The barren side of Brazil: science, water resources, and the debate on the (in)fertile soils of the Brazilian cerrado, 1892-1942

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Abstract

This article discusses the relationship between science and the *cerrado* during the period spanning the publication of a text by Eugenius Warming (1892) and an article by Rawitscher, Ferri, and Rachid (1943), botanists at the University of São Paulo. Warming stated that scarce water resources affected the formation of the characteristic vegetation and low soil fertility in these regions. Arrojado Lisboa, Alberto Sampaio, Philipe Vasconcelos, and Barbosa de Oliveira proposed a variety of plans for economic exploitation of the *cerrado*. The article from 1943 indicated the rich water resources in the region, which helped to boost agricultural experiments. This article especially emphasizes studies on the diversity of vegetation in the regions containing cerrado-type vegetation formations and debates on the (in)fertility of these soils for large-scale farming.

Keywords: environmental history; *cerrado*; agriculture.

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"The soil is bad"

> From 1892 to 1942, so for 50 years after the publication of Warming's work, the idea persisted that vegetation in the Cerrado was limited by the scarcity of water. The German botanist Felix Kurt Rawitscher and Brazilian ecologist Mário Guimarães Ferri disagreed with this opinion. After the publication of this article, an intensive program of research on the savannas began, first at USP and later in different institutions in São Paulo and other Brazilian states (Santos, 1982, p.8).[1]

Research on the scarcity or abundance of water resources in the Brazilian *cerrado* marked the intensified debate on agricultural use of the region, particularly for Brazilian agronomists. Between the publication of a study by the Danish botanist Eugen Warming in 1892 (which was based on the idea that little water was available in the region) and research conducted by botanists from the University of São Paulo (USP) in 1942 which presented more optimistic results on this topic, many other studies attempted to interpret the land of the Brazilian *cerrado* from different viewpoints. Especially after the 1970s, this biome became the object of growing interest among researchers (historians, botanists, agronomists, social scientists etc.), governing bodies, institutions related to natural protection, private enterprise, and we cannot fail to mention the populations who live in this space; each party in its own way attempted to organize a set of activities and policies to preserve the environment or expand the agricultural frontier. In summary, the *cerrado* became part of the national agenda (whether for development or preservation) after Brasília was established as the capital.

In this sense, the central objective of this article is to discuss how the *cerrado* biome became an object of interest to different realms of science, especially during the first half of the twentieth century. To the extent that interest in incorporating this territory grew among national and regional elites (for example, in the movement known as the March to the West), arguments about the economic exploitation of this area also proliferated. However, effective economic exploitation often clashed with the notion that the soils in the *cerrado* were infertile, mainly due to the scarcity of water. Along these lines, this article attempts to demonstrate how the scientific projects were diverse and represented different institutional interests while there were no direct connections between the researchers. As a result, a significant quantity of knowledge that lacked interconnected dialog was generated and pointed in different directions: intensification of livestock raising, forestry, and extractivism, for example. Much more than a horizontal or synchronous dialog with contemporary researchers, the trend toward verticalized or diachronic production of knowledge, in which researchers from the Republican period resumed the studies performed during the Imperial period by the European naturalists Carl Friedrich von Martius (1794-1868), Peter Wilhelm Lund (1801-1880), or Eugenius Warming (1841-1924), yielded practically the same results: the potential scarcity of water would limit the progress of agricultural experiments. But during Second World War, Warming's previously paradigmatic theory related to soil fertility and (in)availability of water resources was

gradually supplanted by research by Felix Rawitscher (1890-1957), Mário Guimarães Ferri (1918-1985), and Mercedes Rachid in 1943.

The articles published by these USP botanists influenced a generation of agronomists, soil scientists, and other researchers. The post-1945 *cerrado* gradually became a fundamental space for agricultural production in the imagination of the elites because of the possibilities offered by fertilizers as well as the climate and topography which favored large-scale production (Silva, 2012). More recently, when the region's potential for agribusiness was demonstrated, a symbolic dispute to "discover" or "conquer" the *cerrado* regions was undertaken, mainly by researchers from public institutions and private agencies: "the vigor of agriculture in the *cerrado* regions is often mentioned," says professor Antonio Brito da Cunha of his colleagues from the University of São Paulo, "but few are aware that it was the work by Rawitscher, Mário Guimarães Ferri, and their colleagues that made it possible for this enormous portion of the national territory to be utilized" (Coelho, 1993, p.6). Meanwhile, in October 2006 the World Food Prize (WFP, considered the Nobel of agriculture and created in 1986 by the American agronomist Norman E. Bourlaug) was awarded to other individuals considered responsible for providing access to this biome as an agricultural frontier (Silva, 2012).

In addition, contributionsby various "forgotten authors" from the First Republic period demonstrate how such plans to economically exploit the *cerrado* regions were historically constructed from empirical perceptions among a generation that left their offices for the Brazilian hinterlands with a desire to contribute in civilizing this territory. While ranching predominated after the end of World War II, the dialog with these authors shows a more complex network of visions and projects that were abandoned because they tended to concentrate economic activities into simplifying approaches, to use the term coined by James Scott (1999, p.87), in an attempt to summarize aspects of a complex world, particularly with the introduction of monoculture farming.

Cerrado, *cerrados*: a brief history of the different uses of the term

The definitions, limits, and characteristics of the *cerrado* do not form a consensus.[2] Especially after the publication of the article "O conceito de cerrado" ("The concept of *cerrado*") by Leopoldo Coutinho (1978) there were doubts as to which *cerrado* was being referred to (in the words of this author), since the term can refer to a biome, phytogeography, physiognomy, and more recently a bioregion in the sense of managing human and natural resources, as suggested by Miller (1997). Walter (2006, p.49) points out that since the time of von Martius, "more than 774 terms or expressions" have been used in relation to the nomenclature for the vegetation in this biome. It is consequently important to reinforce that even today there are disagreements about the characteristics, denomination, or even the extent of the region that can be classified. For example, the study by Rivera-Lombardi (2003, p.27) on intentionally set fires in the region used spatial imagery and found that soils with the characteristics of *cerrado* grasslands were present in Brazilian states within the Amazon region, which questions the notion of a biome or phytophysiognomy that virtually extends into central Brazil and neighboring areas.

