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Building Soil Fertility: Embrapa and the Agronomic Development for the "Conquest" of the Brazilian Cerrado (1975-95)

Kárita de Jesus Boaventura, Claiton Marcio da Silva and Sandro Dutra e Silva

KEYWORDS: **agronomic development, Brazilian Cerrado, agricultural frontier, soils.**

JEL CODES: **N56, O13, Q15, Q18.**

*The history of agricultural intervention in the extensive area currently called the "Cerrado biome" reflects the confluence of several projects involving public and private agencies, which brought together knowledge from agronomy, economics, environmental sciences and other areas over decades. The biggest challenge for this venture revolved around converting large areas of "naturally" infertile soils into arable land for large-scale agriculture. A decisive point in the "conquest of the Cerrado", as advocates of large-scale agribusiness refer to this historic process, was the creation of the Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária-*Embrapa) and its specific unit for this area, the Cerrado Agricultural Research Center (*Centro de Pesquisa Agropecuária dos Cerrados-*CPAC). The institution has coordinated the research on cerrado soil fertility since the mid-1970s, promoting important scientific advances in agricultural productivity in Brazil. This article observes from a historiographical perspective how the Embrapa reports from 1975 to 1995 produced an important range of knowledge about cerrado soils and ecology, which ultimately led to the conceptualization and construction of the "Cerrado Biome".*

Construindo a fertilidade do Solo: o desenvolvimento agronômico da Embrapa na "conquista" do Cerrado Brasileiro (1975-1995)

PALAVRAS-CHAVE: **desenvolvimento agronômico, Cerrado brasileiro, fronteira agrícola, solos.**

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A história da intervenção agrícola sobre a extensa área atualmente denominada de "bioma Cerrado" foi possível apenas a partir da confluência de diversos projetos com agências públicas e privadas, aproximando diferentes áreas do conhecimento, como agronomia, economia, ciências ambientais, entre outras, ao longo de décadas. O maior desafio para este empreendimento girou em torno de converter grandes áreas de solos "naturalmente" inférteis em solos aptos para a agricultura em larga escala. Um dos pontos decisivos para a "conquista dos Cerrados", como os defensores do agronegócio em larga escala se referem a este processo histórico, reside na criação da Empresa Brasileira de Pesquisa Agropecuária (Embrapa) e, mais especificamente, em uma de suas unidades, o Centro de Pesquisa Agropecuária dos Cerrados (CPAC). Nesta perspectiva, a instituição coordenou a dinâmica de pesquisas em fertilidade dos solos de cerrados desde meados da década de 1970, promovendo um importante avanço científico sobre a produtividade agrícola do Brasil. Para este artigo, será observado, a partir de um olhar historiográfico, como os relatórios da Embrapa produziram, entre 1975 e 1995, uma importante gama de saberes sobre os solos e a ecologia dos cerrados e, em última instância, sobre a própria construção da ideia de "bioma Cerrado".

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Kárita de Jesus Boaventura [orcid.org/0000-0001-9894-623X] *is a Statutory Professor in the public primary education system in the State of Goiás. Address: Rua Parintins, Qd. 84, Lt. 9/13, Bl. A, Apt. 303, Residencial Lago dos Buritis, Parque Amazônia, 74840-670 Goiânia (Brasil). E-mail: karitaboaventura@hotmail.com*

Claiton Marcio da Silva [orcid.org/0000-0002-4582-4586] *is an Associate Professor at the Universidade Federal da Fronteira Sul (UFFS), working in undergraduate and graduate courses in History and in the Master's Program of Environmental Science and Technology. Address: Av. Porto Alegre, 1395D, Centro, Edifício Dom Ermildo, Apto. 803, 89802-130 Chapecó (Brasil). Email: claiton@uffs.edu.br*

Sandro Dutra e Silva [orcid.org/0000-0002-0001-5726] *is a Professor at the Universidade Estadual de Goiás (UEG) and Full Professor at the Universidade Evangélica de Goiás (UniEVANGÉLICA). Address: Av. Edmundo Pinheiro de Abreu, n. 423, Apt. 101, Setor Bela Vista. 74823-344 Goiânia (Brasil). E-mail: sandrodutr@hotmail.com*

1. INTRODUCTION

From a political and technical-scientific point of view, the history of agricultural land use in Brazil can be divided into two major questions built over the course of the 20th century: the exploration and recovery of soils with "natural" fertility, and in contrast, the search for possibilities of fertilizing acidic soils. While the first issue occupied the political agenda for practically the entire century –through the opening of new agricultural frontiers or the recovery of fertility in soils that have been exploited for centuries– the second dominated an important part of government and business attention after Second World War. Before this text advances into this debate, however, it is necessary to note that the notions of "natural (in)fertility" –a fundamental category of Western agronomic semantics–, in most cases refer to the intensive and extensive use of soils for the production of agricultural and livestock surplus to supply towns or urban centers. And in this sense, soils are no longer perceived as only a "natural" element, but as resulting from the interaction between society and nature (Worster, 1979, 1982, 2016). In summary, there is an ancient historical relationship involving humans and non-humans, with their long-lived and diversified habits of dispersing fruits, seeds and other organic elements.

Currently, the Cerrado (Central Brazil's tropical savanna) is the country's most important center of food production (Dutra e Silva, 2020). But that was not always the case. Historically, statesmen, scientists, and farmers considered the region unsuitable for agriculture. The soils of Cerrado grasslands, with a higher degree of acidity, were historically considered naturally infertile. In fact, these soils have always harbored high biodiversity: in some cases they resulted from anthropic action and in others from the geological history of these environments (Oliveira & Marquis, 2002; Pennington & Ratter, 2006; Dutra e Silva, 2020). Until the mid-20th century, soils with higher acidity content were related to a political conception of backwardness (Ferri, 1969, 1974; Goodland, 1971; Goodland & Ferri, 1979; Rizzini, 1976). This backwardness, however, was responsible for the maintenance of an important biodiversity, while the soils considered to be of greater fertility were widely exploited by agricultural production, being especially deteriorated by the widespread advance of commodities.

Brazilian environmental history has highlighted the relationship between the exploitation of natural resources in Brazilian fertile soils, especially in studies related to agricultural expansion in the Atlantic Coast Forest (*Mata Atlântica*) (Dean, 1997; Drummond, 1997; Pádua, 2004; Cabral, 2014). These forested areas were used for centuries for the purposes of sugar, coffee, or cotton monoculture. In the second half of the 20th century, this region already presented a scenario of devastation, both in the destruction of vegetation and the soil. Erosion, particularly due to the lack of any practices to replace

lost micronutrients, advanced rapidly in areas occupied by plantations since the colonial period. In regions such as the interior of the state of São Paulo, farmers abandoned old coffee-producing farms and their centuries-old coffee plantations, surrounded by sandy soil, and migrated towards the fertile lands of Paraná (Kohlhepp, 2014). In the first half of the 20th century the forested regions of Mato Grosso de Goiás, as well as northern Paraná, came to represent the new Eldorado supported by policies to expand the agricultural frontier into the *terra roxa* (purple soil) forests (Kohlhepp, 2020; Dutra e Silva, 2017; Dutra e Silva & Bell, 2018; Silva, 2020). But from the second half of the 20th century onwards, the "infertile" lands of the Brazilian interior became the focus of the agronomic development policy for the production of grains and commodities. And this change in the perspective of arable soils in Brazil has a lot to explain us about the history of the Brazilian Cerrado.

This article is an attempt to contribute to the environmental history of the Cerrado by analyzing the processes that were fundamental to the change in the agricultural perspective of the region: from an infertile and unsuitable land for agriculture to one of the most important areas in the production of grains and commodities in Brazil and in the world. This text in particular, focuses its analysis on agronomic research of soil infertility, one of the main dilemmas in grain production and the expansion of the agricultural frontier in the Cerrado. The primary research subject which will be further detailed, is the agronomic research carried out by the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária, Embrapa), at the Cerrado Agricultural Research Center (Centro de Pesquisa Agropecuária dos Cerrados, CPAC), headquartered in Planaltina, in the Federal District. The documents analyzed were produced between 1975 and 1995, a period in which the domain and "conquest" of Cerrado soils took place.

