THE RELEVANCE OF THE CERRADO'S WATER RESOURCES TO THE BRAZILIAN DEVELOPMENT

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ABSTRACT: The Cerrado (Brazilian savanna) is the second largest Brazilian biome (204 million hectares) and due to its location in the Brazilian Central Plateau it plays an important role in terms of water production and distribution throughout the country. Eight of the twelve Brazilian hydrographic regions receive water from this Biome. It contributes to more than 90% of the discharge of the São Francisco River, 50% of the Paraná River, and 70% of the Tocantins River. Therefore, the Cerrado is a strategic region for the national hydropower sector, being responsible for more than 50% of the Brazilian hydroelectricity production. Furthermore, it has an outstanding relevance in the national agricultural scenery. Despite of the relatively abundance of water in most of the region, water conflicts are beginning to arise in some areas. The objective of this paper is to discuss the economical and ecological relevance of the water resources of the Cerrado.

Key-words: Brazilian savanna; water management; water conflicts.

INTRODUCTION

The Cerrado is the second largest Brazilian biome in extension, with about 204 million hectares, occupying 24% of the national territory approximately. Its largest portion is located within the Brazilian Central Plateau which consists of higher altitude areas in the central part of the country. Thus, the geographical area occupied by the Cerrado has a fundamental role in the distribution of water resources throughout the country, feeding mostly of the Brazilian and South American large river basins, and, therefore, acting as an "umbrella". This explains why Cerrado is known as "the cradle" or "the father" of the Brazilian waters. Despite this hydrological importance of the Cerrado, as it had been recognized for a long time, its effective water contribution has only recently been quantified.

The climate in this biome is characterized by a strong seasonality, having about six months of almost continuously rainy season followed by marked drought. Moreover, even in the rainy season, short dry spells can occur in varying intensities. These water deficiency patterns make the irrigation an important practice to ensure the stability of the agricultural production in the region. Among all water uses, irrigation is the one that mostly demands water resources in quantitative terms. In Brazil, it is estimated that irrigation accounts for 69% of the actual consumption of water resources, urban water supply accounts for 11%, livestock 11%, industry 7% and rural supply 2% (ANA, 2005).

The increasingly participation of the Cerrado region in the overall agricultural production of Brazil has been evidenced. Currently, the Cerrado biome accounts for 60% of soybean, 44% of corn, 59% of coffee, and about 55% of beef cattle (Embrapa, 2006). This production scenario has been gradually enriched with other nontraditional crops in the region such as sugar-cane, cotton, cassava, sunflower, barley, wheat, rubber tree, and horticulture. Part of this production is obtained with irrigation systems.

Hydroelectric power plants represent 75% of installed capacity in the country and generated, in 2005, 93% of the electricity consumed in Brazil (Bronzatti e Iarozinski Neto, 2008). They depend on river waters to generate energy.

Despite of the relatively abundance of water in most of the region with an average yearly rainfall of about 1500 mm, water conflicts are beginning to arise in some areas.

The objective of this paper is to present and discuss some data about social, economical and ecological relevance of the water resources of the Cerrado.

WATER CONTRIBUTION

Figure 1 shows the limits of the continuous area of Cerrado in relation to the twelve Brazilian hydrographic regions, indicating the ones that receive waters from this biome.

Fig. 1 - Representation of the Cerrado's continuous area in relation to the regional Brazilian hydrological boundaries (Lima e Silva, 2007).

As illustrated in the Figure 1, eight of the twelve Brazilian hydrographic regions receive water from this Biome. In terms of surface water production in relation to the flow that each hydrographic region discharges into the ocean, the Cerrado contribution to the Amazon (3.8%) and western North Atlantic (8.6%) hydrological regions is not very significant. However, its contribution to the East Atlantic region (21%) is quite representative, being quite significant to the Paraná region (50%), to the Tocantins-Araguaia (60%), and even more important for the regions of San Francisco (94%), Parnaíba (105%), and Paraguay (135%). These figures demonstrate how important is the surface water production of the Cerrado biome and indicate the great dependence of the above mentioned hydrological regions in relation to this biome (Lima e Silva, 2007). The values above 100% indicate that the area of the indicated hydrological region outside of the Cerrado biome has a negative water balance in relation to the surface water flow generated inside the given region. The high dependency on Cerrado water contribution of the San Francisco and Parnaíba regions is explained by the relatively high amount of semi-arid areas prevailing in the basin. In relation to the Paraguay River basin, the large exposure of the surface waters in the wetland/flooded areas of the Pantanal biome greatly contribute to increase evapotranspiration, turning negative the water balance. This means that the Pantanal receives more water from the Cerrado than it provides to the Paraguay River (Lima e Silva, 2007).