Another point that demonstrates the difference between researchers can be seen in how the term is written, which demonstrates the position held by these authors in relation to the topic under study: Rivera-Lombardi (2003, p.27), for example, used Savanna or *Cerrado* (capitalized) "to represent the predominant biome in central Brazil," and *cerrado* (lowercase) "to represent a physiognomic type of this biome" (p.27). The uppercase spelling also represents the political stance of valuing this vast territory as a biome, particularly at the time of the 1988 Constitution, "which left out the Cerrado" (Sautchuk, 2011, p.22). For the purposes of this article, before looking for potential consensus, we will investigate the different uses of the term *cerrado* by researchers and scientific institutions, even when it is used in referring to different parts of what today is understood to be the *cerrado* biome. These studies, as we shall see, compose a true mosaic and address different regions of Brazil (the transition region in Mata dos Cocais in Maranhão, the interior region of the state of São Paulo, and the Araguaia-Tocantins Valley, among others) that were later arranged under a broader concept of *cerrado*.

The *cerrado* is considered "part of the global family of the savannas"[3] and "the major ecological domain of central Brazil, sprawling over two hundred million hectares (and also with some enclaves in Amazonia, especially in Roraima)" (Pádua, 2009, p.133). As for the history of anthropic interaction, unlike the Brazilian coastline where "Tupi-speaking peoples" predominated, the *cerrado* "was occupied by peoples of the Macro-Jê branch" (p.133) who interacted and formed a landscape which was different from other regions in Brazil. For example, fire is a constitutive element of the environment (Posey, 1987) that helps form a landscape characterized by the existence of medium-sized trees with "twisted trunks and branches, deep roots, and adapted to less rainfall" (Pádua, 2009, p.133) which features five distinct physiognomies: "*campo limpo* (grassland *cerrado*), *campo sujo* (open *cerrado*), *campo cerrado* (scrubby *cerrado* transition area), *cerrado sensu stricto* (true *cerrado*) and *cerradão* (dry forest)" (Rivera-Lombardi, 2003, p.22).

The origin of the term dates back to colonial times, when *cerrado* was connected to the Iberian tradition, closer to the idea of "closed" (*cerrado* in Spanish): *mato cerrado* (closed forest), *cerrado denso* (dense *cerrado*), wild areas that were inhospitable or difficult to cross. Bernardino José de Souza (1884-1949) defined *cerrado* vegetation as "tangled woods with a proliferated mass of brambles and vines" (Souza, 1939, p.128). Similar definitions were found in the literature from the nineteenth and twentieth centuries. At times this understanding of the term (which is distanced from the concept of the biome) is used in both popular and academic language; an initial example can be found in Clado Ribeiro de Lessa (1896-1960) and his *Vocabulário de caça* (*Vocabulary of hunting*). In this work, the *cerrado* is mentioned within the parameters of hunters, namely understood as a "*capoeirão* (cleared area which still contains shrubs and bushes) where tortuous trees and intertwined vines abound, making it difficult to see the quarry" (Lessa, 1944, p.51). The American geographer Preston E. James (1899-1986) provided a pragmatic example when he referred to the *cerrado* as "A type of vegetation which is truly intermediate between a typical savanna where the scattered trees permit travel with a Jeep in any direction and a forest in which travel is restricted to cleared routes" (James, 1954, cited in Hueck, 1957, p.68).

To a certain extent, the use of the term by Preston James recalls Viscount Beaurepaire-Rohan (1812-1894) and his *Dictionário de vocábulos brasileiros* (*Dictionary of Brazilian words*) (1894), also mentioned by Bernardino José de Souza, which "distinguishes *'cerrado fechado*,' when the trees are closer to each other, and '*cerrado ralo*' ['sparse *cerrado*'] when they are farther apart so that animals can pass through more easily" (Souza, 1939, p.128).

But the studies that formed the debate on the *cerrado* date back to the nineteenth century. The writings by the Bavarian naturalist Carl Friedrich Philip von Martius and the Danes Peter Wilhelm Lund and Johannes Eugenius Bülow Warming became obligatory references for those interested in this topic, which was not the case with the lesser known studies by the engineers James Baylis (1803-1876) and Gustavo Luis Guilherme Dodt (1831-1903), for example. During the first decades of the nineteenth century, von Martius established an initial overview of Brazilian phytogeography, establishing "a style of interpretation and iconography that highlighted the concrete spatial diversity of Brazilian nature" (Pádua, 2009, p.120). In the 1850s, von Martius drafted "a first phytogeographic map of the country, the *Provinciae florae brasiliensis*, which used neoclassical imagery to divide the vegetation into five kingdoms dominated by deities from Classical Antiquity" (Pádua, 2009, p.120). Within von Martius's classification, the region known today as the *cerrado* comprised the "kingdom of the Oreads" within the "great biogeographical and vegetative domain of the Brazilian Plateau and Midwest," according to Bertran (2011, p.62).