2. A BRIEF HISTORICAL INTRODUCTION OF SOIL FERTILITY IN BRAZIL

In the Western hemisphere, a basic science of fertilization was established by Justus von Liebig in the mid-19th century (Rossiter, 1975). However, as Warren Dean (1997) pointed out, even though the large-scale Brazilian farmers were aware of the renowned fertilization formula (NPK: nitrogen, phosphorus and calcium) proposed by the German chemist, they did not use it, due to the so-called natural fertility provided by felling forests (slash and burn) in the advance of the agricultural frontier. The main point of criticism by both national elites and educated foreign travelers was the "slash and burn" method (Dean, 1997; Silva, 2015), which represented the backwardness of the agriculture practiced in Brazil (Silva, 2015). In contrast, the creation of research institutions and the dif-

fusion of agricultural techniques came to be identified as necessary measures to modernize Brazilian agriculture. On the part of the rural elites, between 1948 and 1949, the Brazilian Rural Society (Sociedade Rural Brasileira) and the Rural Economy Institute (Instituto de Economia Rural) went to the interior of the country in order to promote soil recovery practices. The government of President Eurico Gaspar Dutra (1946-51) started a crusade that called on agronomy professionals to act as missionaries and "evangelize" producers for soil conservation (Medeiros, 1950). Thus, during the first half of the 20th century, the Brazilian state and rural elites promoted the advance of farming towards the new frontiers of fertile soils (Dutra e Silva, 2017). Among other initiatives, they sought to promote the recovery of deteriorated soils (Silva, 2015).

Environmental history, therefore, shows that the expansion of the Brazilian agricultural frontier was related to the history of territorial expansion into tropical forest regions for centuries (Dean, 1997; Dutra e Silva, 2017). However, another important issue for this current, and still underexplored by Brazilian historiography, refers to the expansion of agriculture into large portions of "naturally infertile land". Generally, soil infertility is associated with areas of grassland formation, especially in the neotropical savannah areas of the Cerrado, in the regions of central Brazil, but it can also refer to areas of Cerrado enclaves in the Amazon, in addition to the northeastern Caatinga and southern grasslands (Sampaio, 1938; Löfgren, 1896; Ferri & Warming, 1973).

Savannas and grasslands were often interpreted throughout the Iberian conquest as cattle frontier areas (Mccreery, 2006). From the second half of the 20th century and onwards, the Brazilian state adopted an economic modernization policy based on the industrial model, which outlined increases of food production for urban centers and of commodities for export as fundamental to national development. Faced with this new situation, the geographer of the National Geography Council (Conselho Nacional de Geografia), Speridião Faissol (1923-97), stated that Brazil was at a crossroads in its quest for development: either the soils devastated by agricultural practices of "slash and burn" would be recovered or farming would advance into the infertile soils of the Cerrado (Faissol, 1957). This dilemma is representative of an important portion of Brazilian social and political thought, interested in creating conditions for the advancement of agriculture and livestock (Faissol, 1957: 5). In this sense, more than just expanding the agricultural frontier territorially, it would be necessary –by the government and rural elites– to develop a new technology to literally build the fertility of soils in the central region of Brazil.

Some researches and some experiments were pioneers in this sense, such as the North American Reeshon Feuer (1956), and the Brazilian Mário Guimarães Ferri (Rawitscher, Ferri & Rachid, 1943), Álvaro Barcellos Fagundes, Paulo de Tarso Alvin, and Wil-

son Alves de Araújo (Malavolta, Pimentel-Gomes & Alcarde, 2002). However, such surveys did not hint at large-scale agriculture in the Cerrado grasslands –except in the case of Feuer. Contemporarily with the green revolution, a series of projects and experiments related to the restoration and construction of soil fertility were put into practice with governments and international organizations. Noteworthy for example, is the work of the North American Innovation Research Institute (IRI). Created in 1950 by billionaire Nelson Rockefeller, IRI formed a partnership with the Campinas Agronomic Institute (Instituto Agronômico de Campinas) and private farms in the interior of the state of São Paulo, where it built greenhouses and carried out experiments to recover soil fertility (Silva, 2012). These experiments, including Cerrado soils, gave rise to other partnerships between public and private groups, which at least in theoretical terms, served as the basis for the subsequent foundation of Embrapa (Nehring, 2016).

If the advance of the agricultural frontier in the territory that is currently considered as the Cerrado biome[1] is observed, the occupation of the tropical forested areas in Goiás (the Mato Grosso de Goiás) should be taken as a pioneering process (Dutra e Silva, 2017). However, if the agronomic research related to the improvement of the soil in the Cerrado is considered, the pioneering research presented earlier in this text and other government projects, which in the 1970s were guided by the National Development Policy (Plano Nacional de Desenvolvimento, PND I and II), should be examined. The PNDs sought to strengthen agricultural expansion in the Cerrado through the Cerrado Development Program (Polocentro) and the Japanese-Brazilian Cooperation Program for the Development of the Cerrado (Prodecer). The agricultural frontier expansion project also conceived the demographic expansion, not only for the Cerrado region but also for the Amazon (Mello, 2017).

From the 1980s and 1990s onwards, large-scale agricultural production in the Cerrado was strengthened through public and private investments. New frontiers were incorporated into this expansion process, with an emphasis on products such as soy. At the same time, the phenomenon of agricultural production in central Brazil demonstrated the

1. The division of biogeographic territories or provinces in Brazil follows a tradition of establishing large ecological regions to represent Brazilian floristic formations. The division into biomes is the most recent and the most used in the country. The six major Brazilian biomes are: Amazon, Caatinga, Cerrado, Pantanal, Atlantic Forest, and Pampa. The "Map of Brazilian Biomes" was published in 2004, based on an institutional cooperation agreement signed in 2003 between the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística) and the Ministry of the Environment (Ministério do Meio Ambiente). The territorial and biogeographic division into biomes became a reference for the formulation of public environmental policies in Brazil. The report related to the formulation of maps of Brazilian biomes was only published in 2019, which reinforces the recent use of this category in Brazilian environmental studies (IBGE, 2019a).

leading role played by Embrapa and its Agricultural Research Center of the Cerrado (CPAC). Created in 1975, CPAC established an agronomic research agenda aimed at increasing agricultural production in central Brazil. It should be noted that there are numerous study fronts that make Embrapa an important agronomic research agency. However, this article focuses on studies related to the soil, having as a privileged archival document from Embrapa, produced between 1975 and 1995, relating to the Annual Technical Reports of the Cerrado Agricultural Research Center[2].

The choice of the soil as a theme was based on the classification of research carried out by areas of activity; in general, the reports aimed at the development of the Cerrado for agricultural practice. Thus, the themes ranged from soil improvement, adaptation and genetic improvement of cultivars to the conditions of the Cerrado, development of agricultural techniques and tools that meet the specific needs of the production of different cultures in this biome, among others. Thus, the focus in relation to edaphic studies is justified because, as it has been verified, this theme was present in all reports, and the way to approach these studies was varied, including research on erodibility, acidity, low fertility, and the relationship of soils with water resources.

