

URBAN CENTRALITY IN A TERRITORIAL SYSTEM OF AGRICULTURAL INNOVATION

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Abstract

Agricultural production is distributed across a large portion of Brazilian territory, and the frontier continues to increase. Nevertheless, the same does not occur with the mechanisms involved in the production of scientific knowledge. The aim of this paper is to discuss how the discontinuities between agricultural production and the networks of scientific knowledge lead to a particular type of urban centrality. Therefore, the work is supported by the conceptual basis of a territorial system of agricultural innovation (STIA) in order to situate the urban phenomenon within the innovation process of agriculture in an ensemble of political, economic and social relations. Using data from components of the STIA, the aim is to create an index that indicates the most representative cities in creating and adapting agricultural knowledge. Based on the results obtained, a research agenda is proposed surrounding the urban and regional processes associated with innovation in Brazilian agriculture.

Keywords

Urban Centrality; Knowledge Networks; Agriculture; Regional Inequalities; Territorial Innovation System.

CENTRALIDADE URBANA EM UM SISTEMA TERRITORIAL DE INOVAÇÃO AGRÍCOLA

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Resumo

A produção agrícola está distribuída em ampla parcela do território nacional e sua fronteira continua em expansão. Contudo, o mesmo não ocorre com os mecanismos de reprodução do conhecimento científico. Este artigo tem como objetivo discutir como as descontinuidades entre a produção agrícola e as redes de conhecimento científico criam um tipo particular de centralidade urbana. Para tanto, apoiamo-nos em uma base conceitual de um sistema territorial de inovação agrícola (STIA) para situar o fenômeno urbano no processo inovativo da agricultura em um conjunto de relações políticas, econômicas e sociais. Pautamo-nos em dados sobre componentes do STIA com vistas a formular índices que identificam as cidades mais representativas para a criação e a adaptação de conhecimento agrícola. Com base nos resultados obtidos, é proposta uma agenda de pesquisa em torno dos processos urbanos e regionais associados à inovação na agricultura brasileira.

Palavras chave

Centralidade Urbana; Redes de Conhecimento; Agricultura; Desigualdades Regionais; Sistema Territorial de Inovação.

URBAN CENTRALITY IN A TERRITORIAL SYSTEM OF AGRICULTURAL INNOVATION¹

Fernando Mesquita

Introduction

Throughout the twentieth century and at the beginning of the twenty-first, Brazilian agricultural production was guided by scientific and technical standards that enabled increased productivity and an expansion of cultivated areas across the national territory. Thus, many regions – some previously dominated by natural vegetation, others inhabited by small producers, others still based on extensive cattle raising – became transformed into expansion areas of highly-capitalized large-scale production. However, as we intend to demonstrate, if, on the one hand, crops and pastures that required science and information (SANTOS, M., 2010) began to occupy a large portion of the national territory, on the other, this did not occur with the reproduction mechanisms of knowledge, which enabled this expansion.

Within this context, the aim of the article is to discuss how a particular type of urban centrality has been created in Brazil, resulting from the discontinuities between agricultural production and networks of scientific knowledge.

We begin from the idea that control over the reproduction apparatus of scientific knowledge guarantees an urban centrality (SHEARMUR; DOLOREUX, 2015), and that this leads to some centers exercising the power of command (FERNANDES; SABINO; PIMENTEL, 2021) related to the capability of intervening

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in the scientific-technical pattern of agriculture. This centrality operates on two levels: one, of greater complexity, which has the potential of advancing in the predominant knowledge in the productive sphere; another, less complex, aimed at adapting technologies to edaphoclimatic conditions different to those in which they have been conceived. From this division, two types of urban centrality derive: one concerning the creative capability, and the other concerning the adaptive capability. In order to identify the most representative cities in each case, we have formulated two indexes anchored in the aggregation of indicators from the education system and in research from the area of agricultural sciences, as well as on the qualification of agricultural jobs and on the commitment of producers in attracting knowledge. We propose the notion of a Territorial System of Agricultural Innovation (referred to in Portuguese as STIA), based on applying the study of territorial systems of innovation (FERNANDES, 2016) in agriculture, as a tool to situate the relationship between city and agricultural innovation in a broader ensemble of political, economic and social relationships. Based on this theoretical-methodological proposal, we present a research agenda involving the links between innovation, agriculture and territory.

In addition to this introduction, the article covers four other topics. The first explains the notion of the Agricultural Innovation System (referred to in Portuguese as SIA) as a mechanism for identifying the agents and interactions present in the innovation process of agriculture. Following on, the notion of an STIA is presented as a manner to incorporate power disputes and the importance of the urban phenomenon in terms of the SIA approach. Anchored in the STIA study, the methodological proposal is approached, providing justification for the indicators used to measure the capability for creating and adapting knowledge. The results are then discussed and, in the final considerations, we present the research agenda made available by incorporating the territorial dimension into the SIA studies.

1. The Agricultural Innovation System in Brazil

Between 1970 and 2017, agricultural production in Brazil grew by 3.2% per annum (p.a.), while the use of inputs grew by around 1.2%. This capability for production to obtain a higher growth rate than that involving the use of inputs reflects an increase in efficiency that is expressed in land productivity, which has grown 3.0% p.a.; in labor, which has increased 3.2% p.a.; and in capital, with a growth of 2.7% p.a. The regions with the greatest increase in productivity were the Central West Region – where land productivity grew 5.5% p.a., labor, 5.7% p.a., and capital, 5.4% p.a. – and the South Region – with an increase of 3.6% p.a. in land productivity, 3.9% p.a. in labor and 2.8% p.a. in capital (GASQUES *et al.*, 2020).