Studies on the *cerrado* were significantly and influentially systematized after 1860, when the Danish botanist and professor at the University of Copenhagen Johannes Eugenius Bülow Warming settled in the mining town of Lagoa Santa to observe the flora of the region. Warming's studies, which were originally published in 1892, had repercussions in Europe and were translated into Portuguese in 1908 (Klein, 2002, p.9-10). He followed in the footsteps of the zoologist Peter Wilhelm Lund, who himself had established himself in the region years earlier; the writings of both scientists became a reference for subsequent generations and continued to be the central studies on the *cerrado* at least until 1943, when a group of botanists from the University of São Paulo (Rawitscher, Ferri, and Rachid) cast doubts on some of the principles espoused by these Danish researchers. One of the foundations of their hypotheses was that the region covered by *campos cerrados* did not have sufficient water reserves for economic exploitation, especially for agriculture. Although Warming did not maintain that the *cerrado* was inappropriate for agricultural use (since his studies were not founded on high crop productivity, a topic that expanded in Brazil throughout the twentieth century), the idea that water resources were limited dominated thinking in the first half of the twentieth century, and was only firmly questioned after initial studies by botanists in the 1940s.

The *cerrado* in the early years of the Republic

At the end of the nineteenth century and in the early decades of the twentieth, the *cerrado* was not included under the gaze of science in specific monographs, but rather in publications that addressed the issue as one component of mapping the different phytogeographic regions. Few texts dedicated specific chapters to this topic; it is included

in attempts to compare different landscapes. This argument is clearer in the work by Roy Nash (1895-1975), which will be discussed later. And in *Oeste de São Paulo, sul de Mato Grosso* (*West of São Paulo, south of Mato Grosso*) (1909), the geologist Miguel Arrojado Lisboa (1872-1932) stated that Brazil's physiognomy is intermingled with the savannas: "The *campos cerrados* are the vegetative formations of the plateau, which because of their considerable extension comprise the facies of the country" (Lisboa, 1909, p.113). In part of his study, Arrojado Lisboa attempted to differentiate the vegetation of the region, characterized as "*campos limpos*" and "*campos sujos*." He described the first as a "field without a sub-shrub layer, with only grasses and creeping plants that form isolated and narrow *restingas* [sandy areas], on the humid slopes of streams, also the plain on the far western edge of the plateau (in Mato Grosso). *Campo limpo* is principally a "wooded or scrubland region with a carpet of grasses, with large-scale arborous vegetation that is sufficiently spread out to allow not only free passage of cattle, but also galloping horsemen using a lasso." Meanwhile, *campo sujo* was characterizedas a set of "herbs and grasses" as well as "shrubs and other plants." The "*cerrado*" therefore has "denser or sub-arborous vegetation that is sufficiently developed to choke out the carpet of grasses, blocking or hindering the passage of cattle" (Lisboa, 1909, p.113).

According to his own division, Arrojado Lisboa determined that the soil in the *campos cerrados* was of little value for agriculture. He judged them capable of transformation into good pasture, and noted the opinion of local populations about the infertility of the soils: "The soil is bad," the inhabitants state bluntly (Lisboa, 1909, p.114). Historically, this argument that the *cerrado* was not a suitable place for agriculture dates back to reports by eighteenth-century engineers. In a report from Imperial times, James Baylis (who was hired by the Public Works Construction Company in 1875 to conduct an expedition that investigated connecting the São Francisco River Valley with the Araguaia and Tocantins River Valleys), reported "sandy soil, and not always suitable for agriculture" (Baylis, cited in Oliveira, 1941, p.49). A few years earlier in a report from 1871, the engineer Gustavo Luiz Guilherme Dodt, who was responsible for mapping the Parnaíba River (Gandara, 2013, p.52) in 1867, wrote an opinion similar to that expressed by Baylis on what he considered the general characteristics of the vegetation: "As in my report on the establishment of a resulting agricultural colony, that every part of the province where it is located is only suitable for livestock" (Dodt, 1939, p.78). The expansion of the territory would assist in agricultural production, but not replace livestock as the main element in the economic sector: "It has sufficient land, which lends itself to agriculture in order to produce the food needed for a population much greater than it currently has", but "in no way can be considered an agricultural province" (Dodt, 1939, p.78). Gustavo Dodt (1939, p.79) did not believe that this meant that crops should be abandoned, even if they were not as productive as in other areas of the country: "It seems to me that the main object of an enlightened administration," in this sense, "should be to wrest livestock ranching from the current state it is in and base it on rational principles while simultaneously developing industries which are directly connected to it." The issue did not lie in natural resources, but rather in the "backwards" and "routine-based" population, a debate that would mark the final decades of the Empire as well as the early decades of the Republic (Lima, 1999).

With its plans for nation-building and studies on the general characteristics of the regions and populations beyond the coastal areas, the Republican era included efforts such as the scientific expedition of Arthur Neiva (1880-1943) and Belisário Penna (1868-1939) in 1912 to Piauí, Pernambuco, Bahia, and Goiás.[4] At that time, the region where the *cerrado* was located was the focus of scientific expeditions conducted by Brazilian and foreign scholars, such as the engineer and naturalist Álvaro Astolpho Silveira (1867-1945). In a chapter of his book *Floras e serras mineiras* (*Flora and mountains of Minas Gerais*) (1908), Silveira describes aspects of the *cerrado* regions in the vicinity of Lagoa Santa, which had previously been visited by Warming and Lund.

Like other later authors, Silveira (1908, p.166) described the vast diversity of flora found in the region: "*Cacheta* [*Tabebuia cassinoides*], *gaiteira, piquizeiro* [*Caryocar brasiliense*], *jatobá* [*Hymenaea courbaril*], *jacarandá, vinhático-do-campo* [*Plathymenia foliosa*], the ironwoods, *quina-do-campo* [*Strychnos pseudoquina*], *sucupira* [*Pterodon emarginatus*], interspersed with wolf apple [*Solanum lycocarpum*], various cassias, *muricis* [*Byrsonima crassifolia*], small palm trees, *gravatás* [*Bromelia balansae*]," as well as "other low plants and shrubs, all growing amid 'round grass' or 'field grass' that uniformly covers the land" (emphasis in the original). The description of the specific characteristics found in part of the *cerrado* regions was intended to present the popular names of species in the region to other specialized readers, even those species previously named by von Martius, Warming, Lund, and others. With this swarm of terms which were probably unknown to botanists who did not study the *cerrado* and to readers in general, Silveira's description of so many flora species was meant to highlight the richness of the flora in the region.