The research also considered the dialogue between the reports and the bibliography produced on the Cerrado soil from 1975 to 1995. The main archival documents used in this research were the technical reports produced by Embrapa's team of agronomists and specialists. However, we would like to highlight we used other documents as a complement to the technical reports, such as the papers published by the Embrapa team –and

2. This research is based on documentary data produced by Embrapa Cerrados between the years 1975 and 1995. For this purpose, it takes the Annual Technical Reports of the Agricultural Research Center of the Cerrados as its main document, which were produced in the aforementioned period. Document collection was carried out in Embrapa's digital library, with the analysis and recording of data, creating categories for the objects of study. In this case, this article focuses on the edaphic studies of the Cerrado. The reports comprise a set of ten volumes, totaling 2,802 pages. Each volume corresponds to a technical report with the following dates: 1975-77; 1977-78; 1978-79; 1979-80; 1980-81; 1981-82; 1982-85; 1985-87; 1987-90; 1991-95. The reports were produced by Embrapa researchers, and the manuscripts were digitized because the originals are typed. The language of the reports follows the technical characteristics of the descriptions of agronomic practices and results. The data is descriptive, with a thematic emphasis that follows a standardized script. There are variations, especially in the products, according to the evolution of research in consecutive reports. The reports present a list of the names that made up the administration of Embrapa and of the entire national and international multidisciplinary technical team participating in the research. These documents follow a certain descriptive pattern in their presentation. There is a division into chapters that describe the research, and then the technical activities developed in each period. The reports also bring results and products achieved in each period, containing, for example, the methods used to disseminate research, the technologies developed, the agreements made both within Brazil and abroad, and a list of works published by Embrapa (*i.e.* articles published in external outlets and theses defended).

some with the other collaborators outside Embrapa– in journals specialized in agronomic research. Scientific articles produced by researchers from Embrapa and other universities highlight results, methodologies, strategies, and other methodological choices that help us to understand the historical context of agronomic development in the Cerrado, especially between the 1970s and 1990s. Our central argument is that, in the period of consolidation of agronomic research on the Cerrado, developed at CPAC Embrapa, the dominant topics were associated with edaphic research. The technical and scientific research aimed to conquer the soil with science in order to transform the natural edaphic fragilities.

3. THE CREATION OF EMBRAPA AND AGRONOMIC STUDIES OF THE CERRADO

The report entitled the "Black Book" was the result of a working group of the Ministry of Agriculture (Ministério da Agricultura), formed by Ministerial Ordinance No. 143, of April 18, 1972, whose purpose was to create a national system for agricultural research in Brazil. Led by Minister Luís Fernando Cirne Lima, the group sought to establish a strategic instrument to guide government decisions in the process of reformulating the country's agricultural system (Embrapa & MAPA, 2006). The institutional reform resulting from the Ministry of Agriculture group made possible, among other reformulations, the creation of Embrapa.

Regarding the institutional model, the proposal of the Ministry of Agriculture was to establish a central body of the National Agricultural Research System (Sistema Nacional de Pesquisa Agropecuária), which created councils at the national, regional, and state levels. Embrapa was established as an institution commissioned with the production of scientific knowledge to support agricultural development. Among the different founding objectives of Embrapa we want to highlight: a) to promote, stimulate, coordinate, and carry out agricultural research activities, in order to produce knowledge and technology applicable to agronomic practices in Brazil; b) to provide technical and agronomic services to the government and the agricultural sector; and c) to serve as an institution of technical and administrative support for the national and regional councils for agricultural research (Embrapa & MAPA, 2006).

Embrapa was based on a model of regional units, according to which experimental stations and research centers would function[3]. In addition, the company would have the

3. Embrapa's regional research centers were created in order to identify the natural resources available in the country, analyze the productive potential of soils, and develop technologies that could in-

task of stimulating public-private partnerships and promoting and strengthening experimental activities on private properties. Regionalization followed the guidelines of the national agricultural research plans, based on the potential of each region (Embrapa & MAPA, 2006).

The managers of the national agricultural research system also recommended that the investigative development project should not be an institutional exclusivity. In fact, they encouraged academic collaborations, in which the universities were responsible for basic research, with financial support of the Brazilian government. In addition, the universities were responsible for monitoring this research through graduate programs, in line with ongoing institutional research[4]. The geographical areas identified by the government as priorities for agronomic research were the Amazon, the Cerrado and the northeast region. It is important to highlight that the territorial division by biomes did not yet exist and that the term adopted for what is currently called the Cerrado biome was *Cerrados brasileiros* (Brazilian Cerrados) as represented on the map published by Embrapa in the mid-1970s (Fig. 1)[5]. These territorial units for agronomic research received special attention at that time based on regional needs and specificities (Embrapa & MAPA, 2006).

The CPAC was established in 1975, as mentioned earlier, in the city of Planaltina (Federal District), absorbing the extinct Experimental Station in Brasília. In 1977, CPAC published its first technical report for the period related to 1975-76 (Embrapa, 1977), in which

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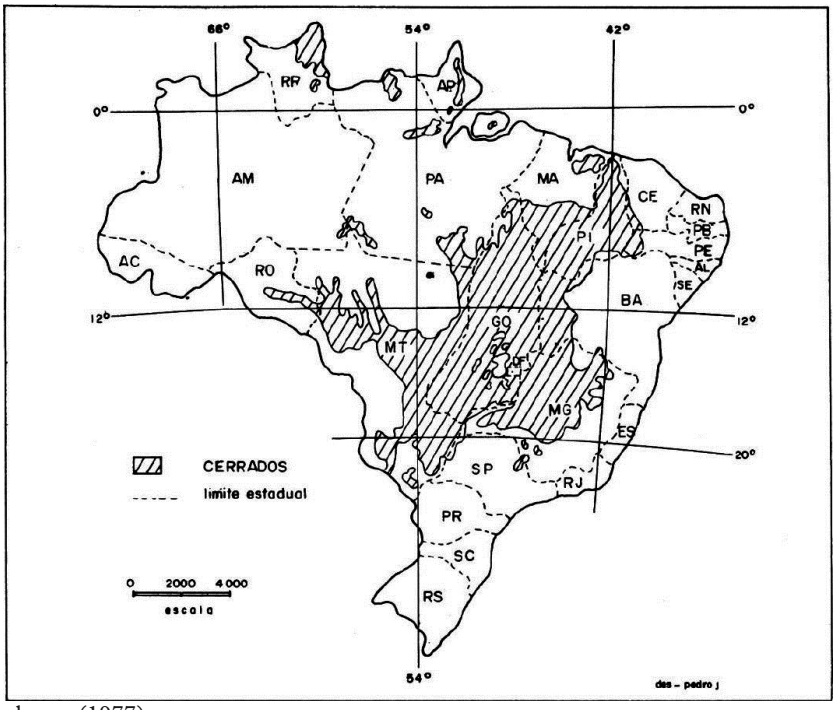
crease production and reduce costs. The research centers were developed based on specific and strategic agricultural products, as well as on regional agricultural potential, with the following characteristics: a) research centers for agricultural products; b) thematic research centers; and c) ecoregional research centers (Dall'Agnol, 2016). In 1974, the first centers were created based on specialized themes, such as beef cattle (Campo Grande, Mato Grosso do Sul), rubber (Manaus, Amazonas), wheat (Passo Fundo, Rio Grande do Sul), rice and beans (Goiania, Goias).

4. A fundamental theme in studies on the institutional role of Embrapa as an agricultural research institution is its relationship with universities. Comparative studies and even studies on the interaction between Brazilian universities are still lacking, especially through master's and doctoral courses, as well as on their dialogue with the production of knowledge at Embrapa. The work that comes closest to a discussion in this sense is the work of Fernando Rogério Jardim (2011), in which the author compares the political economy and practice of research between Brazilian universities and Embrapa, but he doesn't delve much into the relationship between them. However, his work reveals the nature of Embrapa's autonomy as a qualified agricultural research institution, due to its significant scientific output. But, of course, this is a rich topic for future research.