This increase in productivity is not explained by the individual capacity of rural producers, but rather by their integration into an SIA (BONACELLI; FUCK; CASTRO, 2015). The notion of SIA uses the concept of innovation systems – which associates inventions, innovations and dissemination with the collaborations and interdependencies of a set of agents whose decisions and whose behavior (as an incentive or as a block to the innovation process) are shaped by the institutional apparatus (EDQUIST, 2004) – to carry out an analysis of the agricultural innovation process. As Suzigan and Albuquerque (2008) indicated, despite the adverse conditions of Brazil's economic formation, some sectors have managed to achieve greater success in the articulation between national scientific research and the productive segment, such as the sciences of health, aeronautics, and mining, materials and metallurgical engineering and the sciences of agriculture and forest engineering.

The initial moments of SIA in Brazil may be dated back to 1803, the year in which the Botanical Garden was installed in Rio de Janeiro by Dom João VI, as well as from 1859 and 1860, with the initiatives to rationalize agriculture implemented by Dom Pedro II, who created imperial institutes in the provinces of Bahia, Rio de Janeiro, Pernambuco, Sergipe and Rio Grande do Sul with the purpose of organizing agricultural experiments and teaching (RODRIGUES, 1987a). However, these initiatives proved ineffective, given that the abundance of land, land concentration and slave labor relations enabled an increase in agricultural production without changing the technical base (FURTADO, 1972). Therefore, it is common for the genesis of the SIA to be associated with the foundation of the Agronomic Institute of Campinas (IAC), in 1887 (BONACELLI, FUCK; CASTRO, 2015). This is the moment when there was a greater link between research – with the analysis of experiments on planted varieties to improve agricultural practices (ALBUQUERQUE; ORTEGA; REYDON, 1986) – and the productive sector, commanded by the coffee economy towards the west of São Paulo.

The SIA became more complex over the course of the twentieth century as agriculture accompanied the ongoing transformations across the country. Urbanization intensified demand, causing many rural economies, previously focused on self-consumption or a regional market, to focus on serving rapidly expanding cities (SZMRECSÁNYI, 2007, p. 144). At the same time, there was a broader integration of agriculture and industry, either with the machinery and equipment sector, upstream, or with the processing sector, downstream (SZMRECSÁNYI, 2007). Under these conditions, agricultural research not only became diversified (with the growth of new areas, such as phytotechnology, animal science, animal and plant pathology), but was also rationalized around the needs of food production and the

generation of foreign exchange for the process of import substitution (RODRIGUES, 1987b). With a strong role played by the State, new agents joined the SIA, with emphasis on the Brazilian Agricultural Research Corporation (EMBRAPA). Created in 1973, Embrapa promoted an institutional reorganization in the SIA through its work in genetic improvement and management research, in order to transform the Cerrado regions, the Humid Tropics and the Semiarid Region into arable land, by seeking to link research efforts with the states, especially with the State Technical Assistance and Rural Extension Companies (EMATER), through interaction with universities, in order to promote training and qualifications for the workforce, and through an attempt to create a modernizing ideology in the producers (ALVES, 1980; FRONZAGLIA; GONÇALVES, 2006).

During the 1990s, a new configuration of the SIA was introduced with the advance of neoliberalism. Brazil became the target of investments from a highly concentrated, international private sector, which operated in the chains of agricultural and research inputs. In 2009, the four largest research groups in the areas of chemical pesticides, seeds/biotechnology, animal health and agricultural machinery held more than 50% of the international market share (FUGLIE; TOOLE, 2014). Multinational groups, such as Bayer/Monsanto, Syngenta, Dupont and Dow AgroSciences, began to work in the Brazilian SIA and, as a result, shifted part of the research previously carried out in the public sphere, especially with Embrapa, towards the private. This change was more intense in crops, such as soybean, maize and cotton. Fuglie *et al.* (2019) have indicated that the percentage of spending on research by the private sector in the agricultural area in Brazil jumped from 2.9% in 1995 to 14.4% in 2013.

Using the publication of scientific articles as an indicator for the production of knowledge in agriculture, Table 1 demonstrates that universities and public research centers continue to be central agents in the SIA.

The study of the territorial configuration of the SIA refers to the search in order to capture the interactions between science and the productive segment, taking into account the different capabilities to produce knowledge throughout the regions of the country and “the transformations across the territory introduced by the widespread use of technology” (FERNANDES, 2016, p. 115)². We propose to identify the city-countryside relationships and the power disputes in order to scale the urban centralities involved in agricultural growth and productivity. For this, more than one SIA, we propose a reflection involving one STIA.