The presented data corroborate to the sayings that the Cerrado is "the father of the Brazilian waters", "the cradle of the Brazilian waters", or "the big reservoir of the Brazilian waters".

The water production within the Cerrado varies greatly throughout the region. The average long term specific discharges ranges from 3.67 to 24.05 $L.s^{-1}.km^{-2}$ (Lima e Silva, 2007), indicating that this biome has a highly heterogeneous hydrological behavior, which is somehow related to the spatial distribution of rainfall in the Cerrado. This distribution is clearly influenced by the climate of the other surrounding biomes. For example, it rains more in Cerrado´s area closer to the Amazon than those ones nearby the Caatinga.

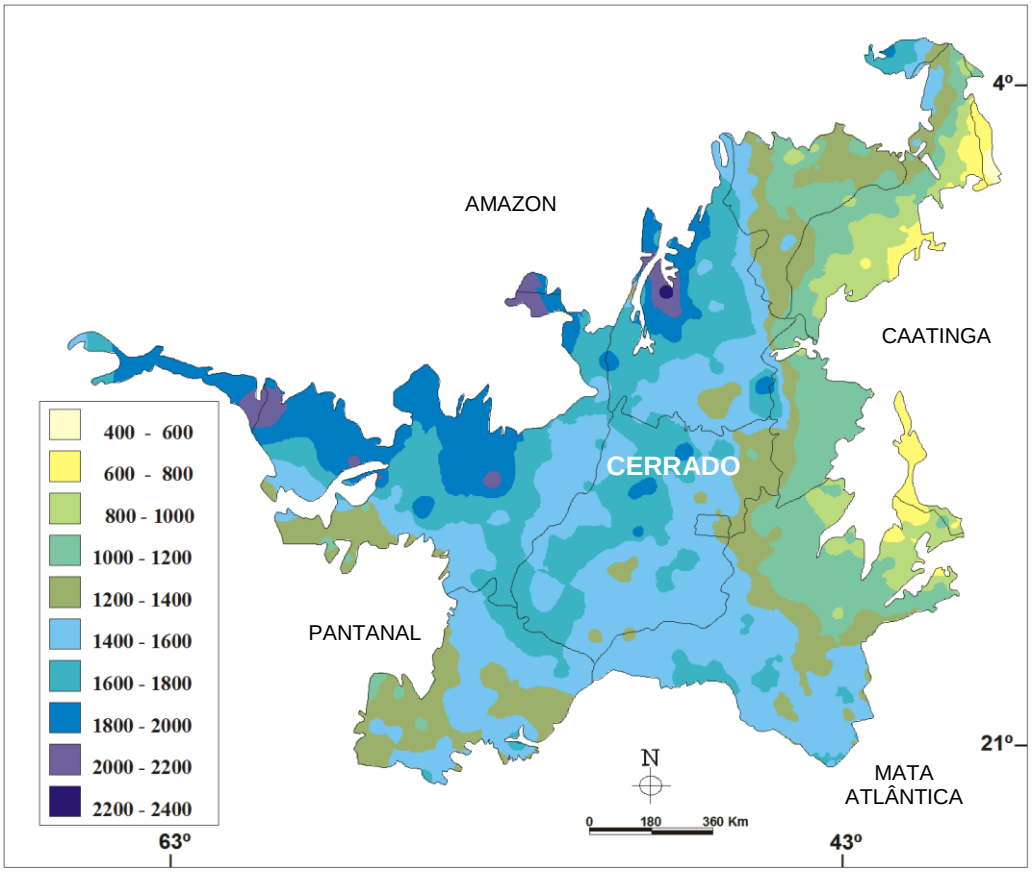

Fig.2 - Annual rainfall distribution in the Cerrado Biome (Silva et al., 2008).

MAIN WATER USES

Based on data presented previously, the water resources of the Cerrado have an importance that extends far beyond the dimensions of the biome. Considering only the issues related to water supply such as water for industry, irrigation, navigation, recreation, and tourism, one can derive several indexes and numbers to demonstrate the relevance of the water resources from the Cerrado to the Brazilian country. Adding to that, it could be also pointed out the fact that the Brazilian energetic matrix is substantially based on hydro-electric power plants, with strong participation of the basins which have their headwaters coming from this biome.

