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Uses of underground water resources in the Hydrographic Circumscription of the Surrounding Furnas Reservoir

Franciny Oliveira de Deus, Marcelo de Oliveira Latuf

Universidade Federal de Alfenas – UNIFAL, Alfenas, MG, Brasil

Abstract: In the recent decades, there has been an intensification of the use of water resources to meet the various demands of the society and, in this bias, groundwater has been used with a greater frequency and volume, due to the lesser influence of meteorological variations on its availability. On the other hand, the collection of groundwater is more expensive when compared to the surface water, since it depends on geological surveys for its use. In the surroundings of the Furnas reservoir, located in the south of the state of Minas Gerais, Brazil, there are demands for the use of groundwater resources such as irrigation, industry and, human consumption, among others. In this sense, the study aims to understand the spatio-temporal dynamics of underground grants granted in the Hydrographic Circumscription of the Surroundings of the Furnas Reservoir in the period from 2001 to 2020, in order to subsidize decision support actions to the management bodies in the various administrative spheres. Therefore, data from underground grants from the Minas Gerais Institute for Water Management were used, where they were processed through electronic spreadsheets and descriptive statistics techniques. On the other hand, the Geographic Information System was used to obtain continuous density surfaces of deferred grants, as well as consumed flows. Results show that 624 underground grants were granted in the study area between 2001 and 2020 and from 2013 onwards, there was a significant increase in the amount granted, and the user segments that had the greatest demands represented the supply of public/human consumption and irrigation/agribusiness consumption respectively. In this context, it is essential that the managing body, as well as the Hydrographic Basin Committee around the Furnas reservoir, carries out the planning and the management in relation to the groundwater resources, in order to avoid future scenarios of conflicts due to the multiple uses of the underground water.
Key words: groundwater; granting; planning; multiple uses

1 Introduction

Groundwater is the water that exists below the surface of the soil, including water from the unsaturated layer of the subsoil and its saturated zone, as well as that contained in intergranular voids of sedimentary rocks or fractures of compact rocks (REBOUÇAS et al., 1999).

According to Martínez et al. (2008) underground aquifers may present discharge and recharge zones belonging to one or more overlapping watersheds, acting as underground reservoirs that function as pipelines under pressure, and may interconnect watersheds arranged several kilometers from each other.

According to Goetten (2015), groundwater management faces difficulties, from overexploitation and pollution, in addition to the lack of monitoring networks, as well as data on hydrogeological limits, lithology, water quality, volume of reserves, usage rates, users and vulnerability, which hinders proper management.

According to Nogueira (2010) in Brazil, groundwater is mainly used for human consumption and widely used in agriculture for irrigation, industry, leisure and tourism, and the increase in the use of groundwater resources can negatively result in the spatiotemporal availability of this resource.

It is estimated that the availability of groundwater in Brazil is around 14,650$m^3.s^{-1}$ and that its distribution across the national territory is not uniform, since the hydrogeological characteristics of aquifers are variable (ANA, 2020).

According to Law No. 9,433/1997, which established the National Water Resources Policy (PNRH), groundwater is a public good, liable to economic value and its management is the responsibility of the States (BRASIL, 1997). In the State of Minas Gerais is Law No. 13,771, of December 11, 2000, which regulates the administration, protection and conservation of groundwater (MINAS GERAIS, 1999).

To ensure the use of water resources among multiple users, there is a water resource use grant. The grant is one of the instruments of the PNRH, which aims to "ensure the quantitative and qualitative control of water uses and the effective exercise of rights of access to water" (BRASIL, 1997).

In Minas Gerais, the Mineiro Institute of Water Management (IGAM) is the body responsible for the management of groundwater resources, this management, carried out mainly through the instrument of granting the right to use water.

According to data from the 2019 Minas Gerais Water Management and Situation Report (IGAM, 2019), the state areas with the highest demands for groundwater use, "are located in the northwest, north and central regions of Minas Gerais in the watersheds of the Doce, São Francisco and Paranaíba rivers" (IGAM, 2019, p.126).

In this sense, it is necessary to elaborate effective strategies in order to avoid future scenarios of water scarcity. Thus, national and state public policies are fundamental for the protection of groundwater resources, but to reach this stage, there is a need for continuous qualitative and quantitative monitoring.

An important tool for monitoring groundwater is the Groundwater Information System (SIAGAS), which is configured in an information system developed by the Geological Service of Brazil (SIAGAS, 2022).

