 2012.

Figure 2 – Embrapa's internal organizational chart, 2012. Macro programs



Source: Embrapa, n/d.

Knowledge governance – coffee, soybean, and sugar cane[20]

Embrapa has played the role of a catalyst by placing Brazil at the frontier of low-carbon agriculture. As we know, leadership at the new agricultural frontier is a hard place to keep. The forms of organizing research point to different ways of doing science and technology. Collaborative knowledge platforms are the main example, and Embrapa has governance (coordination) of some notable experiences (i) the Network of the National Research Project of the Eucalyptus Genome (Rede Genolyptus); (ii) the Brazilian Coffee Research and Development Consortium (CBP&D/Café or Consórcio Café), which gathers more than

[20] According to data from MAPA, the Brazilian coffee crop was of 49.15 million bags (2013/2014); the sugar cane crop for the same year was 633.7 million tons (making Brazil the top producer of the product in the world); and the soybean crop in 2013/2014 was of 30,173 million tons.

sixty different institutions[21]; (iii) and the Citriculture Defense Fund (Fundecitrus), just to mention a few but successful experiences.

The Brazilian Coffee Research and Development Consortium (CBP&DC), coordinated by Embrapa Café, has a larger institutional political organization and was established in 1997. The National Consortium for Soybean Genome Studies (Genosoja) is newer, coordinated by Embrapa Soja, and was founded in 2007 in order to identify and functionally characterize the soybean genes that act in the physiological processes of the plant. The consortium is a form of organization adopted by Embrapa to establish partnerships with other national and international public and private institutions, as a means to keep knowledge governance with regard to soybeans. To some extent, both these consortia hold knowledge governance in these sectors, in which Embrapa is a major reference.

Unlike other crops with historically marked presence of Embrapa, the Corporation did not have a thematic unit dedicated to research on sugarcane until recently, when the Embrapa Agroenergia unit was created with sugar cane, among other crops, as one of its biggest bets. Embrapa has therefore established a partnership with the Inter-University Network for the Development of the Sugarcane Industry (Ridesa), aiming to expand the activities of Embrapa Agroenergia and strengthen its research. Ridesa is similar in design to technological consortia, as it gathers material and intellectual resources as well as infrastructure for research on the sugarcane crop in the country. Ridesa was established in 1991, and its coordination is carried out by the Universities that compose it, in a public institutional arrangement.

[21] As regards coffee and soybean, there are TCs coordinated by Embrapa through its Embrapa Café and Embrapa Soja units. These consortia are different from their objectives to the combination of public and private actors, which implies different knowledge governance conditions for research in these sectors. The coffee TC has unique composition and has given rise to the Embrapa Café unit, which has coordinated the consortium for about fifteen years. The soybean TC has emerged more recently, from an initiative by researchers from the Embrapa Soja unit, having a more precise goal, namely the mapping of the soybean genome.

Coffee Technology Consortium[22]

The Brazilian Coffee Research and Development Consortium brings together over 50 research institutions and is coordinated by Embrapa. It emerged in the mid-1990s in response to the challenges faced by the crop due to market opening, with the expiration of the terms of the International Coffee Agreement (ICA) and the extinction of the Brazilian Coffee Institute (IBC). The creation of the institution was considered an innovative proposal because it aimed to integrate the execution of research activities on the coffee crop – something new at the time –, and it was initially composed of ten founding institutions[23]. Soon after the creation of the consortium, Embrapa Café was created as a decentralized unit which would be responsible for coordination of research demands among participating institutions. The Coffee Program Support Service (*Serviço de Apoio ao Programa Café*, SAPC) was founded on August 30, 1999, in Brasília, and became known by the synthetic name Embrapa Café. More than a corporate management institutional arrangement, a network research platform was being established, as well as a structure able to build consensus

[22] The TC aims to aggregate the human, laboratory, physical and financial resources of institutions for the design and execution of research activities in all areas of the coffee production chain and comprising the main Brazilian coffee producing states: Minas Gerais, Espírito Santo, São Paulo, Paraná, Bahia, Rondônia, Rio de Janeiro, Pará, Acre, Amazonas, Goiás, and Distrito Federal. Research developed by the TC covers the entire production chain, from the production and processing to trading and consumption, including consumer health. See http://www.sapc.embrapa.br/. See also ISSN 1678-1694 Novembro, 2012 Sistema de Gestão do Consórcio Pesquisa Café: Governança Corporativa, at http://ainfo.cnptia.embrapa.br/digital/bitstream/item/86766/1/Sistema-de-gestao.pdf