In the texts approached herein there is consequently no attempt to define the *cerrado* or a general attempt at classification, although they did try to reinforce certain characteristics, especially those hinting at the diversity and impassable nature of the environment: "The dense *cerrado* with its characteristic tortuous trees," as Silveira stated (1908, p.166), was previously described as more inhospitable by Luís Cruls (1848-1908) in his *Relatório da Comissão Exploradora do Planalto Central do Brasil* (*Report of the Brazilian Central Highlands Exploration Commission*), which was originally published in 1894 and reprinted in 1947. According to this Belgian explorer, the term *cerrado* was connected to the idea of dense vegetation that was difficult to traverse: "The *jatobá* [*Hymenaea courbaril*] or *jataí* is one of the most voluminous specimens in the forests of Goiás, and also stands out among the plants of the *cerrados* because of its size" (Cruls, 1947, p.136). In addition to the idea of dense forest, the region and its vegetation were mentioned for their enormity ("through extensive *cerrados"*, p.91), specific nature ("I was finally able to definitively camp on the slope of a slight plateau covered with small, regularly spaced trees that the Goiánians call a *cerrado*," p. 92), or admiration.

Cruls admired the expanse of the backlands. This admiration was particularly visible in the terms he used: the vegetation is "shriveled," the trees "exuberant," "great" and "of excellent quality," while "the other creeping plants" are notable for their "beauty, and brightly colored flowers." From another perspective, in the 1920s the American historian Roy Nash, in his book *The conquest of Brazil* (1939), addressed the theme in an attempt to explain to readers in his country a landscape which was so different in his

eyes. He interpreted the *cerrado* as part of large Brazilian fields present throughout a large portion of the country. To Nash, the *cerrado* was located within the general descriptions of Brazilian grassy landscapes, which were continuous from the southern region. In describing the Brazilian grasslands, Nash referred to the *cerrado* as part of a continuum of fields that advance from the southern region (the Pampas) to what is currently the Northeast (Caatinga), establishing a scale which begins in the open plains of Rio Grande do Sul to the "stunted" vegetation farther to the north; between these extremes were the grasslands characteristic of the Caatinga and *cerrado*. In this part of the text, Nash did not distinguish between these two formations, since his discussion focused on the formation of grassy landscapes in general terms. Similarly (to return to our previous line of argument on this topic), during the period preceding Getúlio Vargas's first administration (1930-1945), the scientific literature did not attempt to differentiate the phytogeographic formations of the central region of the country. Although the Amazon and Atlantic forest were "demarcated" for practical purposes during this period, the writings of von Martius and his phytogeographic definitions still influenced the work of these scientists with comprehensive concepts. In other words, the *cerrado* was still not what later would be recognized as a biome, and the phrase attributed to Luís Cruls mentioned above ("that the Goianians call a *cerrado*") is significant in this sense.

The density of the *cerrado* was frequently emphasized in the scientific literature of the first Republican period. As knowledge of the territory became a necessary task in order to incorporate inland populations and natural resources into the country (Lima, 1999), the *cerrado* was usually described as inhospitable, dating back to the emergence of the term itself ("dense vegetation that is difficult to access"). The admiration for the richness and unique nature of the arboreal formations was also seen among the scientists interested in recognizing the territory; this characteristic extends into other periods, as we will see in the following section. What is important to address here is that the *cerrado* was not isolated from other phytogeographic regions in the narratives by these authors: it was not a biome or specific phytogeographic region, although the region was recognized as *cerrado* in certain parts of the territory because of its botanical characteristics. The bioregion was also not defined as completely differentiated from other formations such as Amazonia or the Atlantic forest. As we have seen in the narratives by Luís Cruls and Nash, the *cerrado* existed in a relationship of continuity: to Cruls, who was interested in understanding a specific region of the territory, the *cerrado* was part of the "sertão" badlands and bordered the Caatinga, featuring grasslands that differed greatly from those in Amazonia or the Atlantic forest, and Roy Nash's argument in this regard was explored above.

The division of Brazilian flora regions proposed by von Martius continued to hold sway over the following years for botanists like Alberto José Sampaio (1881-1946), but as interest from other knowledge areas grew with regard to this topic, there was gradually more differentiation within the composition of these plant formations. While at this time the *cerrado* was referred to as grasslands, plateaus, differentiated tree formations, and a certain variety of species, the concept of *cerrado* gradually became more comprehensive in terms of the region (to encompass all the regions of Brazil), more complex (forests or dense woods, *cerradão*, *campos cerrados*), and better defined (as opposed to Atlantic forest,

Amazonia, or Caatinga, for example). This is all because at the end of the first Republican period, westward expansion displaced a large number of people to these regions, along with scientists from various knowledge areas who were increasingly interested in the study of the *cerrado*. We shall mention some of these researchers below who illustrate the changing interest in this subject during that period.

Botany and studies for agricultural uses: different approaches to the *cerrados*, 1930-1945

In the period following the end of the First Republic, new and more comprehensive studies that directly or indirectly addressed the *cerrados* were conducted by researchers from Brazil and abroad, involving different institutions. The expansion of scientific production on the *cerrado* was greater and more complex than in the preceding period. At this point two general interpretations of the subject can be proposed: the first, which is closer to botany (but not exclusive to this subject), attempted to survey the characteristics and diversity of the *cerrado*, especially its flora, while the second addressed economic exploitation of these regions. Or, as Barbosa de Oliveira (1941, p.7) wrote with regard to the central portion of Brazil, "countless study committees have been organized in different eras, some for purely scientific purposes, others targeting the establishment of steam navigation or railways." Later they also addressed agricultural use and colonization.