5. This is a fundamental point for historical environmental studies that take into account the Brazilian biogeographic formation. In this sense, what was once considered to be a tropical forest in the south-central region of Goiás, for example, is currently evaluated as areas of the Cerrado biome. If we consider the current delimitation of the biomes, we can say that this region received the pioneering agricultural expansion project in the Cerrado during the 1940s to 1950s, and therefore prior to the Embrapa project (Dutra e Silva, 2017; Dutra e Silva & Bell, 2018).

it presented data and plans for the development of agriculture in the Cerrado region, as shown in Figure 1.

FIGURE 1
Map of the territorial distribution of the Cerrados in Brazil in the 1970s



Source: Embrapa (1977).

The reports produced between the years 1975 to 1995 are important data for understanding the initiatives, researches, experiments, agreements, and changes in soil studies on the biome. The intention of this paper is to present a historical perspective of these studies and the main points for improving the fertility of soils in the Cerrado in Brazil based on the role and performance of Embrapa.

3.1. A problematic diagnosis: the annual reports of Embrapa/CPAC and the search for soil fertility (1975-80)

Embrapa was ambitiously conceived as an institution whose mission was to solve the bottlenecks of the country's economic and agricultural policy during the Brazilian military dictatorship. This is because with the entanglement of institutions and laws created from

1964 onwards, Embrapa found fertile soil to develop a research policy suited to the expansion of the Brazilian foreign market and also to the dramatic increase in the global connection of commodities. From a political point of view, the creation of the National Institute for Colonization and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária) in 1970 sought to guarantee the land tenure standard in Brazil based on large properties, without any structural changes. And Embrapa, in turn, was much more in tune with the long-held dream of Brazilian elites for the modernization and expansion of the country's agricultural frontiers (Magalhães, 2020: 16). And, as part of Embrapa's larger structure, the "first generation" of CPAC had a proportionally greater challenge than other research centers in edaphic terms: adapting large-scale production to acidic soils, where pastures were considered to be of low quality and small-scale agriculture historically predominated.

In contrast, the institution embraced the challenge of agricultural development, avoiding political clashes with the Brazilian authoritarian regime (1964-85), through a technocratic posture –consolidated by educating of a large contingent of researchers in US universities, through an agreement– and with a rhetoric aimed at achieving a certain degree of independence in the production of basic agricultural items to supply the domestic market, in addition to having been a collaborator in boosting the country's economic development and socio-political stability (Paolinelli, 2006). Therefore, Embrapa/CPAC reports can be understood from this historical context, but taking into account the internal debates related to advances in the field of science and technology. In contrast, as an important factor to understanding the role of Embrapa between 1975 and 1985, it is understood that the institution was born from the authoritarian regime, at the height of Brazilian political repression. With a liberal guise, *i.e.*, criticizing the state bureaucracy, Embrapa acted in an ambivalent way, introducing and strengthening crops for the foreign market and, as a way of maintaining the stability of the dictatorship, strengthening the domestic market (Biasillo & Silva, 2021).

The data presented in the Annual Technical Report of the CPAC from 1975 to 1977 visualized the leading role of agriculture in the process of economic development in Brazil. Agriculture came to be seen as a strategic area of the Brazilian government, considering that it would be responsible for the objectives of supplying the domestic food deficit and generating raw materials for industries and commodities for export. To this end, the II PND established guidelines for the modernization of so-called traditional agriculture. In this context, the occupation of the Cerrado was seen as an alternative for the expansion of the agricultural frontier, stressing that these areas could be integrated into the production process, as long as the edaphic deficit was resolved and its potential highlighted (Embrapa, 1977).

The initial problem was aimed at solving or minimizing basic limitations to the agricultural use of the Cerrado, receiving the name of Usability; the main results obtained indicated the priority problems for CPAC's work, such as low soil fertility, climate seasonality, and low adaptation of species and varieties of agricultural crops. The report reinforce that the low fertility of the soil occurred because of the "high phosphorus fixation capacity, high aluminum saturation, and low generalized nutrient capacity" (Embrapa, 1977: 41). Among the scarcest nutrients in Cerrado soils, phosphorus, nitrogen, potassium, magnesium and zinc stood out. The edaphic problem then became the main focus of analysis, since the low adaptation of agricultural species was directly related to the "inability of plants to yield under conditions that are not very favorable in terms of acidity and nutrient availability" (Embrapa, 1977: 41). Historically, therefore, CPAC technicians had to adapt an environment that originated at least 45 million years before modern agricultural methods. In addition, the characteristics of the Cerrado differed from those of bordering environments, such as tropical forests (the Atlantic Coastal Forest and even the Mato Grosso de Goiás), as previously mentioned (Dutra e Silva, 2017). Therefore, in the technical rhetoric of CPAC and other research institutions, the agricultural use of this large portion of Brazilian territory was presented as having "potential", and not exactly as a reality.

To minimize the issue of low soil fertility, or specifying the lack of nutrients and acidity, experiments were carried out in different locations of the Cerrado at the CPAC`s areas of influence. These experiments were based on the insertion of nutrients into the soil, accompanied by the planting of different crops and plant species, a method widely disseminated in the Western Hemisphere through agricultural schools. From these experiments, researchers observed the environmental factors involved in the process. The CPAC's researchers analyzed which nutrients increased productivity and in relation to which crop species. At first, the researchers observed average levels of organic matter, low levels of phosphorus, medium levels of potassium, and low levels of calcium, magnesium and zinc and, for this reason, research was intensified on these elements (Embrapa, 1977). With this, CPAC technicians returned to the original questions of adapting the Cerrado to large-scale agriculture: What are the geomorphological elements? What is the natural history of Cerrado soils? And how did this dynamic create an acidic soil? Therefore, little was yet known about the ecological characteristics of this environment considered as part of the global savannas; in addition, structured knowledge about the Cerrado was not widespread, as it is not possible to state that there was a scientific community structured around general studies on this ecological zone[6].

6. As Silva (2012) points out, until the 1940s, farmers were discrediting in the capacity of the Cerrado for irrigated agriculture Between the 1940s and 1960s, studies advanced from different in-

Therefore, the first reports worked on a diagnostic strategy. The second report covered the period from 1977 to 1978 and indicated a real advance in the sense of valuing multidisciplinary practices, mainly related to the low natural fertility of Cerrado soils (Embrapa, 1979). During this period, CPAC came to be conceived of as a technology-generating institution, rather than simply managing agronomic research. Thus, the issue of low soil fertility in the Cerrado were treated not only as scientific projects, but also as experimental and rural extension work. At that time a seminar was held indicating the establishment of a cooperation agreement with Japan on the first project of the Japanese-Brazilian Cooperation Program for Agricultural Development in the Cerrado (Prodecer) in 1979. The Japanese-Brazilian project was motivated by the frustration of the world grain crop in 1973 and the Nixon Shock that devastated Japanese soy imports from the United States. The Japanese government, in turn, sought alternatives and partnerships to produce food, mainly protein. In 1979, activities began in the Cerrado region at the state of Minas Gerais (*Triângulo Mineiro*), a place until then considered unsuitable for export agriculture. The resources from the Japanese government were financed by the Japan International Cooperation Agency (JICA), with support for projects in developing countries, which in turn would benefit Japan through the import of these agricultural products. In addition to funding the creation of the Agricultural Promotion Company (Companhia de Promoção Agrícola), which was responsible for providing technical assistance to farmers, the funds would also be used to train Brazilian technicians at Embrapa's Cerrado Agricultural Research Center[7]. Therefore, the projects of the Brazilian military government and of foreign nations are found in the promotion of technical assistance and colonization activities. But in the late 1970s, the Cerrado soils still imposed a series of difficulties on technicians from Embrapa and agricultural development agencies.