Irrigation

As it was told before, because of the prolonged period of dry season and the occurrence of drought spells during the rainy season, irrigation has become very important to farmers in the region. The governmental incentive for irrigation in the region had been started only in the early 80's and since then its average annual growth in irrigated area has been steadily increasing at rates larger than in the rest of the country.

Lima et al (2007), using geoprocessing tools, counted 6,001 center-pivots in the Cerrado, totalizing an irrigated area of 478.632 hectares in 2002 (Figure 3). It is important to say that many other irrigation methods that were not assessed by using this geoprocessing technique can be found in this region.

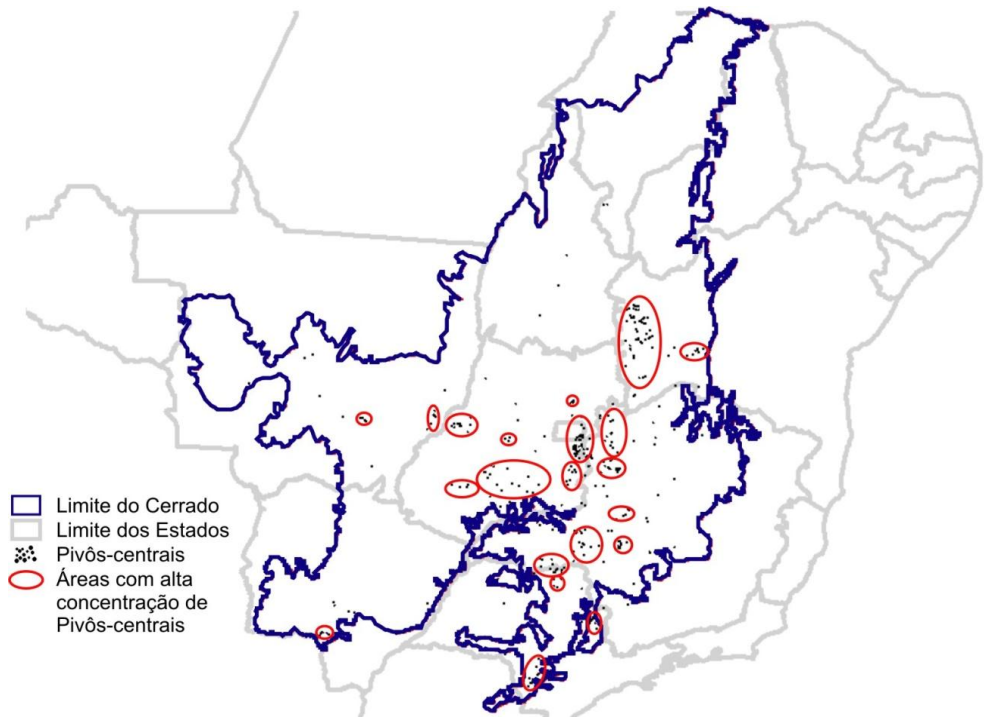

Fig. 3 – Center-pivots installed in the Cerrado region in 2002 in relation to the Brazilian states (Lima et al., 2007).

As it can be seen in Figure 3, some regions have high concentration of irrigated areas, sometimes surpassing the permitted capability of the river water supply, generating potential risks for the occurrence of water use conflicts. Examples of basins that live constantly under the risk of conflicts because of over water use are shown in Figure 4.