In Minas Gerais, monitoring is carried out through the State Groundwater Quality Monitoring Network, which aims at qualitative analysis of groundwater resources in their spatial-temporal variation aspects (IGAM, 2022).

Due to the need for the spatial-temporal diagnosis of groundwater uses through grants granted by the management bodies, the Hydrographic Circuit of the Furnas Reservoir Environment (CH Furnas) is located in the South/Southwest mesoregion of the State of Minas Gerais, a stage of conflicts over the use of water resources and impacts on various economic circuits (LEMOS JUNIOR, 2010; GODOY, 2017).

At CH Furnas there are several users of underground water resources such as irrigation, industry, human consumption among others and, in view of this scenario, the Master Plan of Water Resources of the Hydrographic Basin around Furnas (IGAM, 2013) does not meet the needs of the current management, based on the knowledge of the user segments, demands, consumed flows, captured volumes, among others, since the data on groundwater grants dates "up to August 2008" (IGAM, 2013, p.192).

In this perspective, the present study aims to identify the spatiotemporal dynamics of the uses of the groundwater resources in Furnas CH in the period 2001 to 2020, subsidizing the updating of the database on the uses of groundwater, as well as in the management of conflicts between various user segments.

2 Materials and methods

2.1 Location and characterization of the study area

CH Furnas is composed of 50 municipalities, 34 of which are adjacent to the reservoir (Figure 1), and has an area of 16,643 km² and an estimated population of 949,599 thousand inhabitants (IGAM, 2021; IBGE, 2021).

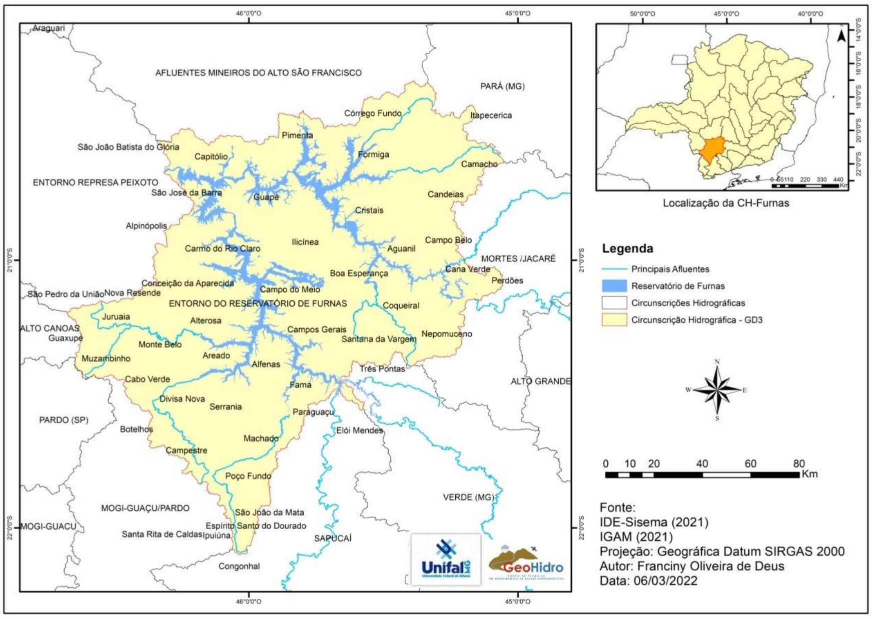

Figure 1. Hydrographic circumscription of the surrounding of Furnas reservoir

Source: The Authors (2022)

The geology of the study area is quite diverse, with the lithological basement associated with crystalline rocks, with different ages and deformations by tectonic events, being superimposed by dentritic covers and colluvium-alluvial deposits (IGAM, 2013).

Four regional geomorphological units are observed: Planalto Centro Sul Mineiro in the Northeast, Planalto Alto Rio Grande in the Southeast, Planalto de Poços de Caldas in the South and Serra da Canastra in the Northwest, with predominance of undulating and strong undulating reliefs (IGAM, 2013).

In terms of pedological aspects, there are two main types of soils in the territorial limits of CH Furnas, one that is characterized by the low development where Cambissolos, Gleissolos and Neossolos are grouped, and the other, characterized by soils with residual horizon, Argissolos and Latossolos (EMBRAPA, 2011).

The predominant climate is Tropical, with average temperatures between 18°C to 25°C, and the seasons are characterized by being rainy (October to March) and dry (April to September) and has an average annual rainfall index of approximately 1,500 mm/year (INMET, 2022).