Issues related to low soil fertility and erosion led CPAC to develop a specific program for this purpose, called "Project for the usability of soil/climate/plant resources of the Cerrado" or, simply, Project Usability (*Projeto Aproveitamento*). The research results carried out by CPAC allowed for the elaboration of new production systems which, based on tests and evidence, would later be disseminated by technicians and researchers to the scientific society (Gastal, 1980)[8]. With that, the results of the researches carried out already

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stitutions, without centralization. This fact suggests that there were divergent interests and that the studies aimed at what we currently call agribusiness were, until then, part of the agenda of small institutions such as the Nelson Rockefeller IRI Research Institute (see Silva, 2012). The creation of Embrapa, in this sense, built a schedule that was centralized in the agenda of large-scale agriculture.

7. For more information, consult JICA (1979a, 1979b) and República Federativa do Brasil (2002).

8. According to Mengel (2015), Edmundo da Fontoura Gastal was one of the most important agronomists for the development of Embrapa's institutional planning system. Gastal had been one of the members of the 1972 High Level Commission, through which the creation of Embrapa had been

allowed for the satisfactory management of the soil, with a tendency to increase production. Scientific production in this period highlighted very different themes in relation to the soil, ranging from the effects of rainfall on soil loss to other erodibility factors, such as tolerance of plant varieties to aluminum, and low phosphorus availability (Dedecek, 1978; Dedecek & Cabeda, 1977; Miranda & Lobato, 1978).

Embrapa researchers aimed to expand the geographical frontiers of production as well as to improve productivity. In order to achieve this they developed techniques to fertilize the soil by intensifying research on acidity. In addition, research was carried out with supplementation through phosphorus, potassium, micronutrients, nitrogen, and organic matter. In this context, the critical level of elements in the soil was first analyzed, citing phosphorus, for example, as a way to verify the level of availability that would be important to reach through fertilization. Afterwards, they tried to measure the amount of phosphate fertilizer needed to increase soil fertility and also to maintain this fertility after absorption by the plants. In the meantime, the effect of these combined nutrients, such as phosphorus and calcium, was investigated (Embrapa, 1980). The report presented studies on the incorporation of limestone for greater fixation of nutrients mixed with the fertilizer, seeking to reduce this acidity. Therefore, experiments were carried out on the doses and depths of limestone incorporation, and how much this technique helped in fixing each incorporated nutrient was measured. Concomitantly, researchers reported which cultures had greater production in the presence of each nutrient, and the nutrient was evaluated by fixation in different techniques. For that reason technicians then carried out a screening of species and plant varieties (Embrapa, 1980).

Historically, this investigation methodology is connected to the model of "nurseries" or "agricultural nurseries", already in practice at universities and agricultural research institutes in the United States for the adaptation of plants from other countries and continents. With the growing participation of Brazilian researchers in graduate programs in North America, models of inductive studies were increasingly adapted, based on samples, which would indicate increased or not increased agricultural potential. Regarding soil management and conservation, the researchers highlighted their concern with the consequences that could be caused by interventions made to correct soil acidity and by its massive exploitation, with erosion being its most worrying aspect (Embrapa, 1980). This is because during 1978 and 1979 there was a record in the number and size of erosions

gestated. In addition, the agronomist was the institution's executive director in the 1970s, being responsible for implementing a research planning and programming system. For Gastal, planning was not just about research programming, but about all the activities necessary to achieve institutional goals (Mengel, 2015).

recorded thus far, adding problems to the already known infertility in the Cerrado. Consequently, researchers observed a great loss of soil nutrients and water in the region. In several experiments, the main factor reducing this soil loss was better coverage with adapted forages and crops. In this regard, researchers obtained positive results when pasture and soy were used as cover during rainy periods. Several technological devices were used by researchers to measure the loss of soil due to climatic and water variations, amidst the cultures of wheat, soybeans, corn, and uncovered soil with conventional cultivation (Embrapa, 1980: 85).

But, in a general sense, this first moment of CPAC consolidation does not represent a turning point in relation to what became known as "the conquest of the Cerrado". In other words, in Brazil, until the beginning of the 1980s, there was no basic science that could deal with the problems of soil infertility and erosion. And therefore, we do not suggest that these pasture-soybean connection experiments simply "opened the gates" of Brazilian savannas to cattle and soy: first, because vast areas of pasture were historically occupied in the Cerrado since the 19th century (McCreery, 2006, Dutra e Silva, 2017). Also, because research on pastures and livestock was the responsibility of other Embrapa research centers, mainly in the state of Mato Grosso. And, above all, because before the expansion of soy production to Cerrado fields, farmers in this region experimented with other crops such as beans, wheat, and corn, which they considered to be less financially risky. Phosphorus fertilization along with other elements served as a kind of turning point, as we will see in the next discussion topic.

3.2. The battle of nutrients and micronutrients: CPAC and soil fertility research during political opening of Brazil

In the early 1980s, researchers continued to focus their research on the introduction of phosphorus into soils and the response of plants to nutrient application. However, at that time, there was still no consensus regarding the strategic planning for the development of new lands with high phosphorus fixation capacity. Environmentally, fertilizer dependence in Brazil was driven by anthropogenic action that caused the depletion of soil nutrients due to the lack of nutrient replacement. In contrast, CPAC's logic in the Cerrado was different: precisely to explore areas with soils of low natural fertility, or in the words of agronomists, "to build fertility". Therefore Embrapa's guidelines on the use of fertilizers were reassessed; and with that, regional studies were carried out by the institution, bearing in mind that phosphate fertilization substantially increased agricultural production. In the early 1980s, some results and conclusions were found that served as national models (Raij, Rosand & Lobato, 1982). In summary, if the first phase of soil fertility re-

search played a role in diagnosing the complexity of infertility, in the early 1980s CPAC established a real battle to identify which nutrients and micronutrients would have a better response in Cerrado soils.

Years earlier, in the late 1970s, studies had already shown that soil preparation for rice production and pastures was not well managed, as the correction of its acidity proved unsatisfactory and fertilization was insufficient. Another approach presented by the report for the period 1979/1980 was in relation to the results on the residual effect of the fertilizers, such as corrective fertilization and the fixation of nitrogen to the soil, among others. In the report, special attention was given to edaphic fertility, addressing the issue of soil acidity and the nutrients associated with it, such as phosphorus, organic matter, nitrogen, potassium, calcium, magnesium, sulfur, and micronutrients. In addition to soil management, the researchers also analyzed other related topics such as erosion and other forms of conservation of the edaphic quality of the Cerrado (Embrapa, 1981). The soil surveys described in this report sought to indicate viable solutions to combat acidity and also rationalize the use of nutrients. The report indicates that Embrapa researchers considered the low fertility of the soil as a result of the lack of nutrients, high levels of acidity, and aluminum saturation, in addition to low cation exchange and low levels of organic matter[9]. The research results allowed for the application of various types of alternative management, combined with different technologies, in addition to the use of credits and financing offered by the government. Among these management interventions, as indicated above, the use of phosphate fertilization stood out–demonstrating as points of attention the calibration of soil analysis methods for phosphorus, the fertilization levels, the effect of liming on the use of phosphorus by plants, the sources of phosphorus that could be used, the residual effect of fertilization, mycorrhizae[10] and the efficiency of phosphorus absorption (Embrapa, 1981). Years later, Embrapa researcher Edson Lobato was nominated for the World Food Prize, along with the then Minister of Agriculture, Alysson Paolinelli, and Andrew Colin McClung from the IRI, precisely because the latter presented research on phosphate fertilization

9. The low cation exchange is the low capacity of the soil to retain nutrients (cation exchange capacity). In the Cerrado, the cation exchange capacity is low, which gives the soil little capacity to retain nutrients, even with the use of fertilization. Therefore, research during this period was aimed precisely at correcting the phenomenon of low fertility. One of the solutions found was the use of limestone for soil correction and increased cation exchange capacity (see Sousa & Lobato, 2004).