2. This and all non-English citation hereafter have been translated by the author.

Agents	No.	%
Universidade de São Paulo (USP)	30,019	9.8
Universidade Estadual Paulista (Unesp)	21,481	7.0
Empresa Brasileira de Pesquisa Agropecuária (Embrapa)	20,255	6.6
Universidade Federal de Viçosa (UFV)	13,621	4.5
Universidade Estadual de Campinas (Unicamp)	9,768	3.2
Universidade Federal do Rio de Janeiro (UFRJ)	9,036	3.0
Universidade Federal do Rio Grande do Sul (UFRGS)	8,507	2.8
Universidade Federal de Lavras (Ufla)	8,328	2.7
Universidade Federal do Paraná (UFPR)	8,223	2.7
Universidade Federal de Santa Maria (UFSM)	6,805	2.2
Universidade Federal de Minas Gerais (UFMG)	6,786	2.2
Universidade Estadual de Maringá (UEM)	5,467	1.8
Universidade de Brasília (UnB)	5,080	1.7
Universidade Federal Rural de Pernambuco (UFRPE)	4,829	1.6
Universidade Federal de Santa Catarina (UFSC)	4,765	1.6
Other agents	143,135	46.8
Total	162,970	100.0

Table 1. The largest centers in relation to publications in the area of agriculture and biological sciences (accumulated total for 2000 and 2021)

Source: Scopus (2021).

2. A Territorial System of Agricultural Innovation

Milton Santos (2010; 2014) emphasized that the relationship between science, technology and information as the basis for the production, use and functioning of space is not restricted to large cities, but underlies the transformation of the rural environment. Competitiveness within a context of globalization broadens the installation of a scientific agriculture, the rationality of which requires a geographical environment based on the logic of a technical-scientific and informational milieu (SANTOS, M., 2010). The reproduction of this milieu in the Brazilian rural areas was only possible as a result of the internalization of part of the scientific and technological command of agriculture, as expressed in the notion of the SIA.

By arguing for the need to consider the STIA, we are following the thinking of Fernandes (2016, p. 132), for whom innovation systems may not be conceived “only as a space for the interaction of components such as companies, universities and government aimed at the production of new products and processes for commercial purposes”. They should be understood as a conflicting field of interests and

disputes over knowledge that opposes, on the one hand, the production of profits and territorialities for hegemonic agents and, on the other, the opportunities to have science as a support for horizontal solidarities (FERNANDES, 2016).

This dispute operates in the context of conflicts in Brazilian agriculture. The political and economic weight of agribusiness signifies that a major portion of scientific research is associated with the interests of these groups. As Oliveira (2016) commented, agrarian researchers become partners in business to reduce the cost-benefit ratio of companies. Technology enables new areas to be occupied across the national territory and the guarantee of control over space by large producers. Furthermore, an increase in private research may aggravate inequality throughout the Brazilian countryside, by reducing the access of small producers who are unable to bear the costs of contracting such services. Although, in Brazil, this is the dominant configuration, other uses for science in agriculture are also possible. One example: the genetic improvement developed by Embrapa Algodão to create naturally colored cotton varieties adapted to the requirements of the textile industry, a use that mostly served small and medium producers in the Northeastern Semiarid Region (LIRBÓRIO, 2017).

Along with the political dimension, reflection on the STIA should emphasize the “importance of cities for the innovative process and of the articulation between city, region and technology” (FERNANDES, 2016, p. 115). Modern agriculture, as explained by Corrêa (2006), involves a set of relationships between the countryside and the city, as in the migratory process resulting from a reduction in the need for agricultural labor; the need for rural producers to interact with bank branches to fund production; the interactions between industry and agricultural production; and, as we will highlight, the continuous need for the countryside to obtain innovations that enable the modernization of the agricultural production system (SCHULTZ, 1965).

The sources of the innovation process in agriculture are located in cities, which is understood as the locus for creating new agricultural work (JACOBS, 1969). These sources may be in the upstream (machinery, fertilizers, seeds and pesticides) and downstream (agribusiness) industrial segment, with competitive pressures for changes in production patterns, and in the centers that conduct and fund the research (POSSAS; SALLES-FILHO; SILVEIRA, 1996). However, it is necessary to be cautious and to recognize that the importance of cities in agricultural innovation does not reduce the countryside to a merely passive function. As Vieira Filho (2018) mentioned, although it may start as a process outside the farms, innovation will become incorporated within the productive units, demanding feedback that may change technologies.

The interdependence between countryside and city is also expressed by the need for agricultural innovation to dispense with a combination of knowledge (MESQUITA; LUNA; SOUZA, 2021). On the one hand, knowledge produced in an abstract, based on the principles and laws of nature, whose learning depends on what Lundvall (2016) treated as *know-why*, are mainly located on cities. On the other hand, practical knowledge, obtained by observing and experiencing natural phenomena particularities of each location, defined by the same author (2016) as *know-how*, depends on the relationship with the countryside.

Our argument is that, because of the way it has been inserted into the territorial division of labor, which conditions the growth of agriculture, each city has a particular role in the agricultural innovation process. In order to operationalize this idea, we discuss two types of centrality. The first is characteristic of urban centers inserted into Jacob's principle of producing new work. For this, the city needs to have a knowledge infrastructure based on the presence of universities with postgraduate courses and research centers and on the existence of a job market that potentializes local face-to-face interaction (STORPER, 2013); to rely on scientific instruments that offer ways with which to know and enable a better relationship between material and human resources (SANTOS, M., 2014); to demonstrate the ability to mobilize financial resources to foster scientific research (SANTOS, M., 2014); and to have managed to accumulate learning and experience over time (KATZ; IIZUKA; MUÑOZ, 2011). We refer to this centrality from the perspective of a creative capability for knowledge in the STIA. Another type of urban centrality is formed in cities with a less complex knowledge infrastructure, with technical assistance services and universities with only undergraduate courses, which enable the promotion of adaptive learning (KATZ; IIZUKA; MUÑOZ, 2011). Although they exert less influence on innovation, these urban centers support the diffusion of technologies, when modifications are necessary to make them profitable in new edaphoclimatic environments (ROSENBERG, 1976). This type of centrality will be contemplated here through the idea of an adaptive capability of knowledge in the STIA.