The Furnas Hydroelectric Power Plant reservoir is located in the southwest of Minas Gerais, 355 km from Belo Horizonte and its main contributors are the Grande, Sapucaí, Verde and Jacaré rivers (LEITE, 2020).

In relation to vegetation, we can mention the Forest Remains consisting of forest formations (primary and secondary) of Semideciduous Seasonal Forest Montana, Field, Rupestre Field and Cerrado Field found in the Atlantic and Cerrado Domains (SCOLFORO et al., 2006). In CH Furnas there is a predominance of pasture areas and in relation to regional agricultural production, coffee, soybeans, corn and sugar cane stand out (LEITE, 2020).

2.2 Methodological procedures

The cartographic basis of CH Furnas was created, with themes that address the limits of the water resources management units of the State of Minas Gerais, Furnas reservoir, hydrographic network and main rivers, administrative limits (municipalities), municipal administrative headquarters, as well as the grants of the use of the underground water resources.

All data were acquired on the portal of the Spatial Data Infrastructure of the State System of Environment and Water Resources of the State of Minas Gerais (IDE-Sisema), by electronic address, except for the data of underground grants, which were acquired in electronic spreadsheet format, via request to the state managing body.

The grant data were processed in order to filter the records contained in the geographical limit of CH Furnas, via Geographic Information System (GIS) ArcGIS © 10.6.1, through their spatialization from the pairs of geographic coordinates and, later, clipped using the Clip function. Subsequently, all spatial data were stored in a Geodatabase in Mercator Universal Transverse Projection (UTM), South Zone 23, with horizontal datum SIRGAS2000.

Soon after, a sample inspection was carried out for inconsistencies in the database provided by the management body, excluding records with a lack of flow granted to consumptive user segments, as well as inconsistencies in relation to the publication of the validity or date of the concession, which were not counted as they did not present the necessary data.

In this process, a sample universe of 10% of the data related to the granted grants was adopted, with a sample universe of 109 verified records.

It was also observed, expressively high flows granted to underground abstractions, such as 9.47E15m^3.h^{-1}, 9.54E15 m^3.h^{-1}, 5.52E16 m^3.h^{-1}, 3.24E16 m^3.h^{-1} among others. Due to the incompatibility of the value presented by the IGAM spreadsheet and the reference flow criterion, such grants were individually verified on the consulting website of the managing body.

However, 26 were not found or were not registered in the consultation system and, thus, these grants were removed from the granted flow statistics and purpose, considering them only for the issue of the quantity of grants granted.

In order to have a better understanding of the temporality about the concessions of grants in CH Furnas, each record was analyzed with regard to the type of capture, purpose of use, flow granted, date of concession and period of validity, through the use of electronic spreadsheets and descriptive statistics techniques.

The spatial analysis of the concessions of grants were elaborated through thematic maps, using the GIS ArcGIS ©10.6.1, from the Spatial Analyst extension. Subsequently, the location and flow data were interpolated using the Kernel Density and Distance Inverse Weighting (IDW) method, respectively.

3 Results and discussion

Upon receipt of the underground grant sheet gently handed over by the managing body, the procedure for verifying consistency of the data was initiated and, unfortunately, inconsistencies were detected in the data concerning: (a) location (coordinated outside the boundaries of CH Furnas), (b) typing (expressively high or low flows), (c) typing (regarding the position of the comma), (d) registration in another CH, (e) zero flow for consecutive uses, (f) multiplicity of purposes intended for the same capture (in this case, it should have an information which is the predominant use), (g) numbers of gateways that are not located on the website of grants of the managing body, (h) absence of flow (empty cells), (i) purpose and (j) date of publication of the grant.

After verifying consistency, 624 grants granted in the Furnas CH area between 2001 and 2020 were identified (Figure 2), with a tendency to increase the number of grants, obtaining an annual average of approximately 31 underground grants granted.