10. Mycorrhizae are edaphic fungi that help plants absorb water and nutrients, especially phosphorus. The first research with mycorrhizae was carried out by the Embrapa team back in the 1970s. Regarding the environmental history of mycorrhizae, the LAHAC (Laboratory of Environmental History of the Cerrados) and SEDMO (Soil, Ecology and Dynamics of Organic Matter Research Group) laboratories have produced important works on this theme. For those interested, see Moura and Cabral (2019), Vieira Junior *et al.* (2020) and Moura *et al.* (2009).

(Silva, 2012), understood as one of the fundamental factors for the so-called "conquest of the Cerrado".

Differently from previous reports, with regard to minimizing soil acidity, Embrapa researchers carried out experiments with the planting of aluminum-tolerant species, incorporation of dolomitic limestone in the topsoil and leaching of basic cations (Embrapa, 1981). Other experiments tried to associate the planting and soil preparation systems with different levels of fertilization and erosion control. Among the experiments, we highlight the so-called *plantio direto* (no-tillage), a system developed by John Landers, an English researcher living in Brazil, which uses plant cover to prevent erosion, with superficial plowing (Ofstehage & Nehring, 2021). Soy was the crop used for tests in no-till agriculture. With these experiments, the objective was to improve the physical, chemical, and microbiological properties of the soil through soybean management, with different methods and times of incorporation of crop residues, and with the succession of different plantations (Embrapa, 1981). Soy later became the main commodity in the Cerrado, making the region the main area in grain production in Brazil, when considering the biogeographic division of biomes (Nehring, 2016; Dutra e Silva, 2020; Silva & Majo, 2021; Rocha *et al.*, 2022; Rocha, Nehring & Dutra e Silva, 2022).

The theme of low soil fertility was still a recurrent theme in CPAC reports during the 1980s. However, studies present a greater specialization, inserting other approaches beyond fertility, proposing research on the biology, management, and conservation of the soil. Research on soil fertility highlighted the use of natural sources of phosphorus in the Cerrado. Regarding soil biology, the results were presented by the researchers with the selection of *Rhizobium*[11] for the fixation of atmospheric nitrogen, in association with legumes (Embrapa, 1982). During this period, the "Use of Natural and Socioeconomic Resources of the Cerrado Program" addressed the low fertility of the soil on the *veranicos* (a dry spell, which is a period of brief drought and that usually occur in the Cerrado in January). The program sought to develop and adapt technologies to increase the efficiency of the use of inputs, "through biological nitrogen fixation, use of mycorrhizae, erosion control, organic matter management, adequacy of the mechanization system, and use of alternative energy sources" (Embrapa, 1982: 25). Researchers studied soil fertility using several methods: one of these added phosphorus to fertilization, when the calibration was not carried out, relating grain yield with soil phosphorus availability (Galrão & Volk-

11. *Rizobium* is a genus of bacteria that has the ability to supply nitrogen to plants. One of the greatest legacies with regard to studies on the inoculation of nitrogen-fixing bacteria was developed by the researcher Johanna Döbereiner, considered the mother of Brazilian microbiology. This technology currently saves $10 billion a year (Döbereiner, 1997; Moura *et.al.*, 2009).

weiss, 1981; Madeira Netto & Macedo, 1981). The results revealed that in the presence of phosphorus, the grain yield was higher (the test was performed mainly with the soybean crop, and later, with the cassava crop), so it was necessary to adjust the ideal amount of sodium that should be incorporated into the soil. Subsequently, research was carried out on the levels of phosphate fertilization. In this sense, the study continued measuring and analyzing the residual effect of phosphorus in the soil and in alternating crops that would follow, such as corn (Embrapa, 1982).

Several factors made it difficult to formulate an overview of the soil science to be applied amongst this immense battlefield where technicians worked to combat soil infertility. Therefore, soil acidity was also evaluated by technicians with different experiments, in which several attempts were made to alleviate this aspect, mainly due to the high level of aluminum and low amount of calcium, which affected root development[12]. Aiming at soil management and conservation, they used the following: green fertilization[13], mainly with leguminous crops (Embrapa, 1982), preparation systems, and ways of applying corrective fertilization in soybean production; and finally studies were carried out on the causes of erosion and the consequent loss of soil nutrients – the results showed a high degree of compromised productivity (Embrapa, 1982). In parallel, many other experiments related to nutrients and micronutrients were developed by CPAC, increasing the technical repertoire for the introduction of varieties in the Cerrado.

The concern of Embrapa researchers with agronomic studies and the ecology of the Cerrado was strengthened throughout the studies carried out by Embrapa, as shown in the reports. For example, the report produced on surveys carried out between 1982 and 1985 presented technological innovations for the employment of a database on the ecology and other environmental analyses of the Cerrado. The analytical option at that time

12. According to Resck (1981a, 1981b) and Resck *et al.* (1981). One of these experiments was to analyze the residual effect of lime applied in different doses at two depths; a priori, in a corn crop, there was a fundamental effect of limestone, with deeper incorporation. Aluminum was the main factor in reducing root growth in soils, but calcium deficiency was found to have the same negative effect on roots. Based on this, Embrapa technicians carried out experiments with calcium leaching, using a simple and inexpensive biological method of transferring pre-germinated seeds to plastic cups containing soil; later, measuring these roots, it was proved that calcium deficiency actually compromised the growth of these structures in the studied soil. Their experiments were carried out mainly with the cultivation of wheat, in periods of rain and dry spells (Embrapa, 1982).

13. According to information supplied by Embrapa, green manure can be defined as an agricultural practice based on the use of plants in farming that efficiently carry out the recycling of nutrients present in deep layers of the soil or even in the atmosphere. Generally they are legumes, grasses, cruciferae, or even cereals, which are applied in crops with the purpose of bringing greater fertility to the soil, due to the rusticity and strong root system of these plants (Espíndola, Guerra & Almeida, 1997).

was that of comparative studies from similar ecosystems, in which the Cerrado began to be analyzed as part of the global savannas. Technicians used the data and information produced by surveys carried out in northern Australia as a reference, which summarized the information on Earth's resources on a common spatial basis. Land systems were delimited under this model by means of satellites and radars, in two phases: the first reduced the information that was known about the Cerrado, through field work that homogenized the descriptive criteria; the second conducted a survey on the areas of greatest interest in the Cerrado, in which the researchers chose to analyze the geo-economic region of Brasília, the Federal Capital. The information collected characterized land, climate, landscape, and soil resources –which were "coded and stored in computerized files for which recovery, comparison, and analysis programs of these data were developed, as well as for printing maps" (Embrapa, 1987: 39). There was great concern on the part of researchers to gather existing data and increase information on areas not yet covered in compatible scales and methods. The results were presented in the form of unpublished and published works, including a soil map (Madeira Netto, 1983), which showed characteristics of climate, soils, vegetation, precipitation, and water deficit (Embrapa, 1987). This option was also based on the comparative conception of the Cerrado with other global savanna formations (Oliveira & Marquis, 2002; Pennington & Ratter, 2006), being also evidence that the use of the concept of biome was still something in construction at that time within Embrapa.

On soil fertility, research was aimed at meeting the nutritional needs of the planted crops. Therefore, research was carried out by Embrapa's team measuring the levels, sources, and times of nitrogen application in corn and wheat crops, in different types of soil and types of irrigation; as well as research with the calibration of soil analysis for phosphate fertilization in soybean and Brachiaria forage crop production, carried out in the municipality of Patos de Minas, in the state of Minas Gerais. As for the use of phosphorus, experiments were also carried out by them to measure the influence of the tillage system on the residual effect of phosphorus fertilization. Also, an agronomic evaluation was made by Embrapa's researchers of the phosphorus sources for the Cerrado region, in corn, Brachiaria and Andropogon forage grass crops (Embrapa, 1987).