Having contextualized the urban centrality in this theoretical axis, we move on to the methodological aspects that support the identification of the most representative cities within their functions in STIA.

3. Elements for identifying urban centrality in the STIA

The methodology is based on the creation of two indexes that aim to identify which cities fit into the types of centrality related to the creative and adaptive capabilities.

Following the idea that centrality is associated with a combination of STIA components, the indices have been created by grouping indicators that, when they appear in the same municipality, expand the final result. We use the procedure developed by Ester Santos (2011), to transform a set of indicators into values between 0 and 1, “with the aim of providing information on the same scale” (SANTOS, E., 2011, p. 411). These values were transformed by calculating the maximum and minimum values obtained through the following formula:

$$I_{ij} = \frac{X_{ij} - X_{ij} \text{ mín}}{X_{ij} \text{ máx} - X_{ij} \text{ mín}}$$

where: I: the indicator to be transformed into values of between 0 and 1; X: the values observed by the indicator; X_{mín}: the minimum value observed; X_{máx}: the maximum value observed; i: each indicator; j: each municipality.

We have used eight indicators: four for the creative capability index and four for the adaptive capability index. We have attributed values to 5,564 Brazilian municipalities. The grouping of indicators has been undertaken based on the calculation of a weighted average. Lastly, the closer the value of the municipality is to 1, the greater its centrality; the closer to 0, the lower its centrality.

In order to identify the creative capability, indicators referring to the presence of three STIA agents were used: i) universities with postgraduate programs (PPGs) in the areas of agrarian sciences³; ii) public and private research centers; and iii) agricultural producers with a potential to interact with the research.

Universities are central to the STIA as they are home to a highly qualified body of scientists who work with the training of researchers and technicians. As Fuglie et al. (2020) argued, for a more efficient participation in the development of agriculture, universities need to have research programs. In the Brazilian case, as revealed by Garcia et al. (2018), after engineering, agrarian sciences represent the areas in which research groups have more interactions with companies.

So as to incorporate the postgraduate system in agricultural sciences into the index, open data were used from Capes – the Coordination for the Improvement of Higher Education Personnel (CAPES, 2021a). We conducted this study on two levels, considering the provision of the service in the municipalities. In the first, we have

3. Following the division established by CAPES, the area of agricultural science is understood as a set of sub-areas of agronomy, forest resources and forest engineering, agricultural engineering, animal husbandry, veterinary medicine, fishery resources and fishing engineering and food science and technology.

identified postgraduate courses, considering both master's and doctoral degrees. The greater the number of courses, the greater will be the exchange of knowledge at that particular location, a key factor in creating new knowledge. The second level refers to a quality attribution. For this, we identified the total number of postgraduate programs with a grade 6 or 7 in the CAPES⁴ assessment. These are the programs that have achieved the best scores, taking into account: i) the program, mainly in terms of lines of research, projects, curriculum structure, infrastructure and the profile of the faculty; ii) training, especially in reference to the quality of theses and dissertations and the intellectual production of students and graduates; and iii) the impact on society, caused in particular by the innovative nature of the intellectual production (CAPES, 2021b).

In addition to universities, agricultural research centers, both public and private, are essential in the creation of knowledge, acting more directly in applied research in the productive sector. The strategy for locating research centers may follow a sectorial logic, with the development of research on specific crops; regional, in order to recognize the potential of the region; or thematic, with studies in lines that affect agriculture horizontally. In all cases, choosing a city to host a research center strengthens its centrality, since they are planned to work in the region or in partnership with other research units and producers throughout the country.

To identify the locations carrying the greatest weight in agricultural research centers, formal employment data from the Annual Social Information Report (RAIS), linked to the Ministry of Economy (ME) (BRASIL, 2021a) were used. Through the Brazilian Job Classification Index (CBO) in this database, we selected the class of researchers in agrarian sciences. The idea was that the municipalities with a higher number of these professionals indicate the location of research centers in the STIA.

The third agent that we consider central to the creation of knowledge is the agricultural producer. The inclusion of this indicator is justified by our understanding that the countryside does not remain passive in the production of knowledge. Farmers may be a central interaction, due to discoveries that are made through practices on the farms, the strengthening of partnerships, or the concession of land for experimental fields. As Brazilian agriculture is highly heterogeneous and not all producers present the same behavior with regard to adopting new practices (PAIVA, 1971), a method was needed, which was capable of distinguishing those who are more engaged with scientific research. For this, we used the RAIS with the aim of selecting workers in the agricultural activity who are identified, by the CBO, in the following classes: production and operations

4. The data used refer to the years 2017 to 2019, which represents partial data from the CAPES assessment period of the 2017-2020 cycle (when the quadrennial evaluation must be completed).

managers; mathematicians, statisticians and similar; computer professionals; physicists, chemists and similar; engineers, architects and similar; biologists and similar; and agronomists and similar⁵ (BRASIL, 2021a). The high number of these professionals working directly in agricultural production indicates a more dynamic productive segment, with greater potential for interaction in the STIA. For this indicator, the total of the municipality was considered equal to the total of its immediate region. The justification for this is that, although geographic proximity to producers is important, it is established at a level that goes beyond the municipal level. This option may be understood as a manner of recognizing the significance of the region in the centrality of the municipality.