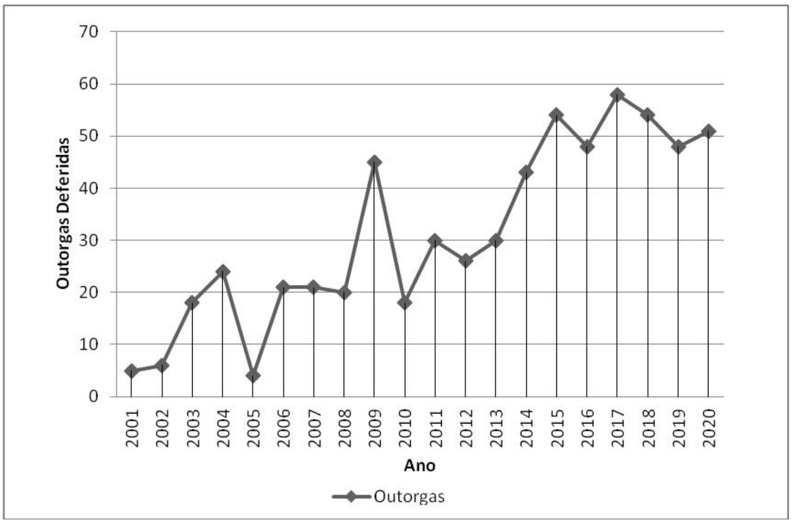

Figure 2. Annual underground grants at CH Furnas (2001 to 2020)

Source: Adapted from IGAM (2021)

From 2009 onwards, there was a significant increase in granting grants compared to previous years, with 45 records. However, from the year of 2011 the concessions of grants showed a trend of gradual increase, especially in 2017, with 58 underground grants granted, representing the largest quantity in the time frame of analysis.

According to Godoy (2017), from 2012 onwards the levels of the Furnas reservoir began to gradually decrease, due to a period with below-average rainfall. According to Hirata et al. (2019), between 2013 and 2017, 48.6% of Brazilian municipalities experienced a water crisis, and 56% of these municipalities used surface water for supply, while only 31% used groundwater. In this period of water crisis, many municipalities entered into a dispute against time for drilling new wells.

In this sense, it is essential to have planning to face the possible climatic adversities that may interfere with the rainfall index, taking into account that groundwater is a resource to be used in case of significant need. From this perspective, from 2012 onwards, a significant number of underground grants accumulated (Figure 3).

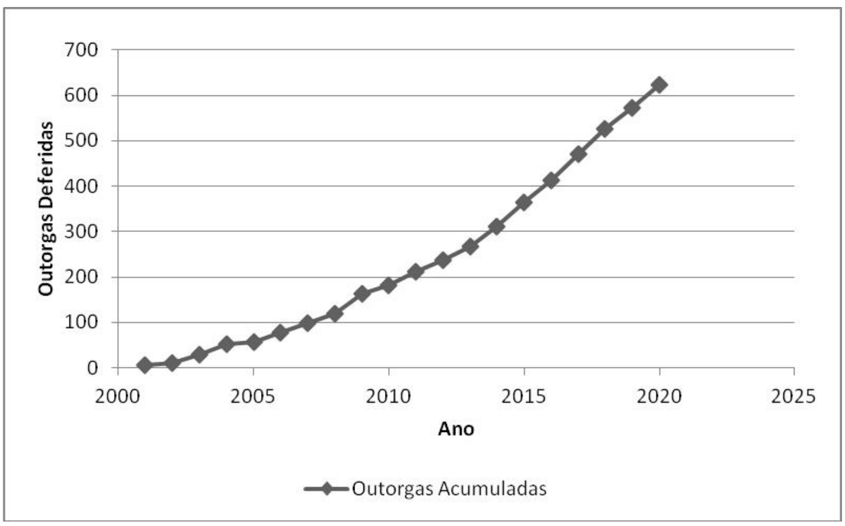

Figure 3. Grants accumulated between 2000 and 2020 at CH Furnas

Source: Adapted from IGAM (2021)

Taking into account that CH Furnas has several users of water resources and, which is a region with tourist cities, it is necessary to understand the dynamics of concessions in order to resolve conflicts over the use of water, as well as to elaborate strategic plans to minimize the effects of scenarios of water scarcity.

From 2012 onwards, there was an increase in the granting of underground concessions to municipalities belonging to CH Furnas, such as the municipalities of Alfenas/MG, Carmo do Rio Claro/MG and Formiga/MG (Figure 4).