[23] Agricultural Development Company of Bahia (EBDA), Agricultural Research Company of Minas Gerais (Epamig), Agronomic Institute of Campinas (IAC), Agronomic Institute of Paraná (Iapar), Institute for Research, Technical Assistance and Rural Extension of Espírito Santo (Incaper), Agricultural Research Company of the State of Rio de Janeiro (Pesagro – Rio), Federal University of Lavras (UFLA), Federal University of Viçosa (UFV), as well as Embrapa and MAPA.

through efforts to coalesce the different interests at stake, in a field of utmost importance in Brazilian agribusiness.[24]

The Brazilian Coffee Institute, created in 1950, was extinguished in 1990 and institutions working with coffee felt the need to ensure continuity of ongoing research activities. The interest of these institutions stimulated the creation of the Coffee Policy Deliberative Council (CDPC) in 1996, a collegiate body linked to MAPA with the purpose of approving policies for the coffee sector.[25] The Coffee TC is an unprecedented and unique experience in the country and abroad integrating traditional scientific, educational and rural extension institutions for knowledge generation and technology transfer, integrated with the various segments of the coffee agroindustrial chain. According Mirian Eira, a researcher at Embrapa, the consortium represents institutions

> gathered by a pluralistic, democratically participatory model, with coordination at the national level and with decentralized execution. The result of this union is hundreds of research and technology transfer activities, in which more than a thousand professionals are involved, including researchers, teachers, extension workers, students, scholarship holders and interns. All research work is geared to the needs of customers – coffee producers, trade, government and end consumer. This targeted research effort has expanded the basis of the evolution of the Brazilian coffee business (Embrapa, 2012).[26]

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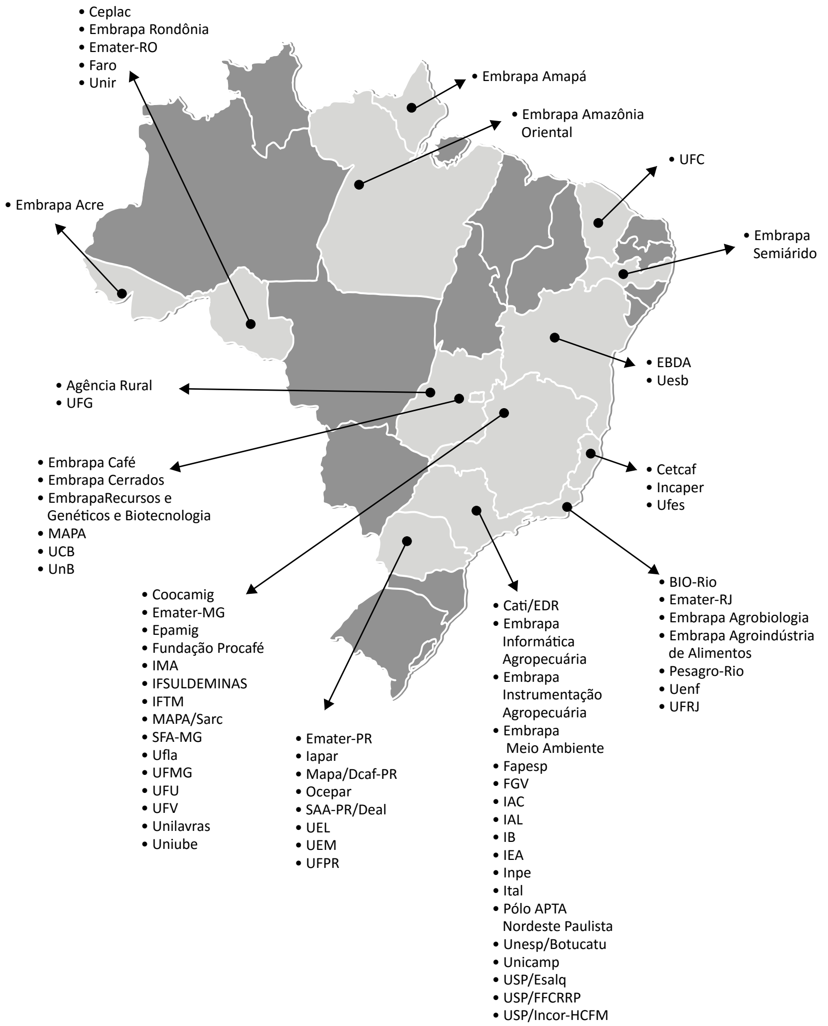
[24] In the 1950s, the first institute having coffee as its sole mission was created: the Brazilian Coffee Institute (IBC). Created with the objective of defining the policy for the sector, coordinating and controlling strategies from the production to domestic and foreign trading, the IBC provided financial and technical support to coffee production and promoted studies and research on coffee cultivation and economy. The institute managed the Coffee Economy Defense Fund (Funcafé), established in 1986 with funds from quotas of coffee export contributions. The fund financed production and new research on the coffee crop.