To identify the municipalities with the greatest capability for adapting knowledge in agriculture, indicators were used that referred to undergraduate courses in the area of agrarian sciences, technical assistance services and producers using technical guidance.

The offer of undergraduate courses refers to an analysis of the role of universities in the STIA as trainers of qualified labor. Municipalities with a wide offer of undergraduate courses and with PPGs are prominent for both their creative and adaptive capabilities, while municipalities with undergraduate courses, but without PPGs, are outstanding only for their adaptive capability.

To incorporate this indicator into the index, we undertook a two-level analysis. First, by the number of students enrolled on undergraduate courses in areas related to agrarian sciences. This data indicates the available vacancies in the municipalities. The second level, as in the case of the PPGs, refers to a quality attribute of the courses. In this case, the number of courses related to agricultural sciences with grades 4 and 5 in the National Student Performance Exam (ENADE) was considered. Data for these indicators were obtained from the Anísio Teixeira National Institute of Educational Studies and Research (Inep) linked to the Ministry of Education (MEC) (BRASIL, 2021b).

A central component of the STIA for adaptive capability is the rural assistance and extension service, as practiced by Emater. Castro and Pereira (2017, p. 9) indicated that technical assistance acts as an interlocutor “between farmers and institutions that generate innovation for agriculture”. As a way of incorporating this component into the index, using CBO, we identified the volume of agrarian technicians in the municipalities. These workers deal with issues related to the

5. These professions are part of the following groups: managers; professionals in the exact, physical and engineering sciences, as well as professionals in the biological, health and related sciences. Within this group, we selected the classes that, to our understanding, are most associated with the development of technologies in agriculture.

application of the product, the way in which they are applied and the dose to be applied (CASTRO; PEREIRA, 2017). This requires the development of knowledge regarding the particularities of the location. The municipalities with the highest number of these professionals are seen as the most relevant in terms of providing rural extension and technical assistance services.

Agricultural producers are also essential for the capability of adapting. In this case, the most relevant aspect is how they use technical guidance, which makes it possible to identify where the ties with services of this type are more intense. For this analysis, we used the declarations made by rural landowners to the Agricultural Census (IBGE, 2021), informing whether or not they receive technical guidance. As with incorporating producers into the knowledge creation index, we consider the data for municipalities as the same for their immediate region. The reasons are those presented for the inclusion of producers in the index referring to the creative capability.

With regard to the time frame, we chose to use the most recent year available on the databases. With this, the analyzes were undertaken for 2019, with the exception of students enrolled on undergraduate and technical guidance courses, made for the year 2017. It is our understanding that this change in the period is not a problem, since few changes will occur in these requirements during a two-year period.

For the final value, the weighted average was adopted. Indicators related to producers received weight 1, because they were analyzed regionally, and the other indicators were assigned weight 2, because they are more linked to urban centrality.

Chart 1 outlines the procedure adopted to compose the indexes related to the creative and adaptive capacities of knowledge in agriculture. We use the indices as a way to capture three levels of centrality: i) for cities that have both creative and adaptive capabilities; ii) for cities with creative capability only; and iii) for cities with adaptive capability only. These rankings were created for cities that achieved a mean score of above 0.20 in the knowledge creation and adaptation indices. In this regard, 43 cities were outstanding: 12 are in the first type of centrality; 2 are in the second; and 29 in the third. A map was drawn up overlaying these urban centers with the percentage of intermediate regions in the value of production of agricultural establishments in 2017 (IBGE, 2021) as a way to illustrate the discontinuities between the territoriality of agricultural production and the production of knowledge in agriculture.

Indicator	Source	Year	Weight	Territorial Unit
Capability for Creating Knowledge				
Postgraduate Program in the field of agricultural sciences	CAPES	2019	2	Municipality
Postgraduate Program in the field of agricultural sciences with an evaluation of 6 and 7	CAPES	2019	2	Municipality
Researchers in agricultural sciences	RAIS	2019	2	Municipality
Qualified job in agricultural production	RAIS	2019	1	Immediate Region
Capability for Adapting Knowledge				
Students enrolled on undergraduate courses in the field of agricultural sciences	MEC	2017	2	Municipality
Undergraduate courses in the field of agricultural sciences with grade 4 and 5 at Enade	MEC	2019	2	Municipality
Agricultural production technicians	RAIS	2019	2	Municipality
Producers receiving technical assistance	Agricultural Census	2017	1	Immediate Region

Chart 1. Indicators related to the creative and adaptive capacities of knowledge in agriculture

Source: Produced by the author.

4. Creative and adaptive capabilities of the urban centers in the STIA

Agriculture plays a central role in the productive deconcentration movement. Since the 1970s, as Cano demonstrated (2008), “soybeans and extensive cattle raising have been deconcentrated towards the border, in search of cheap land, cheap and easy public credit and public infrastructure for logistical support”. This first movement, in the 1970s and 1980s, marked the incorporation of the Cerrado regions into agricultural production in parts of the Minas Gerais Triangle and the Midwest (CAMPOLINA, 2006). In the 1990s, production intensified towards the Cerrado regions of the states of Maranhão, Tocantins, Piauí and Bahia, an area known as Matopiba (FAVARETO, 2019). After the 2000s, the agricultural frontier advanced towards the Amazon, especially in the northern part of Mato Grosso, Rondônia and Pará, where deforestation has been more intense (REYDON; FERNANDES; TELLES, 2020).