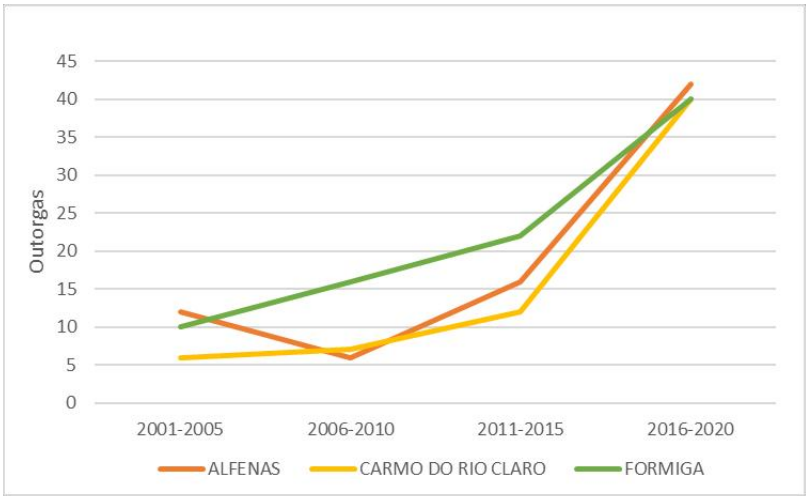

Figure 4. Underground concessions granted in Alfenas/MG, Carmo do Rio Claro/MG and Formiga/MG

Source: Adapted from IGAM (2021)

Regarding the method of capturing groundwater, it was found that capture through an existing tubular well represents 92% of the grants granted between 2001 and 2020 (Figure 5), and this type of capture is carried out mainly for human consumption and public supply.

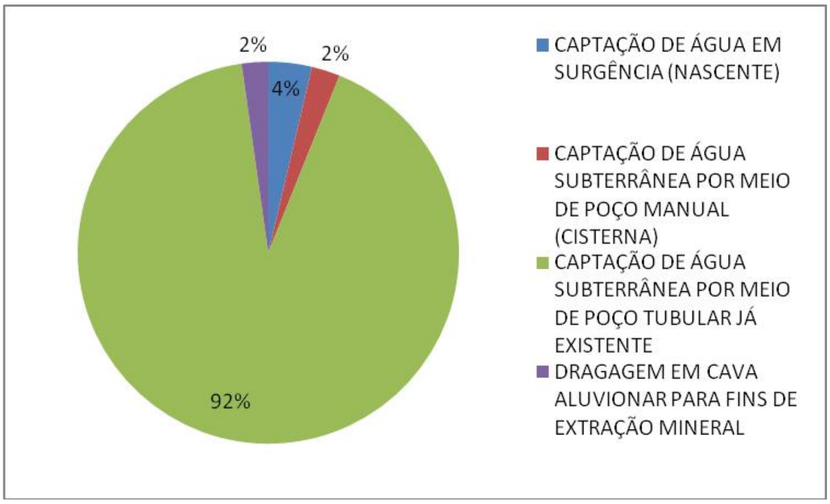

Figure 5. Mode of capture of grants granted between 2001 and 2020

Source: Adapted from IGAM (2021)

According to the State Environment and Water Resources System (SISEMA), in its monitoring report, the Rio Grande basin occupies the third position in relation to groundwater consumption among the state basins (SISEMA, 2018).

For the analysis of the flow granted ($m^3.h^{-1}$) for each purpose, it was necessary to reduce the sample universe to 598 grants, due to 26 grants with identified inconsistencies that were not included in the managing agency's website.

It was identified that the main use of groundwater in Furnas CH is directed to human consumption (Figure 6), which represents 78% of the flow granted between 2001 and 2020, followed by agroindustrial consumption/irrigation and industrial consumption purposes, both with 9%.

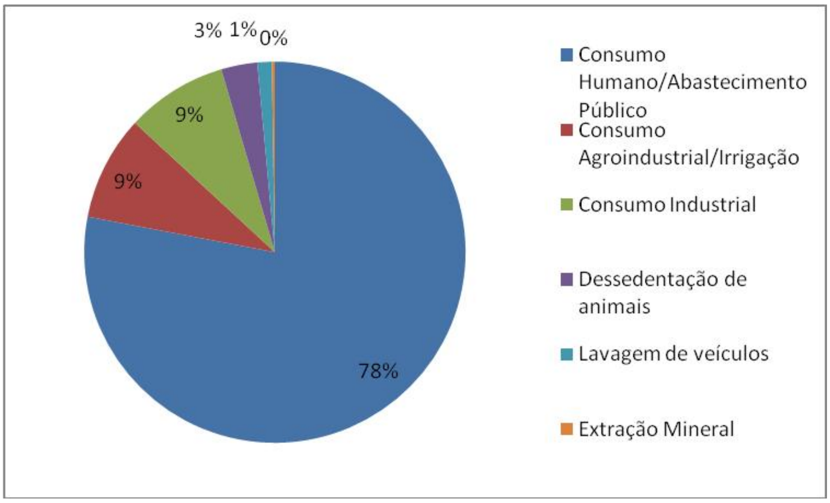

Figure 6. Distribution of flow granted by purpose between 2001 and 2020

Source: Adapted from IGAM (2021)