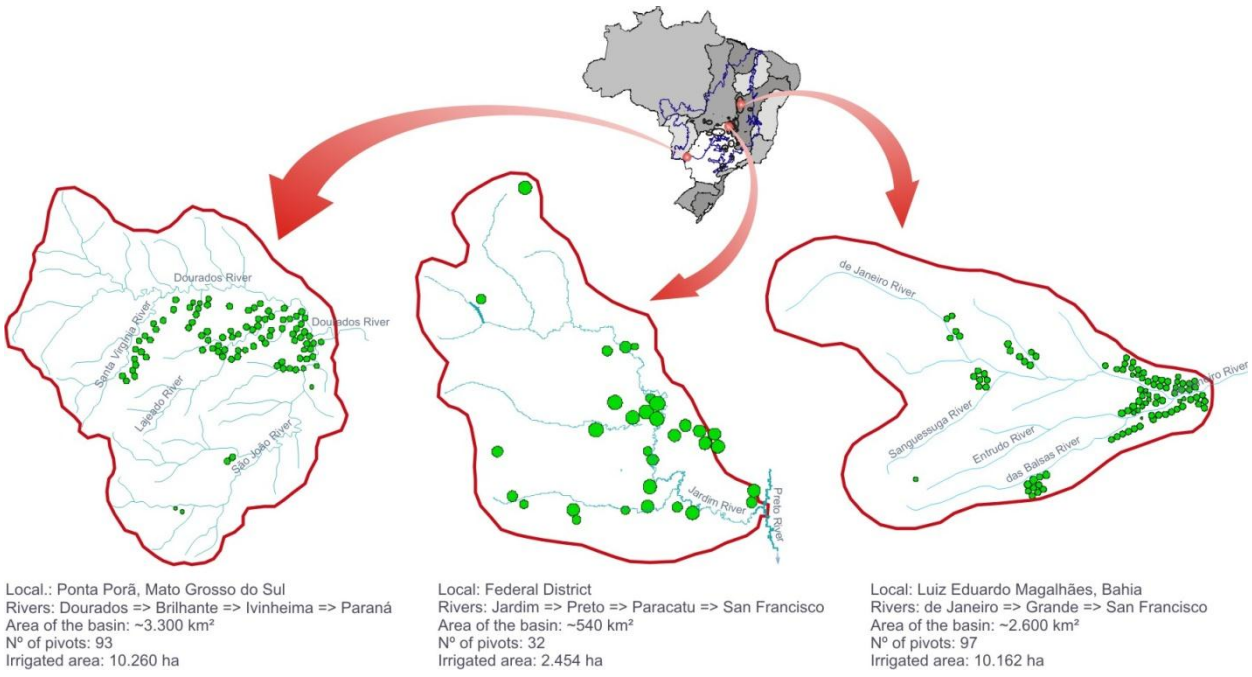

Fig.4 - Examples of irrigated areas by center-pivot in the Cerrado Biome (Lima et al., 2007)

It is important to mention that it has been estimated that Cerrado has an irrigation potential of about 10 million hectares (Christofidis, 2006), but, nowadays, its irrigated area is less than 1 million hectares.

Irrigation is an activity that demands lots of water, however, as rainfall is scarce or unreliable some parts of the Cerrado. Thus, irrigation becomes a necessary practice for the agriculture development and food production safety, in order to either increase productivity or minimize risks of crop failure due to lack of water. Without the use of irrigation, the farmer is restricted to produce one or, two crops per year in the same area, while by using this practice, up to three crops per year could be produced.

In 2003, from the worldwide 1.5 billion hectares of cultivated land, about 44% of the total food production comes from the 278 million hectares (18%) that were cropped under irrigation. Thus, without irrigation, in order to produce the same amount of food in the world in 2003 would be necessary to expand the planted area for about 45%, that is, from 1.5 to 2.2 billion hectares, otherwise, the food production would be about 30% less.

In Brazil, the total planted area in 2003 was 58.5 million hectares, having only 3.4 million hectares (5.9%) under irrigation. However, according to Christofidis (2006), it is estimated that the suitable area for agricultural development in the country is about 110.0 million hectares, from a potentially irrigated area of 29.5 million hectares, that is, 26.7 % of the total. These numbers demonstrate the potential growth of irrigated agriculture in Brazil, which currently uses about 10% of its full potential.

The land use map of the Cerrado, presented by Sano et al. (2008), showed that, in 2002, this biome had 21.5 million hectares of agricultural crops, 54.0 million hectares of cultivated pasture, 3.5 million hectares of reforestation, 0.8 million hectares of urban areas, and 7.8 thousand hectares of mining areas. It represents an occupancy of 39% of the Cerrado, indicating that almost sixty percent of the biome was still under natural vegetation (Figure 5).