The expansion of the frontier promotes the reorganization of agricultural and urban space as urbanization is intensified in areas close to the production regions. As Elias (2013) has argued, the functionality of the provision of services in cities located in such regions becomes interconnected with the demands of agribusiness, as the suppliers of “part of the labor, financial resources, chemical inputs, agricultural machinery, agricultural technical assistance, etc.” (ELIAS, 2013, p. 24). However, with regard to services aimed at incorporating new work into agriculture, their organization across the territory has followed

a particular pattern, which is not directly influenced by the movement of the agricultural frontier.

Table 2 presents the fifteen largest cities on the index for the creative capability of agricultural knowledge. The state of São Paulo is the most prominent, with five cities; Minas Gerais, with two; and Rio Grande do Sul, also with two. Santa Catarina, Paraná, Ceará, Rio de Janeiro and Pernambuco appear with just one city, in addition to Brasília.

Ranking	City	PPG	PPG Grade 6 and 7	Researchers	Producers	Mean achieved
1	Viçosa (MG)	0.95	1.00	0.00	0.01	0.56
2	Piracicaba (SP)	0.63	0.80	0.12	0.05	0.45
3	Lavras (MG)	1.00	0.50	0.02	0.06	0.44
4	Brasília (DF)	0.24	0.00	1.00	0.18	0.38
5	São Paulo (SP)	0.49	0.30	0.17	0.25	0.31
6	Jaboticabal (SP)	0.49	0.40	0.01	0.37	0.31
7	Recife (PE)	0.61	0.20	0.01	0.40	0.29
8	Porto Alegre (RS)	0.37	0.30	0.16	0.18	0.26
9	Campinas (SP)	0.32	0.20	0.18	0.35	0.25
10	Londrina (PR)	0.27	0.10	0.33	0.29	0.24
11	Botucatu (SP)	0.49	0.30	0.00	0.10	0.24
12	Florianópolis (SC)	0.24	0.40	0.15	0.00	0.23
13	Fortaleza (CE)	0.34	0.10	0.14	0.29	0.21
14	Seropédica (RJ)	0.39	0.20	0.09	0.03	0.20
15	Santa Maria (RS)	0.44	0.20	0.00	0.04	0.19

Table 2. Index of cities with the greatest capability to create knowledge

Source: Produced by the author.

The centrality of municipalities such as Viçosa, Piracicaba and Lavras is due to a common cause: the presence of universities with a long trajectory of studies in agriculture, which have enabled cumulative learning and the complexification of knowledge. In relation to cities in the state of Minas Gerais, this trajectory has resulted from a combination of two phenomena: i) the sluggish economy in Minas Gerais at the beginning of the twentieth century, which made the professional education of farmers seen as strategic for economic progress; and ii) the migration of US missionaries linked to the Presbyterian Church, who took the land-grant colleges educational model into the interior of Minas Gerais (ROSSI, 2010), which,

as explained by Rosenberg and Nelson (1994), is based on directing education and research institutions to solve practical problems in the region, such as those arising from agriculture. The Lavras College of Agriculture (ESAL) was a pioneer in this direction, having been created in 1908 as a project directly linked to the missionaries; and the Agriculture and Veterinary Medicine College in Minas Gerais (ESAV), in turn, was created in 1926, on the initiative of the Minas Gerais government, but influenced by the model that had been implemented in Lavras.

The federalization of ESAL took place in 1963, when the Universidade Federal de Lavras (UFLA) was created. ESAV became the Universidade Rural do Estado de Minas Gerais (UREMG) in 1948 and, twenty-one years later, in 1969, it became the Universidade Federal de Viçosa (UFV). In the current context, the UFV is outstanding for being the Brazilian university with the largest number of graduate programs in the areas of agrarian sciences with an assessment of between 6 and 7, as is the case of programs in Animal Science, Genetics and Breeding, Plant Physiology and Entomology. UFLA has the highest volume of postgraduate programs in the areas of agricultural sciences.

The centrality of Piracicaba is essentially due to the role of the Luiz de Queiroz College of Agriculture (ESALQ). This university, founded in 1901, represents one of the pillars of the research and teaching system that has been built up in the state of São Paulo since the end of the nineteenth century, working towards the qualification of labor both for the productive sector and for research centers (ALBUQUERQUE; ORTEGA; REYDON, 1986). Currently, ESALQ is prominent for the volume of excellent postgraduate programs in agricultural sciences, with top marks in areas such as Genetics and Plant Breeding, Nuclear Energy in Agriculture, Soil and Plant Nutrition, Phytopathology and Entomology. Piracicaba is also relevant for being the headquarters of research centers, especially the Sugarcane Technology Center (CTC). As one of the main knowledge-producing centers in the sugar-energy sector, it maintains partnerships with several sugarcane producers across the country (MESQUITA *et al.*, 2019).

Brasília, since its foundation, was planned to exercise a political function, as the seat of the Federal Government, and of the economy, as a driving force for the growth of the Cerrado regions, while emphasizing its role in the modernization of agriculture (CAMPOLINA, 2006). Because of this, the centrality of the Brazilian capital is based on the actions of the State, which, among other measures, define it as the main location for installing Embrapa units. Currently, Brasília has the units for Agro-energy, Coffee, Cerrado, Horticulture, Technological Information, Products and Market, Plant Quarantine, Genetic Resources and Biotechnology (BONACELLI; FUCK; CASTRO, 2015).