In Table 1, it was observed that the purpose of Human Consumption/Public Supply showed considerable growth from 2008 onwards, as well as the purpose of Agroindustrial Consumption/Irrigation, which until 2008 had a consumed flow rate of 33.4 $m^3.h^{-1}$ and which in the time period from 2001 to 2020 increased to 293.4 $m^3.h^{-1}$.

Table 1. Comparison of flow granted by purpose between the present study and the Water Resources Master Plan of CH Furnas

Purpose	2001 to 2020		PDRH (until 2008)	
	Flow rate ($m^3.h^{-1}$)	%	Flow rate ($m^3.h^{-1}$)	%
Consumption Human/Supply Public	2.575,7	77,9	282,0	30,85
Consumption Agroindustrial/Irrigation	293,4	8,9	33,4	4,75
Industrial consumption	283,6	8,6	356,7	39,04
Desedentation of animals	101,4	3,1	93,5	10,23
Washing vehicles	40,0	1,2	138,2	15,12
Mineral extraction	8,6	0,3	-	-
Deferred average flow rate	550,5	-	180,76	-

Source: Adapted from IGAM (2021)

At CH Furnas the largest user of groundwater is Human Consumption/Public Supply, while the second largest user is agroindustrial consumption/irrigation with 9% of the flows granted, representing 293.4$m^3.h^{-1}$. The other uses are related to industrial consumption, animal dehydration, vehicle washing and mineral extraction, with a total of 433.62 $m^3.h^{-1}$.

The study area has water as one of the bases that sustain its economy, either by the Financial Compensation of Water Resources (CFRH) received by municipalities, due to the generation of electricity, or by activities related to agriculture and tourism (ALAGO, 2006). However, surface water is not always available for these activities, so it is necessary to use groundwater.

Using the sample field of 624 underground grants granted between 2001 and 2020, it was found that 428 are in force in CH Furnas, of which 85% are for human consumption/public supply (Figure 7), with grants valid until 2055.

In their study, Hirata et al. (2015) reported that groundwater is the exclusive option for 48% of municipalities with a population of less than 10,000 inhabitants and for 30% of those with 10 to 50,000 inhabitants.

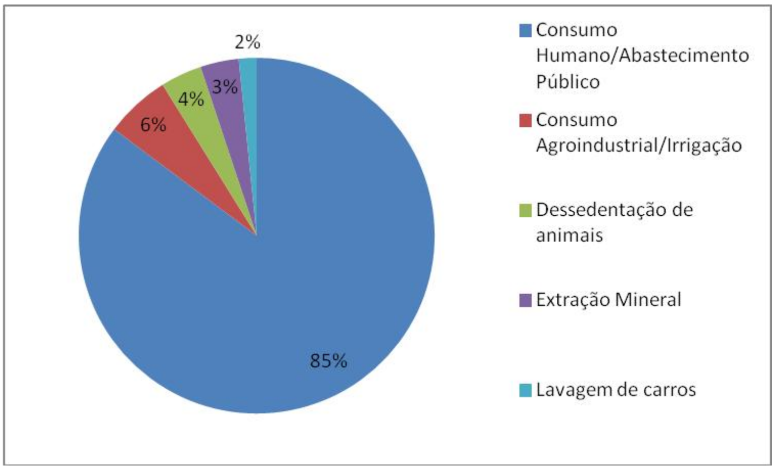

Figure 7. Purpose of current grants Source: Adapted from IGAM (2021)

The segments with the highest groundwater consumption were identified (Figure 8) and it was noted that users of Public Supply/Human Consumption, Irrigation/Agroindustrial Consumption, Industry and Mineral Extraction from 2010 increased considerably the demand for the use of the water resources in CH Furnas.

Given the scenario of increased consumption of underground water resources in Furnas CH, it is necessary to monitor these uses in order to avoid future water scarcity in the region.