In an example of the first approach, Frederick Charles Hoehne (1882-1959) made some brief mentions in this regard in his book on agriculture and botany in colonial Brazil. In this study, the *cerrado* was understood as almost a "backdrop," as the space housing certain species of Brazilian flora which were more evident (Hoehne, 1937, p.99, 221, 226); outside the field of botany was Afrânio Peixoto (1876-1947), who mentioned the "grassland zone," i.e., "the savannas of central and southern Brazil," only as an example of the environment's influence on living conditions for Brazilian populations (Peixoto, 1938, p.105). Archeological studies of this period also mention the *cerrado*, for example a text by Hannibal Mattos (1886-1969) describing explorations in Lagoa Santa, where Eugene Warming had been decades earlier (Mattos, 1941).

On the other hand, a broader approach to the *cerrado* was seen in 1934, even as part of a larger scheme of interpretations of the different Brazilian landscapes was proposed by Alberto José Sampaio, a professor of botany at the National Museum. In that year, Sampaio published a course he had led two years earlier under the title *Fitogeografia do Brasil* (*Phytogeography of Brazil*). Taking a nationalist tone, Sampaio (1934, p.240-241) attributed scientists a fundamental role in conserving and better utilizing natural resources: "In the field, in the jungle, it is immersed in nature that scientists are made," he stated, and that botany is "essentially a science of the *sertões* [hinterlands], where its true original fields of study lie." In this way, Sampaio adapted the systematic approach of Adolf Engler[5] and divided the country into two "floristic or geobotanical provinces," Amazonian Flora/Brazilian Hileia and General Brazil/Extra-Amazonian Flora, which contained the Coconut Groves Zone, the Caatingas Zone, the Coastal Forests/Eastern Forests Zone, the Araucaria/Pine Forests, the Maritime Zone, and the Grasslands Zone

(Sampaio, 1934, p.84). Extending this argument, the region currently understood to be *cerrado* was distributed within the two main regions (Amazonian Flora and General Flora), predominating in the latter region, and was divided among the other subdivisions of Extra-Amazonian Flora. In this way, Sampaio demonstrated that there were no fully demarcated borders between what we today call biomes, but rather that the characteristics of a large area could be found within another area on a smaller scale; for example, *aroeiras* (*Astronium* sp.) were found in the southern region of Pará (Amazonia), trees which are "very characteristic of central and northeastern Brazil" (Sampaio, 1934, p.84). Meanwhile, Amazonian Flora advances into states like Maranhão (Extra-Amazonian), forming "eyelash-like riparian structures in the northern part of the state" along with "large coconut groves or immense forests of babassu palms that characterize the central northern region" (Sampaio, 1934, p.84).

In looking for a broader interpretation of the different Brazilian flora formations, this author did not specifically address the *cerrado*, but rather the phytogeographic characteristics of the *cerrado* in relation to other formations: "In Brazil, the largest area, General Flora, is also grassland, with grassy savannas or fields without trees from Goiás to the south, and savannas or wooded grasslands predominate," he states, "especially in Minas but also from Rio Grande do Sul (savannas or coastal grasslands) to the far north of Amazonia" (Sampaio, 1934, p.86). The "Coconut Groves Zone" mentioned by Sampaio and located "mainly in the state of Maranhão and part of Piauí" was "basically characterized by concentrations of palm trees" such as "groves of babassu, carnauba, buriti, and açai palms." In this area "also occur *campos cerrados*, *caatingas*, sandy regions, aquatic flora in ponds, lakes, and rivers, riparian vegetation, and even Amazon forest. It was a transition zone between Amazonia and the Northeast" (Franco, Drummond, 2005, p.145). The *cerrado* was consequently not only part of the "Grasslands Zone," as Franco and Drummond maintain (2005, p.147) with regard to Sampaio's work, but was already scattered among the other regions that comprised Brazil. And while the botanist proposed that the nation should "infiltrate the hinterland" to create a "prosperous and happy rural population," historians recall that Sampaio opposed uniformization of the landscape (Franco, Drummond, 2005, p.147), which was so common in areas where monocultures were prevalent.

We can consequently observe that in the early 1930s, efforts to build models of the different Brazilian landscapes comprised a rich mosaic (at least for Sampaio), without completely demarcated borders, full of optimism about floral diversity and potential economic exploitation. But although Sampaio briefly mentioned the possibility of using the "Grasslands Zone" as a space for settlements of rural populations, it should be noted that the work in question, which was dedicated to the study of Brazilian phytogeography, did not propose systematic occupation schemes in the *cerrado* or any other area. During the following period, on the eve of the March to the West (1940), the second argument appeared: studies on agricultural utilization of the *cerrados*.

"The very *cerrados* and *cerradões* so scorned by our people are not so useless:" studies on agricultural use of the *cerrado*

Sampaio's contemporary Phillipe Westin Cabral de Vasconcellos (1892-1986), an agronomist with the São Paulo State Forest Council and later director of the Escola Superior de Agricultura Luiz de Queiroz (ESALQ) and editor of the *Revista Agricultura*, utilized a historical perspective to address the traditional use of this space in the inland region of that state as pasture in his "Do valor e da exploração dos cerrados" ("On the value and exploitation of the cerrados"), which he presented at the first Brazilian Congress of Agronomy in 1936 and published four years later. Here the approach differed greatly from Sampaio, placing the debate on the *cerrados* firmly within the realms of agronomy, and consequently seeking to also understand potential agricultural uses. For Vasconcellos (1940, p.822), in the state of São Paulo a large number of "good" properties were fetching increasing prices, while the "bad" properties "did not produce what would be expected from rational agriculture." This movement to utilize infertile land was growing in the state, neglecting the *cerrados*: "The truth is that some farmers have already been looking to establish pastures sown under thin groves of trees, in a truly integrated forest-pasturecrop" (p.822). Vasconcellos was aware of the rising land prices, and considered that "in those [lands] that are cheaper because of their poor composition, bad topographic situation, or where there are other obstacles such as excessive stones that it [agriculture] will find its place" (p.822). Utilization of these spaces for agriculture was consequently not very profitable and very laborious.