[25] The council aims at making public policies concerning the production, trade, export and marketing, as well as establishing an agronomic and market research program to provide technical and commercial support to the development of the coffee agro-industrial chain (Embrapa, 2012).

[26] The consortium is responsible for the design and implementation of the National Coffee Research and Development Program, which supports projects and mobilizes about 1,300 researchers and extension workers. This program works as science and technology arm of MAPA and of the Coffee Policy Deliberative Council.

Embrapa Café is in charge of the coordinated strategic management of the research program, with the goal of supporting technological innovation and, as per its official document, the sustainable development of the Brazilian coffee production chain. Resources for research and coordination come from Funcafé.

Figure 3 – Institutions participating in the Coffee Research Consortium



Source: www.consorciopesquisacafe.com.br.

The implementation of the consortium has allowed to establish formal and effective channels of scientific and technological exchange between consortium institutions through systematic dynamics. The TC has replaced an informal and individual model with an institutionalized and collective research model for greater benefits for the coffee industry. Since the establishment of this institutional arrangement, funds from sources external to Funcafé have reached 50% of total fund resources. [27]

The consortium has had several achievements in terms of technology for the coffee sector, including:

• genetic improvement, cultivars with high-yield and high-quality potential;

• biotechnology studies, gene mapping based on DNA markers and characterization of nucleotide modification markers, from the database of the Coffee Genome Project. The project raises Brazilian coffee production to a leading position in coffee genetics research worldwide;

• multiplication of materials of high agronomic value in bioreactors, evaluation of field conditions, biofactory with large seedling production capacity;

• forestation of coffee farms: characterization and assessment of technologies for usage, practice and management of forested coffee agricultural systems, ecophysiological, edafic and phytotechnical impacts of shading, impact of intercropping on sustainability, evaluation of cultivars, organic materials, and plants as nutrient sources in fertilization for the sustainability of coffee agroecosystems.

• irrigated coffee production: improvement of the irrigated coffee production system, definition of technologies for the use of

[27] In 2011, Funcafé provided to the national coffee sector funds amounting to R$ 2.44 billion to finance the upgrading and boost productivity in coffee cultivation, processing and export; research development; promoting domestic and foreign markets, as well as the livelihood of rural workers (Embrapa, 2012).

irrigation, fertigation in different production systems, competitiveness and sustainability;

• organic coffee production; design of a standard system for the production of organic coffee, evaluation of unusual coffee fertilization management systems, focus on nutrition, health and soil protection;

• Conilon coffee production technologies; enhancement of the production process and cultural practices to increase coffee productivity and sustainability;

• sizing of the coffee plantations, geoprocessing technologies, encouraging geographical indications, denomination of origin, so as to promote the sustainability of coffee production in various territories;

• climate change: studies on potential strategic technology solutions to maintain productivity and mitigate the effects of climate change on coffee production;

• nematode control: studies on the genetic variability of nematodes and establishment of crop management practices with biological control in infested coffee producing areas.

It is important to note that these actions are focus on the fields of biotechnology, ecophysiology, biotic stress response, genetic improvement, disease prediction system, and harvest improvements. They also emphasize sustainability issues, such as climate changes, pest bioecology, development of sustainable production systems, water use optimization. A third emphasis not shown on the above list of priorities, but reported in other sources on the consortium, refers to the demand side, including, on the one hand, the importance of beverage quality, as expressed in *gourmet* coffees, and, on the other the effects of coffee on human health – both positive effects, such as reduction in depression and coronary disease rates and the prevention of degenerative disease, and negative ones, derived from excessive consumption. [28]

[28] file:///C:/Users/Anacelia2/Downloads/Cafe-e-saude-humana.pdf. "Few people know that coffee is a nutraceutical (nutritional and pharmaceutical) beverage, richer in minerals that sports drinks, containing vitamin B (niacin) and caffeine,

Embrapa Soja and Genosoja[29]

The National Consortium for Soybean Genome Studies (Genosoja) has formalized Brazil's participation in the International Soybean Genome Consortium – *ISGC*), formed in 2007 by 25 research groups from different parts of the world, including countries like the US, China, Japan, Korea and Brazil.

Genosoja is led by Embrapa Soja, funded by CNPq, and involves more than nine institutions in the country. The Brazilian consortium aims to act as a national counterpart to the ISGC, thus contributing to studies adapted to the tropical reality. More specifically, it aims to deal with mechanisms that will improve the conditions for development of the plant in Brazil, thereby ensuring resistance to diseases and drought, among others.