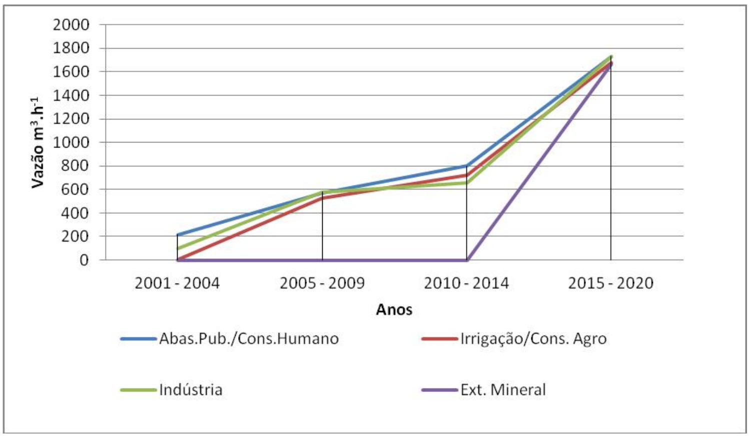

Figure 8. Underground flow granted by purpose throughout the historical series

Source: Adapted from IGAM (2021)

Regarding the types of aquifers, Nogueira (2010) reports that the State of Minas Gerais has three porous, karstic and fractured types and, these, grouped in three hydrogeological provinces called Paraná, São Francisco and Escudo Oriental Sudeste.

The Hydrogeological Domains would be the entities resulting from the grouping of geological units with hydrogeological affinities, based mainly on the lithological characteristics of the rocks and being classified into 7 domains, which are the Cenozoic Formations, Sedimentary Basins, Porous/Fissural, Metasediments/Metavolcanic, Volcanic, Crystalline, Carbonates/Metacarbonates (BOMFIM, 2010).

In CH Furnas, the presence of the 5 domains was verified, the most frequent being the Crystalline domain (Figure 9) and, according to Bonfim (2010), among the fissile aquifers tends to be the domain with the lowest hydrogeological potential. Thus, areas where these characteristics occur should receive greater attention when it comes to granting underground grants.

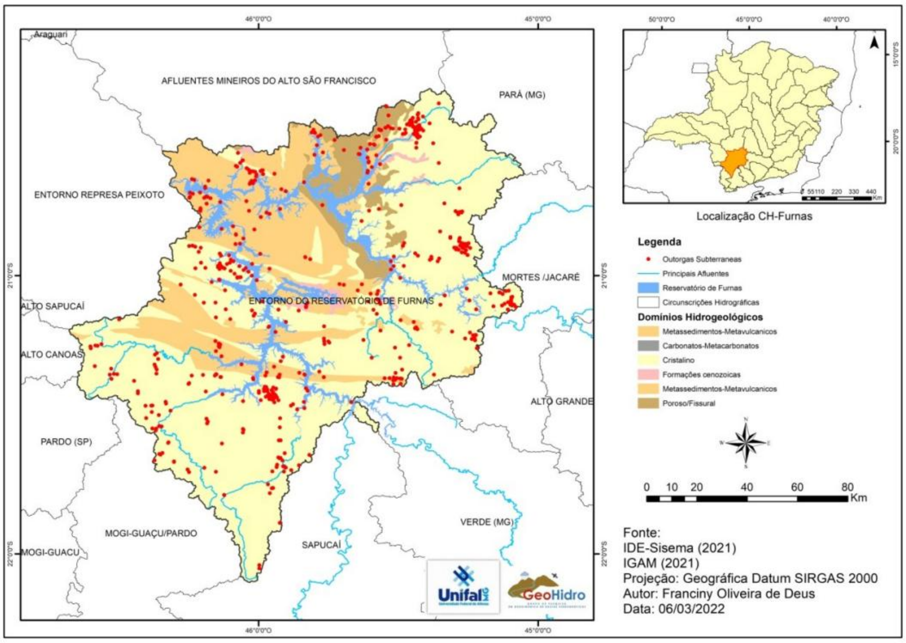

Figure 9. Hydrogeological domains in CH Furnas   Source: Authors (2021)

Figure 8 shows that the largest number of grants granted is in the Crystalline hydrogeological domain, presenting a lower primary porosity and the occurrence of groundwater is conditioned by a secondary porosity represented by fractures and cracks, which translates into random, discontinuous and small-extension reservoirs (BONFIM, 2010).

Another characteristic according to the aforementioned author is that in general, the flows produced by wells in the Cristalino domain are small and the water, due to the lack of circulation and the type of rock (among other reasons), is mostly salinized.