Instead of these lands, Vasconcellos (1940, p.822) proposed utilizing the *cerrado* in São Paulo: "Our *cerrados* are notable for their good topography, in general, but the composition of their soil leaves much to be desired." In his view, the *cerrado* was not only the result of the "natural conditions" that produced these formations, but the poor fertility of the land had an anthropogenic influence, as demonstrated in the following argument: the large quantity of sand, "the poor quality of the binding material, the dryness, and the tannic material dropped by the plants" lead to an acidic humidification "where sub-eropyta flora [*sic*] finds its habitat" (p.822). Because of the large amount of organic material generated, the soil would not be depleted, which would change after human interference: "However, men working to feed their cattle new growth constantly set fire to the vegetation, and also utilize the wood" (p.822), without letting the environment reestablish itself. Anthropic activity also appears in Vasconcellos's argument, since he states that "many of today's fields were formerly *cerradões*," in other words, forests that became grasslands and were consequently no longer able to produce "arboreal vegetation." Reforestation was then proposed as an alternative: "We should look after this as soon as possible by investigating reforestation of these grasslands if we do not want to have true sandy deserts with risks to neighboring land" (p.822).

The following argument demonstrates the economic usefulness of these formations: "The very *cerrados* and *cerradões* so scorned by our people are not so useless," stated the author; here "lives a flora rich in fruiting plants," as well as tannin-containing and medicinal species (Vasconcellos, 1940, p.825). With this, Vasconcellos criticized the forms

of land use in the interior of São Paulo state, as well as the process of "repressing worthless species," in other words, species without commercial value but whose "function in the biological equilibrium of the flora" was still not known (p.825). Based on his experience on a 185-hectare property, this author suggested that management for lumber production should be reasonable, allowing up to 5 years for the species to regenerate: "The owner could directly utilize the harvest, but the more general rule is to sell to a railway supplier or to cities," since "in an isolated village these people spend their free time in gardens, small fields, and caring for livestock" (p.827-828).

In conclusion, Vasconcellos (1940, p.828-829) proposed that the natural or deforested grasslands "should be the first in the state to be reforested," introducing natural and exotic species for economic uses. According to his suggestions, activities in these areas would include "testing integrated forest-livestock production" and advising loggers to "clear cut when they plan to reestablish [the forest] through coppicing" (p.829). As for the "worthless species," the author suggested not eliminating them completely, mainly because "their function in the biological equilibrium of the flora is not known" (p.829); they should consequently "be cut under the same conditions as the exploited [species], so that they do not form solid stands which are not useful" (p.829).

Vasconcellos's approach shows a break with the other texts mentioned previously because of his specific suggestions for experimentation in the *cerrado*. Assuming that some areas of the *cerrado* in São Paulo were heavily modified by human activities, Vasconcellos proposed rational exploitation of these areas, reintroducing native species and utilizing other exotic species for commercial purposes. The richness of the *cerrado* was still unknown, and the author's conservationist aspirations were expressed in his appreciation for "worthless species," in other words, for advising against the destruction of flora along with their properties which were not yet known to science. The commercial exploitation of the *cerrado* was a fundamental topic in Vasconcellos's article. In the following decade, two other studies (this time in the form of technical reports) investigated the central regions of Brazil identified by the occupation of the *cerrado*, with a much stronger emphasis on commerce.

"A great opportunity for the future of the Brazilian economy:" the Tocantins-Araguaia Valley Navigation Commission and the Cooke Mission in Brazil

The report of the Tocantins-Araguaia Valley Navigation Commission was published by Américo Leônidas Barbosa de Oliveira in 1941; within the perspective of the New State and the movement to expand westward, this report sought to incorporate the central and northern regions of the nation by exploiting their natural resources. This author believed that the central government would look for ways to "support private initiative and foster progress throughout the vast valley," which in his opinion was "far from being the rich and bountiful Canaan it has been proclaimed to be" (Oliveira, 1941, p.7). Although the central issue was the exploitation of the Araguaia and Tocantins Rivers, Barbosa de Oliveira returned to the studies by Arrojado Lisboa in an attempt to attribute potential economic value to the banks of these rivers: "The *campos cerrados* of Mato Grosso" are "comparable to those in Minas Gerais and southern Goiás," but superior to those of the São Francisco

River because they are located "in a region that is better irrigated by abundant creeks and perennial streams" (Lisboa, 1909, p.141). Barbosa de Oliveira maintained that if these areas were irrigated, they could be modified for cultivation: "It is clear that human intervention can alter the ecological framework of an entire region through forestation and irrigation, which transforms deserts into fertile and productive valleys," he wrote. In this way, "the progress of machinery provides man with resources to build artificial rivers and grow the crops he wishes, transforming the face of the earth through intensive colonization" (Oliveira, 1941, p.51). On the other hand, the author did not consider the large investment needed to irrigate these areas reasonable. He believed that there were more fertile areas with more rainfall in other areas of the country that were worth exploring before the *cerrado* regions of the Tocantins River, "but it costs money. Astronomical and staggering figures in comparison with what is available" (Oliveira, 1941, p.51).