Commercial production of soybeans began in Brazil in the 1960s, when producing this crop became an option for the summer, after the wheat crop, contributing to increased swine and poultry production. In the 1970s, the upsurge in soybean prices in the world market and the flow of the Brazilian crop during the American off-season required investment in technology to adapt the crop to Brazilian conditions. In

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which is safe in the existing dose of 3 to 4 daily cups (up to 500 mg/day), which stimulates attention, focus, memory and school learning. Besides, coffee contains chlorogenic acids, natural antioxidants which, in the appropriate roasting process, forms quinides, which help prevent depression and its consequences (smoking, alcoholism, drug abuse and suicide). (...) Daily and moderate coffee consumption by adults can also help fight depression, the fourth cause of death in the world today, but which will become the second by the year 2020, according to information from the World Health Organization (WHO), after myocardial infarction. Therefore, a good way to avoid depression and its consequences, as well as myocardial infarction, is the adoption of daily and moderate coffee consumption..."

See also 24 ENCAFE, Encontro Nacional das Indústrias do Café, at http://www.abic.com.br/publique/cgi/cgilua.exe/sys/start.htm?sid=279, on the effects of coffee in the prevention of degenerative diseases.

[29] Information presented here was collected from the website of CNPq Research Groups Directory (http://dgp.cnpq.br/buscaoperacional/detalhegrupo.jsp?grupo=00925014BKW6DN).

1975 the Embrapa Soja unit was created in Londrina, Paraná, which was dedicated to the””tropicalization” of the soybean, allowing the grain to be planted in low-latitude regions. The result was a revolution in the world soybean market, which has made Brazil one of the largest producers of this grain, currently only behind the United States.[30]

Embrapa Soja is a national and international reference in soybean research, and has developed pioneering technologies such as soil and fertility management. It has introduced biological nitrogen fixation by Rhizobium[31]; appropriate crop management for the different Brazilian ecosystems; integrated management of pests and weeds; biological control of the soybean caterpillar and the green stink bug, the most common pests attacking the crop; among others (Embrapa Soja, 2012).

30 "The importance of certain structuring agroindustrial chains that functioned as drivers and showcase for the process – like those of soybean, orange and poultry, whose consequences far surpass the effects of catching-up – must be highlighted. Soybean expansion in the 1970s is a case in point, which promoted land redistribution and enabled medium and small producers in the south of the country, mainly through the production of soybean and wheat in the same crop calendar. In addition to allowing effective catching-up with the United States and Argentina, it moved the agricultural frontier toward the center-west and center-north, and thus dramatically increased the Brazilian production potential. It managed to solve technological problems created by the extension of the border, cheapened production and pressed for the creation of an intermodal transportation network, resulting in cost reduction. Research on the Brazilian soybean emphasized biological nitrogen fixation in the soil, which reduced the use of fertilizers and made its continued expansion sustainable. Through the articulation of grain-bran-oil and grain-feed-meat chains, it contributed for the industry to offer more diverse and sophisticated food, not just more competitive, which was able to meet the new demands of consumers (functional foods, transgenic versus traditional versus organic food). In this sense, it enabled increased international competitiveness of the agri-food system. Finally, the development of new soy products and processes (soy ink, biodiesel, traceability, labeling) indicate its technological frontier" (Castro, 2007, p. 297). On the catching-up of agriculture and competitiveness of the agroindustrial chain of soybean, see Castro, A.C. (1996, 2009, 2010, 2011, 2012).

31 Döbereiner, Johanna – A Importância da Fixação Biológica do Nitrogênio para a Agricultura Sustentável, 1990, Embrapa CNPAB researcher in Seropédica, was a pioneer in research on nitrogen fixation by Rizhobium found in legumes, like soybeans. This characteristic of Brazilian soybeans not only affords it leadership in research, but, above all, results in unprecedented savings in "inside-the-gate" production costs.

The Genesoja Consortium was established in 2008 and comprises a specific research group in CNPq, gathering more than 50 researchers.[32]

Figure 4 – Institutions participating in the Soybean Genome Consortium

Source: www.scielo.br/scielo.php?pid=S1415-47572012000200001&script=sci_arttext#fig1

[32] Among the institutions participating in the Genosoja TC are: Embrapa Recursos Genéticos e Biotecnologia (Cenargen, Brasília, Distrito Federal), Universidade Estadual de Campinas (Unicamp, Campinas, São Paulo), Universidade Estadual Paulista Júlio de Mesquita Filho (Unesp, Botucatu, São Paulo), Universidade Federal de Pernambuco (UFPE, Recife, Pernambuco), Universidade Federal do Rio Grande do Sul (UFRGS, Porto Alegre, Rio Grande do Sul), Universidade Federal de Viçosa (UFV, Viçosa, Minas Gerais), Universidade Federal do Rio de Janeiro (UFRJ, Rio de Janeiro, Rio de Janeiro), as well as a private partner, namely Cooperativa Central de Pesquisa Agrícola (Coodetec, Cascavel, Paraná).