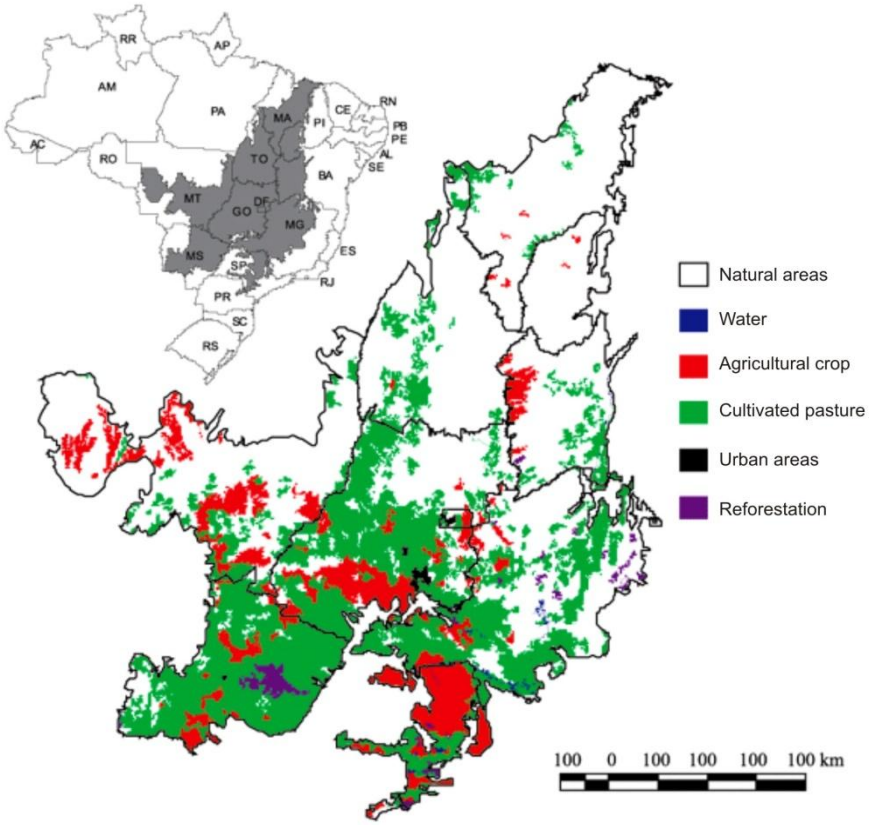

Fig. 5 - Spatial distribution of the land use classes in the Cerrado biome in 2002 (Sano et al., 2008).

Comparing Figures 3 and 5, it is possible to notice that the agricultural cropped areas are almost at the same places where the center-pivots systems are concentrated.

The numbers show that less than 5% of the cultivated area in Cerrado is under irrigation, reinforcing the idea that there is a great potential for expansion of irrigated agriculture in this region.

Hydroelectricity

Be favored by natural resources that become sources of energy production is strategic for any country. It reduces the dependence on external supply and can be the anchor for a governmental effort to provide vital services to impulse social and economic development of any region. In the case of the water potential for generating energy, it is even more interesting by the fact of the low cost of that energy compared to other sources (coal, oil, uranium and natural gas, for example).

In Brazil, according to the Brazilian Energy Agency database (BIG-Aneel), in November 2008 there were 227 Very Small Hydro Power Plants (CGHs), with a total capacity of 120 MW; 320 Small Hydro Power Plants - PCHs (2.4 GW of installed power capacity); and 159 Hydroelectric Power Plants (UHEs), with a total installed capacity of 74.6 GW. Therefore, in November 2008, hydroelectric power plants, regardless of their size, accounted for 75.68% of the total power capacity installed in the country, of 102.3 GW.

Fig. 6 – Installed power capacity by State in 2008 (Adapted from ANEEL, 2008).

As shown in Figure 6, there is a large number of hydro-power plants located in the biome, taking advantage of the large number of rivers and waterfalls that occur in the transition from highlands to lowlands. The states with the largest installed capacity to generate hydroelectric power are Minas Gerais, Sao Paulo and Paraná.

The first two are under strong influence of the Cerrado biome. In the Pará State case, there is only one large hydropower plant UHE Tucuruí, in the Tocantins River), which receives about 70% of its water from the Cerrado. The same happens with the UHE Itaipu (in the Paraná River) and the hydro plants installed along the São Francisco River (Figure 7).

Fig. 7 – Hydropower plants with installed capacity higher than 100 MW that receives water from the Cerrado biome.

Considering only the 21 hydroelectric plants shown in Figure 7 and their respective generating power capacities aligned with the hydrological contribution of the Cerrado, already reaches more than 50% of the hydroelectric capacity installed in the country (~ 38.0 GW). It is important to observe that the capacity installed in rivers as Grande, Tietê, Paranapanema, and others, that are very relevant for this sector, are not considered in Figure 7, as it can be noticed by comparing the Figures 6 and 7.