Table 3 presents the most prominent cities in terms of adaptive capability. The state of Minas Gerais has three cities; Paraná and Rio Grande do Sul have two; Amazonas, Ceará, Goiás, Mato Grosso, São Paulo, in addition to Brasília, appear with only one city.

Ranking	City	Graduation	Graduation Grades 4 and 5	Technicians	Producers	Mean achieved
1	São Paulo (SP)	1.00	0.43	0.79	0.10	0.65
2	Curitiba (PR)	0.47	1.00	0.46	0.56	0.63
3	Porto Alegre (RS)	0.39	0.57	1.00	0.31	0.61
4	Goiânia (GO)	0.52	0.57	0.64	0.12	0.51
5	Fortaleza (CE)	0.29	0.57	0.60	0.23	0.45
6	Brasília (DF)	0.53	0.57	0.20	0.28	0.41
7	Uberlândia (MG)	0.50	0.57	0.12	0.40	0.40
8	Viçosa (MG)	0.42	0.86	0.02	0.16	0.40
9	Manaus (AM)	0.35	0.57	0.27	0.22	0.37
10	Lavras (MG)	0.44	0.71	0.04	0.19	0.37
11	Londrina (PR)	0.43	0.57	0.07	0.40	0.36
12	Santa Maria (RS)	0.27	0.57	0.03	0.76	0.36
13	Cuiabá (MT)	0.42	0.57	0.15	0.16	0.35
14	Chapecó (SC)	0.15	0.43	0.17	0.85	0.34
15	Recife (PE)	0.34	0.43	0.33	0.03	0.32

Table 3. Index of cities with the greatest capability to adapt knowledge

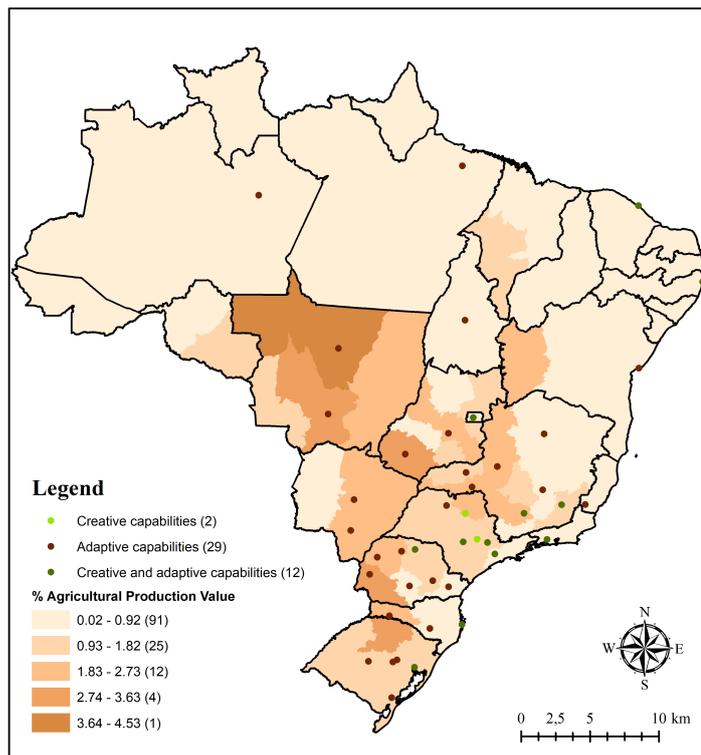
Source: Produced by the author.

The fact that São Paulo ranks in first place is hardly surprising. On the one hand, this position is explained by the large number of students enrolled on undergraduate courses in the areas of agrarian sciences; on the other, due to the dynamism of the services economy in the capital of São Paulo, which generates jobs for agricultural technicians. Curitiba's ranking in second place is due to the education system, since the Universidade Federal de Paraná (UFPR) and the Pontifícia Universidade Católica do Paraná (PUC-PR) obtained grades 4 or 5 in Enade, for courses in the areas of agricultural science. Porto Alegre, which ranks third, is the headquarters of Emater/RS and important cooperatives, which has resulted in an increase in the number of agricultural technicians.

The adaptive capability index also reveals greater dispersion across the territory, which may be observed in a comparison between Tables 2 and 3. With

regard to the creative capability, the municipality that ranks 15th achieved an average of 0.19, whereas in adaptive capability, this value was 0.32.

Map 1 summarizes the results obtained in the three levels of urban centrality in the STIA, superimposed onto the intermediate regions with a greater participation in the value of agricultural production in the country.



Map 1. Percentage of intermediate regions in the value of agricultural production and the most representative cities in agricultural knowledge networks

Source: Production value (IBGE, 2021). Cities: Produced by the author.

The discontinuities are more intense when comparing the main producing regions and urban centers with the capability of creative and creative/adaptive knowledge, where new work in agriculture is produced. A portion of these centers is constituted as metropolitan regions, such as Porto Alegre, São Paulo, Campinas, Florianópolis, Recife and Fortaleza; another portion is of medium-sized cities located in agricultural pioneering areas in the country, such as Piracicaba, Botucatu and Jaboticabal in the interior of São Paulo; Londrina, in the interior of Paraná; Seropédica, in the interior of Rio de Janeiro; and Lavras and Viçosa, in the interior of Minas Gerais. The only center that is geographically close to recent expansion areas is Brasília.