The Genosoja Consortium aims to facilitate the exchange of information, technology and knowledge generated for the soybean crop, benefiting not only the members of the consortium, but also the entire scientific community conducting research on the soybean crop, which is the main commodity of Brazilian agriculture. Among the objectives of the project is the identification and functional characterization of the soybean genes involved in important physiological processes of the plant[33]. In this sense, the studies of the Genosoja consortium aim to better understand the molecular mechanisms of the plant, seeking to enable the development of technologies that will lead to new alternatives in addressing the main problems limiting the exploitation of the crop, such as biotic and abiotic stresses, by means of studies with structural and functional genomics, transcriptomics and proteomics.

According to the coordinator of Genosoja, the consortium is a national arm of the international soybean genome consortium, which gathers Brazilian, American, Korean, Chinese and Japanese researchers. In this sense, it places Brazil in the high-end soybean research circuit. The genetics of soybeans, with approximately 66,000 genes, has been sequenced by the United States. However, very little is known about the function of each gene, and the challenge for the international consortium is to learn about these functions. Therefore, participating in this international consortium allows Brazil to be linked to numerous labs around the world researching the genes and characteristics of soybean, taking local specificities into account.[34] Even before the establishment of the Genosoja Consortium, a consortium for the study of soybean rust had been created by the Ministry of Science and Technology (MCT), with the support of MAPA. When the Technology Platform for the Study of Soybean Rust was created, involving

[33] Resistance to diseases, specifically Asian soybean rust and nematodes, drought tolerance, nitrogen fixation and grain quality.

[34] "Genosoja will be very important for the development of new cultivars related to these characteristics, not only for the members of the consortium, but for the whole scientific community working with the soybean crop, as all data generated will be made available to the public after the end of the project" (Agronline, 2012).

phytopathology, genetics, and biopathology, the consortium received funds from FINEP (Financier of Studies and Projects) from 2004 to 2010. After accomplishing the genetic sequencing of the soybean, the challenge has become the knowledge and mapping of gene functions, based on Brazilian and international research.[35] After identification of the genes linked to characteristics for the improvement of soybean production, research now aims to select some of these genes to pursue better understanding of the molecular mechanisms that can enhance soybean production. The Genosoja Consortium is divided into its components, including the management and handling of different aspects of the soybean genome (Benko-Iseppon; Nepomuceno; Abdelnoor, 2012):

I. Project management – responsible for organization, meetings, integration, and research reports.

II. Structural genomics – includes research on physical genomic architecture, analysis and sequencing of gene-rich regions, comparison with other wild relatives of the Glycine genus, synteny studies and indication of important regions for resequencing, identification of single-nucleotide polymorphisms (SNP), which are important for mapping and marker-assisted selection.

III. Transcriptomics – comprises the largest research group, responsible for approaches to different expression profiles, using strategies to access transcripts under different biotic (Asian soybean rust: *Phakopsora pachyrhizi*, CPMMV: *Cowpea mild mottle virus*, nematodes: *Meloydogyne javanica* and *Pratylenchus brachyurus*) and abiotic (hydric stress) factors. Strategies used: a) subtractive cDNA; b) SuperSAGE; c) microRNA libraries; d) cDNA sequences of roots infested with the nematode *M. javanica* compared to stressed control.

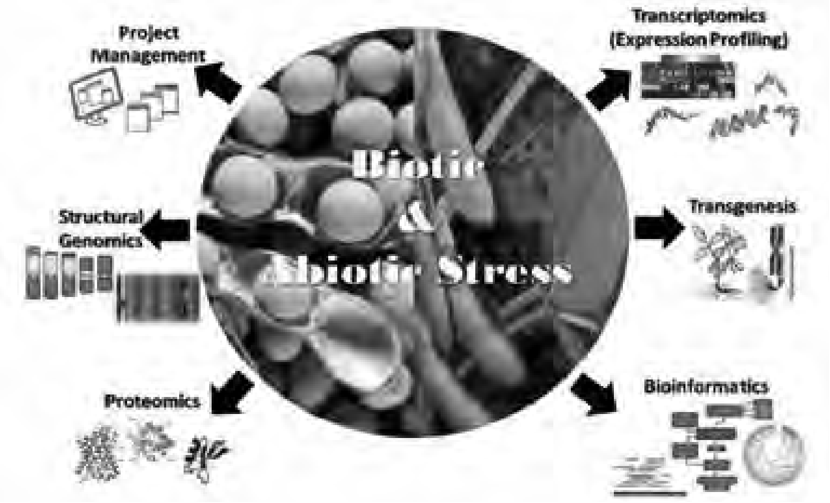
IV. Proteomics – profile of soybean protein, low protein mass and identification of peptides and protein-protein interactions.