Water supply

In 1991, the population of Cerrado was estimated at 21 million (Pereira et al., 1997). In 1996, it was about 28 million (Sawyer, 2002). Based on 2010 data, it is estimated that the Cerrado has currently about 32 million inhabitants (Veloso, 2011), which represents approximately 17% of Brazil's population (~191 million inhabitants).

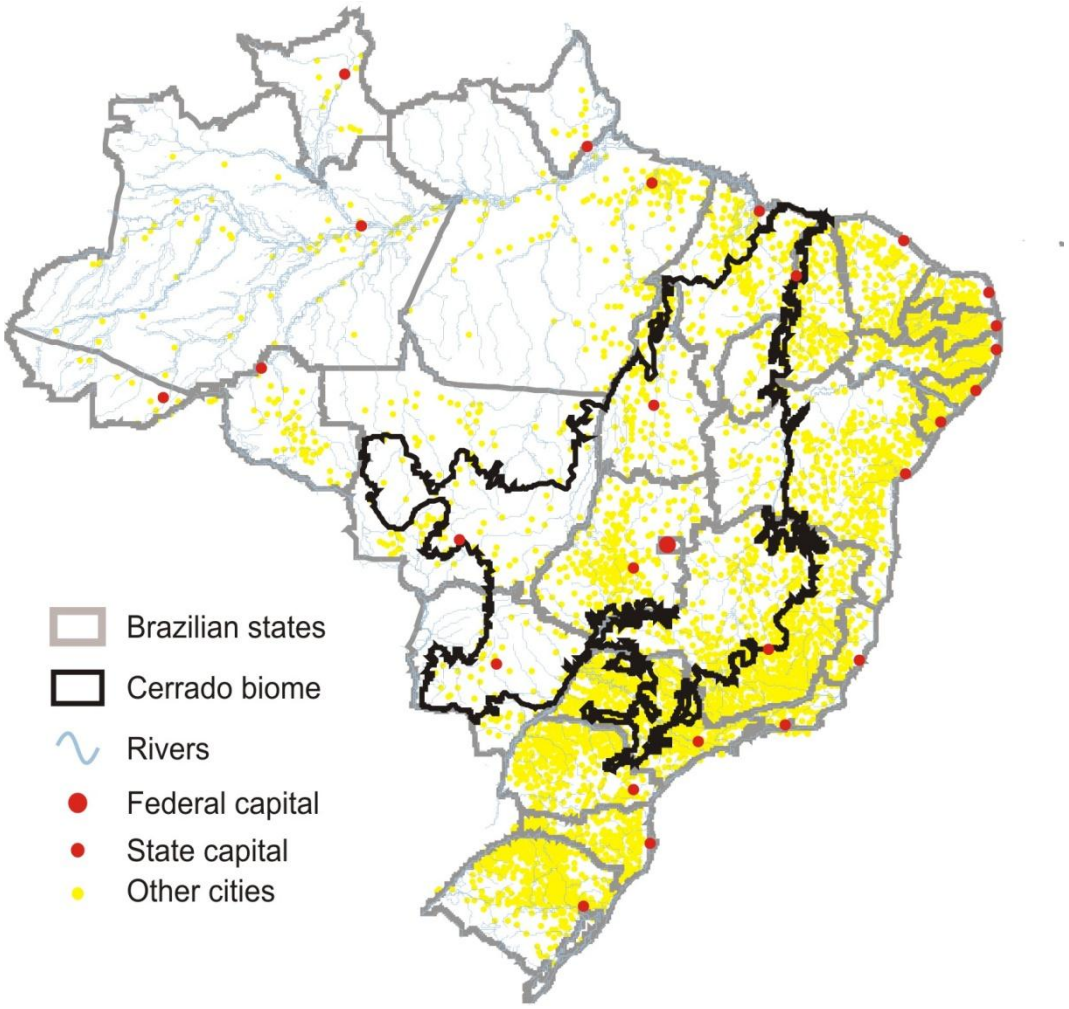

Fig. 8 – Spatial distribution of the Brazilian cities in relation to the Cerrado biome.