The presence of urban centers in metropolitan regions is explained by their ability to have a larger scale of research, to enhance face-to-face interaction and to attract funding both for researchers and for the acquisition of laboratory equipment. However, the fact that non-metropolitan urban spaces share the centrality with the metropolises in the STIA is representative. This is explained because knowledge in agriculture does not only depend on externalities resulting from the agglomeration economies present in large cities, since other dimensions are involved, such as the need for research to have experimental fields in order to identify how crops react to natural conditions and to gather data and observations that support scientific production. In this case, the high price of land and real estate pressure could become complicating factors for maintaining these fields in metropolitan areas. Another factor is the role of the State, with policies that direct investments towards the interior of the federative units in universities and agricultural research centers, with the aim of promoting regional development.

With regard to the adaptive capacity, there are greater continuities between agricultural production and knowledge. This is explained by the fact that these services present a lower degree of complexity, which simplifies their territorial dispersion; and a greater need to produce knowledge arising from their proximity to the countryside in order to facilitate contact with producers, in addition to recognizing the particular requirements of the edaphoclimatic conditions.

The spread of urban centers capable of promoting agricultural adaptation is due mainly to the growth of undergraduate activities during the 2000s and 2010, with an expansion in the number of vacancies and in the offer of courses in the interior of the country (DINIZ; VIEIRA, 2015), thereby forming a workforce in these places which was capable of absorbing external knowledge. Another responsible factor, especially with regard to the states of Paraná and Rio Grande do Sul, is the role of technical assistance and its integration with producers⁶. Castro and Pereira (2017) explain this phenomenon by the mean profile of agricultural enterprises in the southern region of the country, which have a higher level of education; for the role of cooperatives, which have a technical body to support farmers; and by producers integrated with local agro-industries, such as poultry and pigs.

By way of conclusion

The argumentative structure of the article began with the economic and historical approach of the Brazilian SIA. Following on, we included the

6. While throughout Brazil, in 2017, 20.2% of producers reported receiving technical guidance, in the South, the percentage was 48.6% (IBGE, 2021)

territorial dimension in order to situate the agricultural innovation process in a context of power disputes, and to discuss its unequal distribution throughout Brazil. Emphasizing the urban centrality in STIA, we consider, like Jacobs (1969), that the productivity of agriculture is based on the relationship with cities, but it is necessary to recognize that i) the countryside is not a passive entity in the production of knowledge and ii) that each urban center plays a particular role within a hierarchical knowledge network. By applying this principle to Brazilian agriculture, the article has demonstrated the main locations in terms of creative and adaptive knowledge capabilities in agriculture, as well as the differences between these territorialities and those that mark the productive sector with the movement of the frontier.

Given these results and the theoretical structure surrounding the STIA, the study presents four paths for future research:

1. Differences in the production capacity of science and technology have constituted vectors of regional inequalities within the context of globalization. It is true that agriculture has had a historic role as a force for productive deconcentration in Brazil. However, the core STIA segments are still concentrated in certain points close to the traditional production zones. An absence of cities with the potential to boost the dissemination of knowledge in the regional production system in new areas of agricultural expansion restricts economic potential and creates dependence on distant urban centers for updating production processes. The case of the northeastern portion of Matopiba is representative of this, which, despite being an outstanding region of high agricultural growth, especially with soybean production, does not record any city among the most representative in the creation or adaptation of knowledge, which suggests that other locations polarize this region. It is necessary to push forward investigations with regard to the way in which this growth dynamic functions with a low level of local interference of knowledge and to identify which centers are polarizing the new areas of expansion.
2. Along the lines of this reasoning, the geographical dissociation between the spaces of production itself and the spaces for creating scientific knowledge in agriculture renders it necessary to understand the breadth of the influence zone of urban centers with greater creative capabilities in the STIA. As there are few such places within a context in which agricultural production occupies a large extension of the territory, the tendency is that the reach of urban centers – such as Lavras, Viçosa and Piracicaba, for

example – covers a significant portion of the country, attracting interests from companies and universities from distant regions for partnerships focused on innovation and research.

3. It is common for studies that deal with the innovation process in industry and services (FERNANDES; SABINO; PIMENTEL, 2021; STORPER, 2013) to valorize metropolitan regions as being the command centers of knowledge. Our results, however, have demonstrated that, in agriculture, medium-sized cities – some with less than 100,000 inhabitants, such as Viçosa and Jaboticabal – have a higher centrality than most metropolitan regions in Brazil. It is necessary to understand to what extent these cities manage to maintain this degree of centrality and whether, in the current context, they have accentuated or lost their position in the STIA.
4. The ongoing digital transformation has expanded the use of information and communication technologies and automation in agriculture. These changes have opened up paths for research into two directions: i) to reflect on how the STIA historically built in Brazil has conditioned the development of digital technologies, and which groups may benefit from these technologies; ii) to reflect on the implications that digital technologies may have on the STIA, for example, accentuating consolidated urban centralities or creating new ones.

Studies along these lines of research support an understanding of how innovation, agriculture and territory are linked in a peripheral context. This understanding becomes essential due to the sluggishness of the Brazilian economy, which has indicated natural resources as one of the few alternatives for innovation. Studies on the SIA have already contributed towards this direction, but there is still an open field when we incorporate the territorial dimension for reflection on power relations and the urban and regional dynamics involved in the innovative processes of Brazilian agriculture.

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