Regarding soil biology, a major concern raised by researchers was nitrogen fixation. For that, several experiments were carried out by them such as the selection of strains of *Rhizobium japonicum*, *Rhizobium phaseoli*, and *Rhizobium leguminosarum*, inoculated to soybean, bean, and pea production, adapted to Cerrado conditions in different soils. Other experiments evaluated the effect of pesticides on soybean and pea nodulation, the selection of *Rhizobium* strains for forage legumes, in addition to the selection of efficient mycorrhizae species in different crops of coffee, cassava, and papaya. In this last research, the

effect of mycorrhizae on the yield of cultivated plants was also measured by them, aiming to improve the efficiency of phosphate absorption, with the multiplication of spores and the production of inocula, measuring the levels and checking the sources of phosphate (Embrapa, 1987).

Until the 1960s, studies on soil science considered that biological nitrogen fixation would be an alternative for edaphic improvement, but that it would be impossible to compete with mineral fertilizers[14]. However, the work carried out by Johanna Döbereiner on the biological fixation of nitrogen in tropical legumes was fundamental for the agronomic development in the Cerrado, especially after the Brazilian soybean improvement program. If we consider the green revolution processes in the United States, based mainly on technologies resulting from the intensive use of nitrogen fertilizers, Döbereiner successfully investigated the use of the *Rhizobium* bacteria in the biological fixation of nitrogen in the soil. These studies were important from an economic point of view because they helped to reduce the use of nitrogen fertilizers and made Brazilian agriculture more competitive in the international market (Döbereiner, 1997).

In this sense, the second phase of the CPAC studies demonstrates a certain advance in relation to the previous period, more focused on a diagnosis of infertility problems in soils. The repertoire of techniques created at that time has two distinct characteristics from the previous period: first, technicians deepened the experiments in fertilizers and fertilization. They had an important reference based on the study of samples that indicated good results at the beginning of the decade, especially using phosphorus. Secondly, these studies are contemporary with the increase in agricultural intervention in the Cerrado, from cooperation and colonization projects such as Polocentro, indicating the greater need for the knowledge produced in the institution to reach producers through technical assistance and rural extension. In contrast, although this phase of consolidation of research on soils at Embrapa promoted encouraging results for large-scale agriculture, it was still limited in comparison with the later period, which coincides with the Brazilian neoliberal governments, which in turn undertakes a greater relationship with private agribusiness companies. Therefore, in the next topic we will address how Em-

14. Regarding nitrogen, during this period the experiments with nitrogen fertilization in corn crop continued. With potassium and magnesium, the experiments took place in soybean and corn plantations, also with good results –as well as the sulfur applied in tests on corn crops. The micronutrients tested were boron, cobalt, copper, iron, manganese, molybdenum and zinc, but only zinc proved to be essential for cultivation, and these researches were carried out in rice, corn, soy, wheat and grasses. Another option used as a way to alleviate the nutritional deficiency of Cerrado soils was the green manure made with legumes; this method was used in the maize-wheat-maize-wheat sequence (Embrapa, 1985).

brapa and soil research were articulated in the democratic and neoliberal context between 1985 and 1995.

3.3. Agronomic development and the ecology of the Cerrado (1985-95)

The first decades of Embrapa were fundamental for the consolidation of its administrative structure and institutional identity. The institutional identity and mission were initially constituted based on statutes, custom, and convention, making impossible therefore, any action that would promote substantial changes in the company (Mengel, 2015). In the 1990s, Embrapa's investments and participation in the development and transformation of agriculture in Brazil were significant. At the beginning of the decade, the Cerrado accounted for 30% of national grain production and 40% of meat production (Embrapa, 1994). However, according to CPAC documents, the company's objectives continued to be linked to more ambitious national projects, such as the reduction of hunger that affected 30 million Brazilians (Embrapa, 1994). As can be seen, at the beginning of the decade there was a perspective of growth in the national agricultural production from the opening of the agricultural frontier in the Cerrado.

The agronomic challenges presented to the Cerrado were considered "second generation", and the reality of agricultural productivity in the region was no longer questioned. The focus was on developing technology that would overcome inappropriate land use. In other words, the Cerrado acting as an agricultural frontier in the period 1987-95 was a reality, and Embrapa's strategic actions aimed to reinforce broader objectives in relation to the Brazilian policy for agriculture. Considering the political scenario, after 1985 the country entered a process of re-democratization. This implied the extinction of some institutions created during the military regime and the creation of new institutions, guided by the new legal system under the Federal Constitution of 1988. In the case of Embrapa, the institution proved to be strong and expanded its powers to know the ecology of the Cerrado. The environmental challenges of the Cerrado was included in CPAC's schedules and projects at that time.

The 1985 to 1987 report presented a significant change from previous reports for two reasons. First, the environmental conservation concern goes beyond soil conservation against erosion. In this sense, agricultural modernization was associated with the development of sustainable practices for the conservation of natural resources, in general, that would guarantee the rational occupation of the Cerrado. Secondly, the report indicated that agricultural production in the Cerrado was a goal that had already been achieved, as this region stood out in the national scenario of food production. Thus, other goals

needed to be established, and among these, was the concern with the sustainable use of natural resources (Embrapa, 1991: 24).

Compared to previous studies, the report however did not present much news. Edaphic research still dominated most studies on the Cerrado, with an emphasis on fertilization and soil correction. Advances in research on the introduction and management of nitrogen and phosphorus in soils stood out. Regarding micronutrients, several experiments highlighted the effects of using sulfur, boron, copper and cobalt. These experiments took into account their effects on oxisols in the Cerrado, on crops such as soybean. Other experiments were carried out by Embrapa's team in order to incorporate the use of gypsum in Cerrado soils (Embrapa, 1991). As for soil biology, nitrogen fixation was a constant concern for them, and on this topic experiments were carried out to select *Rhizobium leguminosarum* (pea) strains adapted to savanna conditions. In the use of mycorrhizae, the phosphorus level was defined for the maximum effect of symbiosis in *Pinus* spp. and in *Eucalyptus* spp.; there was also a selection of efficient ectomycorrhizal fungi for *Pinus* spp. and for *Eucalyptus* spp. Other important points addressed in the research were the influence of inoculation of endomycorrhizal fungi on the use of residual phosphorus by soybean and the influence of soil and crop management (soybean, black velvet bean, rice, sorghum and cabbage) on the behavior of endomycorrhizal fungi in Cerrado soils (Embrapa, 1991). In soil management and conservation, researchers gave special attention to organic fertilization, aiming to make an assessment through comparisons of the level of degradation of organic matter in soils, under different managements, in virgin areas, forests, pastures, and in rotational monocultures (Embrapa, 1991: 107). In this context there was also an evaluation of the effect of the incorporation of green manuring and crop residues in the soil. Finally, the nitrogen mineralization of legumes was measured by Embrapa's team as green manure, under different managements, in a dark red oxisol, in addition to evaluating the legumes during the dry season (Embrapa, 1991).

A recurring theme between the late 1980s and early 1990s –when democracy supported popular yearnings for social justice– was the paradox between the advance of Brazilian agriculture and the persistence of low social indices, with an emphasis on persistent hunger in Brazilian society. Thus, the politicians or researchers that supported the expansion of the agricultural frontier in the Cerrado sought to incorporate social discourses into the scientific production of food. The reports reinforced the idea that Brazil had one of the biggest agricultural frontiers for the production of food, and instead of using the generic concept of Cerrado, they started to adopt the concept *Cerrado biome*. However, CPAC reinforced that this region still needed special attention in solving problems that impeded its further exploitation.

Another theme that appears in this period is the expansion of Graduate courses in Brazilian universities (Oliveira & Marquis, 2002) and the process of intense training of CPAC researchers. The documents highlighted the priority lines of research for CPAC in relation to the development goals of agronomic research in the Cerrado, with an emphasis on environmental characterization (survey and adaptation of existing studies of natural resources in the Cerrado); socioeconomic characterization (micro and macroeconomic analysis of the agricultural sector in the Cerrado); development of information systems (analytical procedures for storing/processing geo-environmental information and remote sensing); and environmental analysis (Embrapa, 1994). The CPAC, in partnership with the University of Brasília, created a doctoral course in phytopathology, with the aim of training new researchers for the region. In relation to the themes and lines of work, the report presented a continuity of previous researches and projects (Embrapa, 1994).