In contrast with Vasconcellos, Barbosa de Oliveira argued that there were other areas that could be exploited before turning to parts of the *cerrado*, such as those bordering the Caatinga and near the São Francisco River. And in the second report from the early 1940s, which was written in 1942 (published in 1949) by the American economist Corvin D. Edwards (1901-1979) of the Cooke Mission to Brazil, the *cerrado* was only mentioned once, as an example of a region like Amazonia which has not been widely exploited by civilization. He initially referred to the "majority" of the Amazon rainforest, "expanses of tropical jungles and equatorial forests" which had not been exploited "by civilized man," the "forest provides access" in an eastward direction "to the land of sparse forests and plains covered in *cerrados*, with scarce rainfall and frequent droughts" (Edwards, 1949, p.77). The region where the state of Goiás is located, which houses a large portion of the *cerrado*, was only mentioned with regard to its potential for inland navigation or mineral exploration, unlike the report by Barbosa de Oliveira (Edwards, 1949, p.77). While the Tocantins-Araguaia report mentioned the *cerrado* region closest to the São Francisco River basin and the difficulties of irrigation there, the Cooke Mission report addressed another area closer to the Araguaia River that represented "a great opportunity for the future of the Brazilian economy." According to the Cooke Mission report, "most of the soil is fertile; its forest resources remain unexploited and underutilized, and its mineral resources have hardly been recognized" (Edwards, 1949, p.78).

Because of its great expanse, studies prior to the early 1940s addressed the *cerrado* within the regions or "flora provinces" within the country. Up until World War II, the studies on the *cerrado* were truly a mosaic, with each author essentially interested in a specific part, its physiognomy, or its botanical characteristics: Warming's *cerrado* blends into Lagoa Santa, while that of Vasconcellos extends into the interior of the state of São Paulo, Barbosa de Oliveira's into the border between the *cerrado* and Caatinga near to the bed of the São Francisco River, and the Cooke Mission report addresses the portion in the state of Goiás that borders the Amazon rainforest. This mosaic was gradually reinvented by scientific studies, the founding of experimental stations, and the continuity of missions to the region, and the pursuit of better identification of what would become the concept of *cerrado*. In fact, only after the formulation of public policies were the different parts of the *cerrado* unified under the concept of a biome in the 1970s.

However, the study conducted by the researchers from USP in the 1940s on the resources within the *cerrados* in the interior of São Paulo state was the first attempt to build a general framework, and it influenced subsequent studies in two respects: the agricultural use of the region, because of the large quantities of water there, as well as the formation of an idea of natural identity that decades later became the *cerrado* biome. Rawitscher, Ferri, and Rachid did not propose this scheme, but since the article and Ferri's doctoral thesis the following year were considered the main watershed in studies on agricultural use, other researchers developed the idea.

"When the burnings cease, the grassland is soon covered with forest species:" Rawitscher, Ferri, and Rachid and the debate on water resources in the *cerrado* (1943)

In the early 1940s, three researchers from the Department of Botany at the São Paulo Faculdade de Filosofia, Ciências e Letras, Felix Rawitscher, Mário Guimarães Ferri, and Mercedes Rachid, conducted a study in collaboration with the Experimental Hunting and Fishing Station in Emas (Pirassununga). Theodosius Dobzhansky, a biologist and professor at the University of São Paulo, had influenced the Brazilian researchers in their search for "work on Brazil's natural problems." This "was the same point of view as Rawitscher, who led these efforts by beginning studies on the *cerrados* region, which until that time had been considered unfeasible for agricultural production" (Coelho, 1993, p.6). The research in led to a 1943 article written by Rawitscher, Ferri, and Rachid which addressed the importance of water balance in understanding and utilizing Brazilian vegetation; in 1944, Mário Guimarães Ferri defended his doctoral thesis entitled *Transpiração de plantas permanentes do Cerrado* (*Transpiration in perennial plants of the Cerrado*).

However, it is important to mention that in 1941, before these studies, a researcher at the São Paulo State Department of Vegetable Production named José Setzer published a study in the bulletin *Bragantia* investigating the main characteristics of soils in the state of São Paulo. In his study, Setzer demonstrated that among the different soil types found in the region, the *salmourão* (granite/gneiss derived soil) "from poor quarzitic schists" comprised the *campos cerrados*, "not infrequently containing the indaiá palm [*Attalea* spp.] with its underground trunk," which was an example of a "very sandy soil, poor, dry, and acidic but deep" (Setzer, 1941, p.288). Nevertheless, Setzer only argued that other soil types related to the Cerrado's vegetation existed (such as "Cerrado forests"), along with consequently greater reserves of water, without specifying depth or establishing any more detailed argument on the water resources of the region in question. Meanwhile, unlike Setzer, Rawitscher, Ferri, and Rachid resumed and questioned Lund's argument on the formation of the *cerrado*: the Danish botanist believed that the formation of this differentiated space was linked to "the devastating action of continuous fires," since according to the climatic conditions these areas "should belong to the forest region" (Rawitscher, Ferri, Rachid, 1943, p.267). Using methods from the discipline of ecology which prior to that time had not been well-known among Brazilian researchers (Felippe, 1994, p.265), these three authors suggested that "the transpiration of plants can reach

much higher values than are generally supposed, to the extent that a forest can transpire multiple times the water evaporated by a lake of the same surface area" (Rawitscher, Ferri, Rachid, 1943, p.267). Consequently, "a good amount of water is removed from the large reserves that the very deep soils of Brazil store during the period of heavy precipitation in the rainy season" (Rawitscher, Ferri, Rachid, 1943, p.267). Later on, these researchers suggested that a "*campo cerrado* is thought to remove and release less water from the soil than a dense forest," (p.267) as long as the climatic conditions are equal. For this reason, "in southern Brazil, the granites and gneiss were transformed *in situ* into muddy layers," and "the inhabitants of these regions drill wells that often reach depths of 10 to 20 or more meters through perfectly decomposed rocks in which no stone fragments can be found" (p.267). For example, sugarcane plants were found "with roots up to 5.20m deep," a considerable size, keeping in mind that "longer-lived trees and shrubs may have deeper roots" reaching up to 6m (p.270).