[35] The Genosoja Consortium began with CNPq funding resources amounting to R$ 6 million, plus R$ 2 million in counterparty funds from Embrapa, through the Embrapa Network for Soybean Genome Studies (Regesoja).

V. Expression assays (transgenics) – considering results of transcriptomics and proteomics: valuable genes are being transformed.

VI. Bioinformatics – Genosoja database, tools integrating project data, comparison with sequences available in public databases of other research projects.

Figure 5 – Functional organizations of the Genosoja consortium



Source: www.scielo.br/scielo.php?pid=S14154757201200020001&script=sci_arttext#fig1.

If, on the one hand, Genosoja has a specific role within genetics-based research on the soybean crop, for which it gathers different Brazilian research institutions, on the other hand it is coordinated by Embrapa Soja, which keeps numerous other partnerships in soybean research. In this context, Genosoja is included in a broader collaborative knowledge platform, managed by Embrapa Soja.

Ridesa[36] and Embrapa Agrobionergia

The Brazilian Federal Government has a minor role in the field of sugarcane, especially after the termination of the National Sugarcane Improvement Program (Planalsucar)[37], in the early 1990s, when its activities were absorbed by| Ridesa (FURTADO, 2008)[38]. Ridesa is a successful example of networking for the technological advancement of sugarcane seed production. The public-private partnership involves more than 300 companies producing sugar, ethanol and energy, as well as nine Brazilian federal universities.[39]

Ridesa was established in 1991,[40] located in areas of operation of Planasucar coordinations, from which it absorbed staff and headquarter and experimental station facilities, including university professors.

[36] Information from the website <http://www.ridesa.com.br/?pagina=home>.

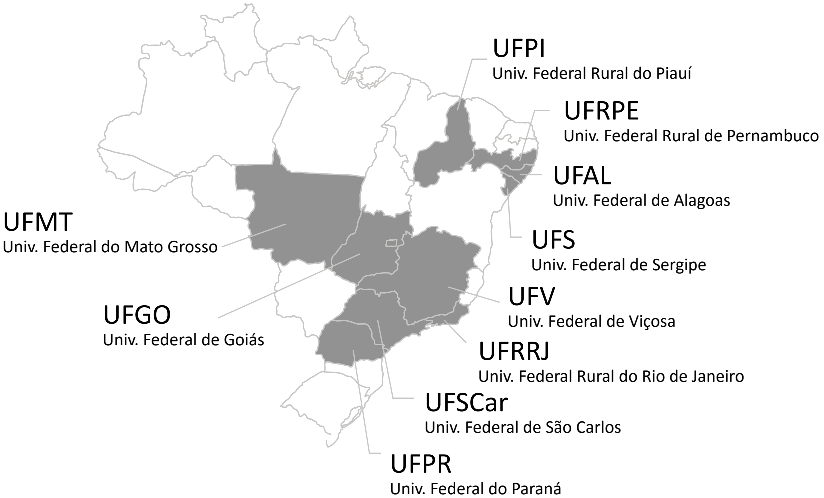
[37] The National Sugarcane Improvement Program (Planalsucar) has had as many as 30 experimental stations throughout the country, making significant contribution to the improvement of sugarcane productivity in the Northeastern states (FURTADO, 2008).

[38] It is clear, however, that the main sugarcane research center in Brazil is the Sugarcane Technology Center (*Centro de Tecnologia Canavieira*, CTC), which is a private institution. To learn more about this institution, as well as other groups investing in research in the sugarcane industry, see Vieira Júnior, Buainain, Silveira and Oliveira (2009).

[39] Because Ridesa is exclusively devoted to research on sugarcane, it is the interest of Embrapa Agroenergia to establish a partnership with this network to enhance its research focused on sugarcane.

[40] Initially through an agreement signed between seven federal universities: Universidade Federal do Paraná (UFPR), Universidade Federal de São Carlos (UFSCar), Universidade Federal de Viçosa (UFV), Universidade Federal Rural do Rio de Janeiro, Universidade Federal do Sergipe (UFS), Universidade Federal do Alagoas (UFAL), and Universidade Federal de Pernambuco (UFPE).

Figure 6 – Functional Organizations of Ridesa[41]



Source: http://pmgca.dbv.cca.ufscar.br/htm/pmg/histor.php.