In the 1990s, CPAC had a more integrative posture with other Embrapa research centers, at least from the point of view of pursuing academic partnerships and cooperation. Thus, the reports sought to reinforce that the research was not carried out exclusively by CPAC, but that Embrapa's scientific project was carried out in a collaborative way, through a multidisciplinary team that involved national and foreign researchers[15]. It also highlighted the role of agreements and partnerships established, mentioning projects with CIAT/Colombia, CIRAD/France, ORSTOM/France, and the Japan International Cooperation Agency (JICA/Japan). What stands out in this last report, which highlights nearly twenty years of research by Embrapa, is that edaphic studies continued to have relevance within CPAC. Even in this period, with the agricultural frontier of the Cerrado expanding, once again researchers sought to develop projects that could minimize the limiting factors for greater exploitation of the then Cerrado biome[16] (Embrapa, 1997). But in gen-

15. Embrapa's reports generically indicated the composition of multidisciplinary teams. However, when observing the production of articles published in the period, it is possible to consider that there is a predominance of agronomists in the coordination and leadership of the studies. Other professionals linked to ecology, biology, veterinary medicine, botany, chemistry, in addition to other areas of engineering, were part of the work and scientific production team.

16. Edaphic research and experiments carried out during this period highlighted: the evaluation of the effect of savanna cultivation on methane and nitrous oxide fluxes; evaluation of the response of common bean to inoculation and nitrogen fertilization in two Cerrado soils; selection of *Bradyrhizobium japonicum* strains for soybean inoculation in soils with established populations of homologous strains; in addition to the use of gypsum in Cerrado soils. Studies related to soil and soybean showed a growing line, for example, in research on the effect of seed treatment with pesticides on soybean inoculation and on the efficiency of mycorrhizal fungi in plant growth at different levels of acidity and phosphorus in the ground. In relation to studies on the form of fertilization, it is worth highlighting the research on the variation in the response of plants to arbuscular mycorrhiza, as a function of the particle size of the phosphate fertilizer, and also on the efficiency of phosphate fertilization in two cropping systems in a red-yellow latosol. And within the sustainability projects, a research project

eral, even with all the advances in grain production in the Cerrado in the first half of the 1990s, the topic of ways to solve the limiting problems of the soil in the Cerrado remained on the CPAC scientific agenda. One of the hypotheses, as the report did not present this context, was the continuous expansion of the agricultural frontier of the Cerrado at that time to the bordering region among the states of Maranhão, Tocantins, and Bahia, currently known as Matopiba (Dutra e Silva et al., 2018; Boaventura & Dutra e Silva, 2021).

4. FINAL CONSIDERATIONS

Embrapa can be described as a successful case of a public company, associated with a national project for the development of agricultural research. One of the factors behind this success may be related to its organizational model and the consolidation of its identity, whose bases were built during the civil-military dictatorship and remained after the redemocratization process. The institutional identity reinforces that agricultural research projects had a degree of autonomy in relation to different governments and even to the Ministry of Agriculture over time. In other words, Embrapa was characterized much more as a state project than a governmental one. One of the points that reinforces this institutional identity can be seen in the internal debate that science establishes with itself. In other words, the internal scientific context matters more than the external political context – although with the frequent supply crises in the international context of the 1970s, food production also meant certain stability for governments.

If we consider global data on grain production, taking soy as an example, Brazil is the world's largest producer and exporter of soy. According to data from the Foreign Agricultural Service/United States Department of Agriculture, Brazil is responsible for 37.7% of world soy production. And 72.3% of all soy produced in Brazil is exported, which places the country as the largest exporter of this commodity in the world, accounting for 54.5% of all soy exported in the global grain and commodity market[17]. If these data are considered in a historical perspective, agricultural production, due in part by the creation of Embrapa, has grown very rapidly. In this sense, the role of the Cerrado in increasing grain production and productivity is significant. The Cerrado acquired a leading role in the advancement of agricultural production and productivity, as the region has stood out in the

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that investigated the use of sewage sludge as a source of phosphorus and nitrogen for corn stands out (Embrapa, 1997).

17. United States Department of Agriculture, Foreign Agricultural Service. Top Countries by Commodity (soybean) https://apps.fas.usda.gov/psdonline/app/index.html#/app/topCountriesByCommodity

production of different cultivars, when considering production by biomes (IBGE, 2019b; Imaflora, 2019).

The study on the topic of (in)fertility of the soils of the Cerrado contributes to the understanding of part of this historical process, especially when considering the advancement of production and productivity. According to Nehring (2016), this agricultural transformation should not be credited only to the role of national research institutions such as Embrapa, nor only to public policies aimed at agronomic development. He believes that these advances must be understood in the context of the Green Revolution and the technology transfer model, which aimed to modernize agricultural sectors on a world scale. In this sense, we highlight the strategic participation of institutions such as the Rockefeller and Ford foundations, which worked mainly with the Consultative Group of International Agricultural Research Centers (CGIAR), and during the 1940s to 1970s invested in the scientific training of human resources and in technologies. At the same time, this investment also had the ideological appeal of disseminating the principles of agricultural efficiency from industrial inputs (Perkins, 1997; Smith, 2009; Patel, 2013; Parayil, 2003).

The advance of western agricultural science has taken different forms around the world, involving different actors such as governments, private/philanthropic institutions, universities, among others. However, when historically the success stories of the Green Revolution are considered, surprisingly Brazil is rarely mentioned (Nehring, 2016). Even with the "Miracle of the Cerrado", in which the country achieved impressive gains in productivity and adhered to the model of agricultural industrialization, the agricultural history related to the Green Revolution does not present Brazil as a typical model. For Nehring (2016), this can be explained by the model adopted by Embrapa, which despite having involved collaborative work with United States specialists –one of the fundamental points for the objectives and methods of the Green Revolution–, had a strong national policy for the development of Brazilian agricultural research. The Rockefeller Foundation's pioneering role in the agricultural modernization of the Cerrado found a government actor who advocated more interventionist actions that differed from the work of the CGIAR in other countries (Patel, 2013; Silva, 1997). International cooperation, especially through technological transfer and scientific exchange with institutions in the United States, began to be redefined within Embrapa's institutional policies. This may be the reason why a large part of the initial research and cooperation work with the United States remained practically invisible, mainly that related to the Cerrado. Nehring (2016) states that Embrapa itself was concerned with maintaining this visibility and ensuring political support and legitimacy as a public research organization.

The agricultural history of the Brazilian region currently considered as the Cerrado biome has intrigued different areas of knowledge, whether because of the economic indicators related to agricultural production and productivity, or because of the rapid transformation processes of the natural landscapes of this ecosystem. The very use of concepts and the political form of mapping and territorial delimitation are indications that history, especially environmental history, has an important role in the critical exercise of environmental issues involving the Cerrado or any other ecosystem (Dutra e Silva, 2020; Dutra e Silva & Barbosa, 2020). The historiographical approach can be revealing, not only in considering the existing scientific and institutional processes, but also in bringing environmental elements to the debate. Thus, an environmental history of the Cerrado is challenging beyond the fact that it is more than simply being a biome. As we have demonstrated, this region presents historical challenges regarding the different moments of territorial occupation and socioeconomic elements resulting from the expansion of the agricultural frontier. In this sense, agronomic research helps to reflect, among other things, on the different processes related to the development and consolidation of institutions; the historical results of scientific investment and international exchange networks; and their relationship with broader socioeconomic processes, which go beyond national borders, evidencing what Donald Worster (1982) called the natural world without borders.

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