This study consequently represented a major challenge to the idea held by Warming and Lund, namely that the *cerrado* had sparse water resources. To the Danes, the lack of these resources lay in the constitution of the *cerrado*: "Lund defended the notion that the constant fires which had been regularly set since before the Europeans arrived in the Americas turned the Catanduvas (a virgin wilderness specific to the highlands) into *cerrados*" (Marchesotti, 2011, p.61); in this sense, "later" the *cerrados* transformed "into *campos limpos*." On the other hand, "Warming agreed with Lund on the idea that constant fires can transform forests into *cerrados* and *campos limpos*, but felt that this hypothesis could not be generalized as the origin of all the *campos limpos* in Brazil" (Marchesotti, 2011, p.61). But neither considered that a large quantity of water resources was available, even in great depths. Therefore, as a complement to Rawitscher, Ferri, and Rachid's questioning, the lack of surface water was linked to the fires: "we found the existence of large water reserves in the soils in the grasslands, water that is perfectly within the reach of many plants with deep roots. The drought and lack of water in the superficial soil layers" results from the "yearly fires that expose the fields to direct insolation," suggesting that the species in question do not grow because of this exposure to strong heat: "When the burnings cease, the grassland is soon covered with forest species" (Rawitscher, Ferri, Rachid, 1943, p.290).

An "undisturbed" forest would lead to diminished underground reserves as the plants absorb greater quantities of water; because the fires and heat in the region made it more difficult for plants to grow, large water reserves were maintained in the region. Under other conditions, such existing reserves might maintain "lush" forests and not only the "dry" type forests, as suggested decades before by Lund: "We can assume that the regions we studied would be able to maintain even forests of this type," (Rawitscher, Ferri, Rachid, 1943, p.290) since "the conditions existing in the *campos cerrados* of the type we studied are not arid, as they are generally believed to be, when they are included in the phyto-geographic category of savannas" (p.291). In this way, "the arid appearance," according to these authors, is the result of "the yearly fires" that uniquely expose the surface and consequently lead to drought (p.291).

Final considerations

During the half century between Eugene Warming's work on Lagoa Santa (1892) and the studies by Rawitscher, Ferri, and Rachid (1942) in the region of Pirassununga (SP), interests in the Brazilian *cerrado* region grew considerably among researchers and institutions. In this study, we focused on how certain authors who wrote about the region's natural resources proposed using the *cerrados* for certain economic activities, based directly or indirectly on Warming's ideas. In most cases, the proposed economic exploitation was mainly based on attempts to construct activities related to an environment where water was predominantly believed to be scarce. As we stress herein, this argument incorporated the notions which were systematized in Warming's book, even though these were already present in reports by engineers during the Imperial period such as Baylis and Dodt. On the other hand, the turning point which the work of Rawitscher, Ferri, and Rachid represents was later remembered by agronomists and other researchers who were interested in boosting the fertility of these lands. In the context of the March to the West, the articles and experimental reports mostly addressed economic exploitation of the region, an argument that was further expanded after Second World War as scientific expeditions continued and especially with the construction of research institutions in the region and study incentives from international agencies. By the early 1960s the research already demonstrated that it was possible to increase soil fertility, manage water resources, and adapt hybrid seeds to the region; even so, it was only in the 1970s that the Brazilian government placed agricultural occupation of the *cerrado* on its agenda of priorities. Since that time, the contradictions in this process have become more evident for society: on the one hand, great optimism in relation to agricultural production in the region, and on the other hand, the critical role of environmental degradation following in the footsteps of industrial agribusiness.

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NOTES

[1] In this and other citations of texts from Portuguese, a free translation has been provided.

[2] For an overview of the formation of the *cerrados*, see especially Ribeiro (2006a, 2006b) and Walter (2006).

[3] According to Goedert, Wagner, and Barcellos (2008, p.50), "savannas are ecosystems characterized by the presence of a continuous layer of herbaceous vegetation and a discontinuous canopy of shrubs and trees" which cover "almost a quarter of the earth's surface, discounting the area covered by the oceans. They are found on all continents, with a notable presence in more than thirty countries. They have a long history of human use and currently are home to approximately a fifth of the world's population." The main determining factor of this ecosystem is the pattern of annual rainfall distribution, with two distinct seasons (dry and rainy). The amount of rainfall and duration of these seasons affect the type and

volume of vegetation cover, the type of predominant fauna, and consequently the level of use and human occupation. *cerrado* formations represent 10% of all tropical savannas.

[4] On the influence of medical-sanitarian thinking and the expeditions of the Oswaldo Cruz Institute in the "invention of Brazil," Nísia Trindade Lima (2009, p.244) states: "The importance of representations of social life created by physicians has been recognized in various national contexts, particularly with regards to the established relationships between diseases and national identity. In Brazil, since the nineteenth century theses from medical institutions discussed topics such as family, race, gender, sexuality, and above all the possibilities of civilization; however, it was primarily during the second decade of the twentieth century that medical-hygienist thinking most strongly influenced representations of Brazilian society. The repercussions of the reports from the scientific expeditions were greatly important in this process, and the greatest impact was undoubtedly from Arthur Neiva and Belisário Penna in 1912." On this topic, see also Lima (1999).

[5] Adolf Engler (1844-1930), who was influenced by Darwin's theory of natural selection, developed a phylogenetic classification system for plants (the Engler system) in 1892. "Based on the genetic relationships between plants, these systems emerged from the theories of evolution and the origin of species proposed by Wallace and Darwin, which came to demystify the dogma of the constancy and immutability which were accepted by the scientists of that era. Most phylogenetic systems attempt to establish the genetic relationships between plants, classifying them from simplest to most complex, but recognize that there are simple conditions that represent reductions of more complex ancestral conditions" (Martins-da-Silva et al., 2014, p.29).

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