It is observed in Figure 8 that, besides the federal capital (Brasília-DF), four state capitals are located in the Cerrado biome (Goiânia-GO, Palmas-TO, Cuiabá-MT, and Campo Grande-MS). Capitals as Belo Horizonte-MG, Teresina-PI and São Luiz-MA are located nearby the boundaries of this biome. The last two are supplied by water resources from Cerrado. This phenomenon also happens in relation to the capitals that are more than 500 km far away from the Cerrado boundaries. This is the case of Aracaju-SE, which is entirely supplied with water from the Sao Francisco River, where almost all the discharge comes from the Cerrado region (94%).

The yellow dots on the map (Figure 8) represent the main city of each Brazilian county. There are more than a thousand of them in the Cerrado biome, and some of them are quite populated, as Uberlândia-MG (600,000), Anápolis-GO (335,032), Uberaba-MG (296,000), Rondonópolis-MT (200,000), Porto Nacional-TO (50,000), Barreiras-BA (137,832), Balsas-MA (83,459). Many important cities out of the Cerrado's boundaries receive waters from this biome, as some in the São Paulo state and others located along the São Francisco, the Paraná, and the Tocantins Rivers.

Therefore, the waters of the Cerrado supply more than the 32 million people living within its boundaries. It is noteworthy that the São Francisco River Transposition Project, which predicts to provide water for more than 10 million people in the Northeast Region of Brazil, is tremendously dependent on water coming from the Cerrado.

Waterways

Nowadays, inland waterway transport (IWT) has a small participation in transporting people and goods in Brazil. This is due to several factors. Many rivers of Brazil come from the plateau (Cerrado biome), which have waterfalls that are excellent for power generation but a problem for navigation. In the case of lowland rivers (i.e. Amazon and Paraguay), which are easily navigable, they are far from major economic centers of Brazil. Thus, the waterways use in Brazil depends on the construction of dams (sluices), dredging, and especially ports that enable multimodal integration.