Ridesa is responsible for creating clones of sugarcane seedlings from seeds produced in its germplasm bank, where over two thousand genotypes are registered, including cultivars in the country, clones, and different species imported from different sugarcane producing regions in the world. Cultivars under the acronym "RB" – once produced by

[41] In 2015, Ridesa completed 24 years. The institution includes 31 research stations in states where the sugarcane crop is more significant, including Paraná, Mato Grosso, São Paulo, Goiás, Minas Gerais, Rio de Janeiro, Sergipe, Alagoas and Pernambuco. The network also develops research in experimental areas linked to the nine universities that are parties to the agreement, especially in graduate courses. These universities emphasize the Sugarcane Genetic Improvement Program (*Programa de Melhoramento Genético da Cana-de-Açúcar*, PMGCA), which uses the acronym "RB" to identify its cultivars, having released 65 cultivars. In 2004, Ridesa added Universidade Federal de Goiás and in 2007, Universidade Federal de Mato Grosso, strengthening its research structure, creating three new experimental stations for the *cerrado*: one located in Goiânia (GO), belonging to UFG, and another in Cuiabá (MT), belonging to UFMT. A third experimental station in Capinópolis (MG), belonging to UFV was also aggregated, and its works began as early as 2003. Data from Ridesa indicates that the network manages about 80 varieties of sugarcane cultivars, which were patented in the name of Planasucar and, today, in the name of the member institutions directly responsible for the technology developed (including UFSCar, UFAL UFRPE, UFRRJ, UFPR and UFV).

Planalsucar and now by Ridesa – have good market, and estimates are that they are grown in more than 50% of the area with sugarcane crops in the country, representing up to 70% of the planted area. Data presented by Ridesa (2012) shows the breadth of technological results achieved in the context of research on the sugarcane crop and the importance of partner institutions.[42]

Embrapa Agroenergia

The resumption by the Brazilian government of research on sugarcane through EMBRAPA is a recent development taking place in the context of a paradigm shift for the Corporation, namely gearing its research to the production of biomass for energy, not only food, production[43]. This new orientation is due to the current scenario of energy shortage, caused by the end of the fossil fuel era due to a reduction in oil, coal, and natural gas reserves (Embrapa Agroenergia, 2008, p. 7).

In 2006, MAPA launched the National Agroenergy Plan and established guidelines for public and private actions to generate knowledge and technologies for sustainable agriculture for energy production and the rational use of renewable energy. Thus, it stimulated the creation of Embrapa Agroenergia, under the name

[42] The germplasm bank is located in the Serra do Ouro Flowering and Crossing Station (UFAL), in the municipality of Murici, state of Alagoas. In gathers over 2000 genotypes including cultivars used in the country, clones and different species imported from different sugarcane producing regions in the world.

[43] According to Rufino (2006, p. 82), , since its establishment in 1974, so as not to duplicate actions and dilute existing resources, Embrapa has not included in its program research on coffee, sugarcane and cocoa, since these crops had their own research institutes, respectively, the Brazilian Coffee Institute (*Instituto Brasileiro do Café*, IBC), the Sugar and Alcohol Institute (*Instituto do Açúcar e do Álcool*, IAA) and the Executive Committee of the Cocoa Crop Plan (*Comissão Executiva do Plano da Lavoura Cacaueira*, Ceplac), linked to the Ministry of Industry and Commerce. With the extinction of these three institutions for political reasons, in 1991, and also considering its administrative and financial commitments, Embrapa did not take over the duties of knowledge and technology generation for these three production chains.

National Center for Agroenergy Research (*Centro Nacional de Pesquisa de Agroenergia*, CNPAE)[44].

In the Brazilian agroenergy scenario, the sugarcane crop is a major focus of research. According to Embrapa Agroenergia (2008, p. 23), competition with other institutions working for the improvement of this crop may inhibit the advancement required for the expansion of its agribusiness. Among the opportunities for technological cooperation, the company proposes to establish, in partnership with its units, Ridesa and other institutions, the conceptual basis for the consolidation of a new public program for the improvement of sugarcane in the country (Embrapa Agroenergia, 2008, p. 26). The organization of an institutional arrangement promoting closer links between institutions working with sugarcane in Brazil and optimizing their research is, at the moment, a great challenge to be overcome.

Considering the issue of sugarcane, there is strong demand for the creation of a specific unit within Embrapa, which is also expressed in debates of the Sectorial Chamber of Sugar and Alcohol, mostly from Northeastern groups. [45] A fact that has pushed for the demand is that Alagoas is the only Northeastern state that does not have an Embrapa unit and where Ridesa's germplasm bank is located. During our interviews, we have observed that there is no actual mobilization

[44] According to Embrapa Agoenergia (2008, p. 9), the National Center for Agroenergy Research (CNPAE – Embrapa Agroenergia) was established by Board Resolution No. 61 of 24 May 2006 (BCA No. 25 of 29.05. 2006) as a unit of Embrapa's decentralized structure, for the development and promotion of innovation and technology transfer. These technologies advance towards sustainability and competitiveness for agroenergy chains. This is the 41st Decentralized Unit of Embrapa, and its 38th Research Center, fitting into the category of thematic center and operates throughout the national territory. Embrapa Agroenergia involves four working platforms: Ethanol, Biodiesel, Energy Forests and Byproducts and Waste Materials, whose concern is to promote the improvement of raw materials, processes of biomass conversion into energy, and the forms of energy obtained, thus ensuring scientific and technological competitiveness and integration of Embrapa's responsibilities.