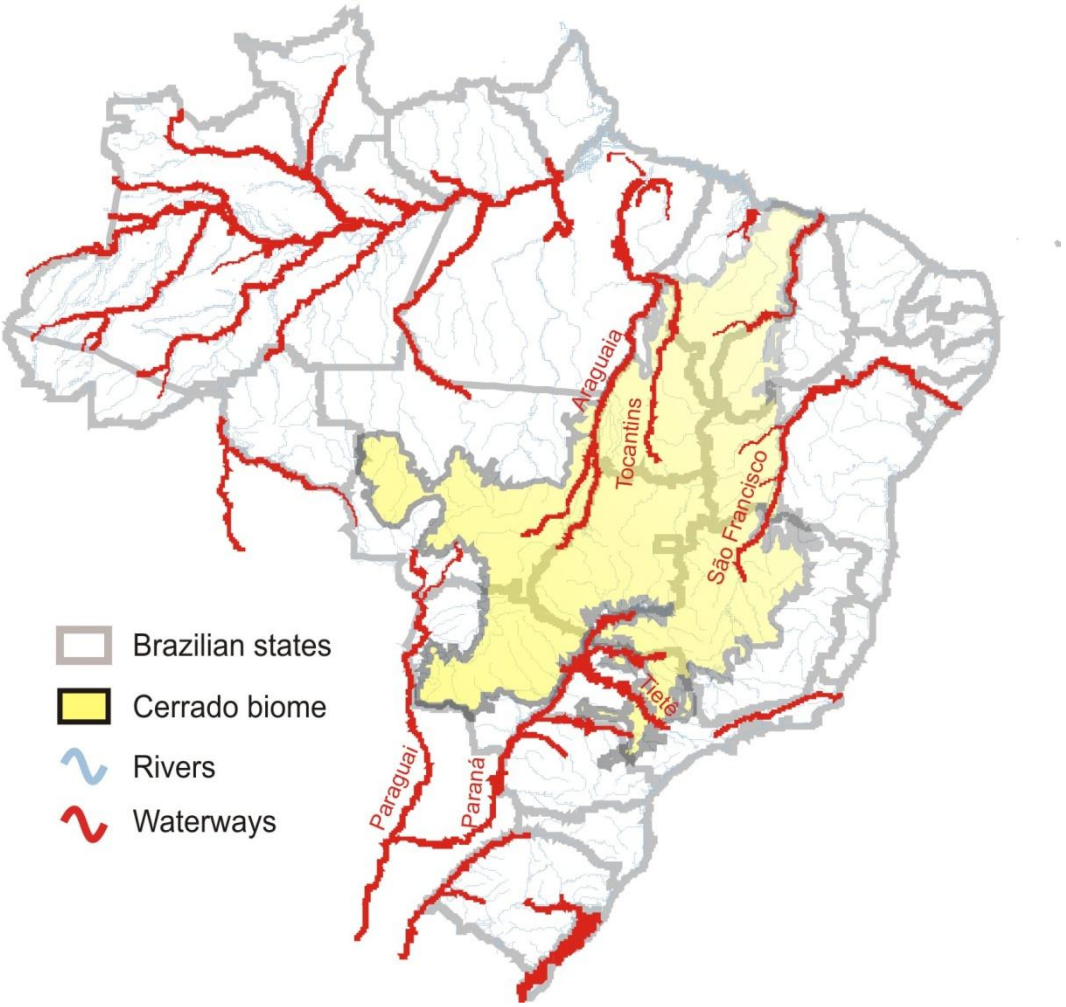

Fig. 9 – Brazilian waterways in relation to the Cerrado biome.

During floods season, the Tocantins River is navigable over a distance of 1,900 km, between the cities of Belém, in Pará State, and Peixes, in Goiás. The Araguaia River crosses the Tocantins State, from north to south, and is navigable in 1,100 km. The construction of the Araguaia-Tocantins waterway aims to create an intermodal transportation corridor in the North Region.

In the San Francisco waterway, the main navigable patch is between the cities of Pirapora, Minas Gerais State, and Juazeiro, in Bahia State, a route of 1,300 km.

The Tietê-Paraná waterway has a great economic importance allowing the transport of grain and other goods from three states: Mato Grosso do Sul, Paraná, and São Paulo. It has 1,250 km, 450 km in the Tietê River, in Sao Paulo, and 800 km in the Paraná River, that flows to the Atlantic Ocean between the borders of Paraguay and Argentina. To enable these 1,250 km of waterways, it is necessary to conclude the sluice of the Jupiá dam, connecting the two Rivers, Tietê and Paraná.

It is important to remember that the San Francisco, Tocantins, Araguaia, Paraguay, and Paraná rivers are significantly dependent on the waters produced in the Cerrado biome.

MAIN WATER CONFLICTS

Water conflicts occur because the demand for water resources at some place extends far beyond the amount of water available at a given moment.

Two types of conflicts over water use are more common in the Cerrado biome, those linked to water use for irrigation, and those related to sewage discharge in urban areas. The first one derives from lack of knowledge and planning, mainly while defining the river supporting capacity in relation to the area that can be irrigated in the basin. The second one is due to the deficiency in sanitation systems to meet the needs in the region, which deteriorate water quality of the rivers that receive effluents from the cities. The regions where these types of conflicts occur more often can be identified in Figures 3 and 8, respectively. In general, those conflicts occur in local scale, in small basins, channels or reservoirs, and among neighbors.

However, there is also large scale conflicts such as the ones between the agricultural and hydro-electricity sectors in the São Francisco River Basin; waterways and electrical sectors, in the São Francisco, Tocantins/Araguaia ,and Paraná River Basins; environmental agencies against the construction and operation of reservoirs in large basins; and others. Comparing the information presented in Figures 3, 6, and 9, it is easy to identify where some of those problems occur more intensively.

FINAL COMMENTS

In general, the status of the Cerrado water resources can be classified as good, however, mainly in the urban areas and where the agricultural occupation is more intense, conflicts over water use are already present. The proper use of the water resources of the Cerrado, as presented, is essential not only for the population and the environment in the region, but to a great extent of the country.

Considering the fact that the Cerrado occupies the highest part of its major river basins, the water use in this biome, as well as the water that flows throughout its boundaries, require great attention from the Brazilian government and its citizens. The relevance of the Cerrado water resources on supplying a major portion of the water flowing through the main hydrographic regions of Brazil shows the dependence of the Brazilian development on this biome.

Due to population growth and the consequent intensification of the water demand for its direct consumption, food, goods, and services production, the trend is to increase the number of regions submitted to water scarcity and water pollution. In order to avoid, minimize or remedy such situations, it is important to have efficient systems of land-use and water resources management. These systems should be decentralized and allow the society participation, fundamentally based on data, information and knowledge to support decisions and actions taken for the proper utilization of the environmental resources available in the watersheds.

Many challenges must be overcome to meet the necessary conditions for the proper management of water resources of the Cerrado, which has been an everyday preoccupation of the entire Brazilian society.

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