[45] The Brazilian union of sugar producers has recently ceded an area next to UFAL for extension of Embrapa's existing experimental field. This field is currently linked to Embrapa's Coastal Tablelands unit, in Sergipe, and is within the area belonging to UFAL, in the capital city of Alagoas.

within the Company for this to occur, given that the units prioritize the cross-sectionality of research topics, which does not point towards the building of another product-focused unit.

Table 1 – Characteristics of the TC and network institutional arrangements for soybean, coffee and sugarcane in Brazil

Characteristics	Soybean	Coffee	Sugarcane
Research-oriented institutional arrangement	Genosoja/Embrapa Soja	Coffeee Technology Consortium/ Embrapa Café	Ridesa
Year of creation of the consortium or network	2007	1997	1991
No. of institutions involved	9	+ 50	9
Public institutions involved	Embrapa Soja, Embrapa Cenargen, UFV, UFRGS, UEP, UFPE, Unicamp, UFRJ, UFPR	EBDA, Epamig, IAC, Iapar, Incaper, Pesagro-RJ, Universidade UFLA, UFV, Embrapa and MAPA	UFPR, UFSCar, UFV, UFRRJ, UFS, UFAL, UFPE, UFG and UFMT
Private institutions involved	Coodetec (Cascavel, PR)	-	300 companies in public-private partnerships
No. of Brazilian researchers involved	50	1300	-
Scope	National and international Genosoja project	National and international	National
Coordination	Embrapa Soja (Londrina/PR)	Embrapa Café (DF)	Alternated between the institutions involved
Institutional mechanism for the debate of policies for the sector	Sectorial Chamber of the Soybean Productive Chain	Coffee Policy Deliberative Council	Sectorial Chamber of the Sugar and Alcohol Production Chain

Source: Prepared by Sílvia Zimmermann.

Preliminary Conclusions

It can be considered that Brazil is at low-carbon tropical agriculture frontier and Embrapa has played a central role in this process. The historical path which, since the 1950s, has led the country from technological catching-up to its current position at the knowledge frontier was not the object of this work. By taking a position at the technological frontier, the country weighs the risk and benefits of defining its own frontier. Knowledge governance in the knowledge networks and markets has been decisive for the attainment of this position in technical terms. This is the case of the coffee, soybean and sugarcane innovation platforms, which are institutional arrangements favoring innovation.

These complex structures redefine old concepts like technological catching-up: there is no longer a roadmap to be followed, and leapfrogging is the only alternative; leading countries may be peers/ partners; the concepts of secondary innovation, open innovation and cooperative networks are new ways of delivering innovation, which contributes to the deconstruction of the concept of catching-up.

There is still great uncertainty regarding what may be considered "superior" innovation, as tensions must be accommodated between formerly foreign goals in the innovative territory (e.g. social inclusion and sustainability). Another understanding derived from this discussion is that this depends on strategic choices, as well as on the conditions to implement them.

In a recent article in compared state capabilities, which compared the institutional architecture of science and technology in Brazil and China, the conclusion was: "the existence of a structured consensus on which sectors should receive incentive from the entrepreneurial State, where the technological frontier lies in these sectors, and which countries have reached it, depends on: *i)* the backing of institutions capable of carrying out prospective and retrospective studies actually considered in the decision-making process; *ii)* undertaking of continuous technology prospecting, subject to periodic review processes; *iii)* ability to take conflicts of interest into account, but also to neutralize them in the building of structured consensus; and, finally, *iv)* a deep-rooted and effective financial system for innovation. Two conditions seem essential for coordination of national modernization processes: structured vision for the future and state capabilities for their implementation. This does not refer to a continuum of skills or capabilities, but to a range of decision-making processes on long-term strategies, as well as coordination in the design and implementation of technology policies" (Castro, 2015, p.3).

In order to examine decision-making processes, it is paramount to consider: the relationship between decision makers and funders – research institutes, think tanks, universities, and others – or the institutional backing of strategic decisions; whether or not there is an effort towards a prospective view of technology; governance structures and power relations, where possible; and conventions, shared beliefs and consensus behind visions for the future and influencing the path taken and choices made.

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