In Furnas CH, 41% of the underground grants refer to the Crystalline hydrogeological domain (Figure 10), and in many regions such as Formiga/MG, Campo Belo/MG and Alfenas/MG, there is a high density of grant concessions, as well as the highest flows granted.

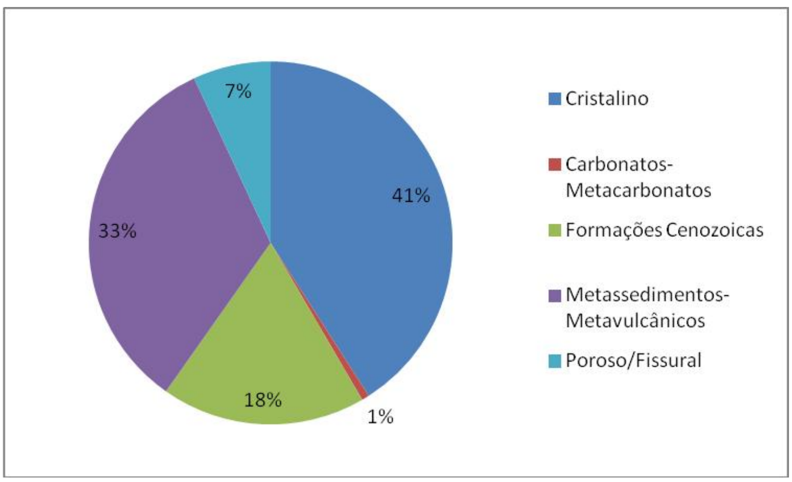

Figure 10. Proportionality of hydrogeological domains in Furnas CH

Source: Adapted from IDE-Sistema (2021)

The spatial distribution of underground grants granted between 2001 and 2020 are mostly located close to urban areas, mainly in the municipalities of Alfenas/MG, Campo Belo/MG, Carmo do Rio Claro/MG and Formiga/MG (Figure 11). The main purpose of groundwater use in these municipalities is human consumption/public supply. For the municipality of Formiga 89%, Campo Belo 76%, Carmo do Rio Claro 74% and Alfenas 67%.

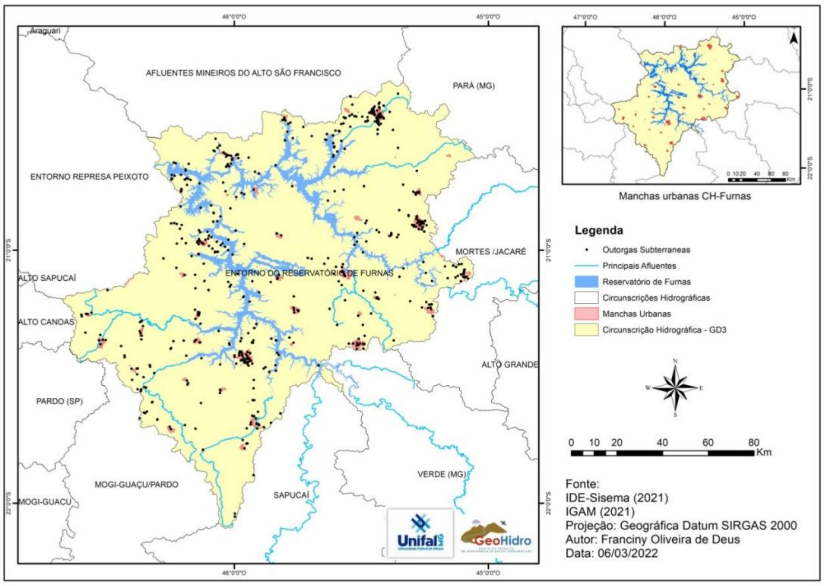

Figure 11. Urban stains and underground grants at CH Furnas (2001 to 2020) Source: The authors - (2021)

According to ANA (2020) in its report on the Conjuncture of Water Resources, the history of the evolution of water uses is directly related to economic growth and the process of urbanization and industrialization of the country. Thus, the tendency is that there is an intensification of the uses of water resources, and thus, areas with greater pressures and, consequently, conflicts over use will arise.

It was observed that the concentration of the density of granted underground permits is related to municipalities that have a high population contingent for regional standards (Figure 12), with permits for human consumption/supply, as well as in areas where agriculture prevails, mainly with coffee cultivation.

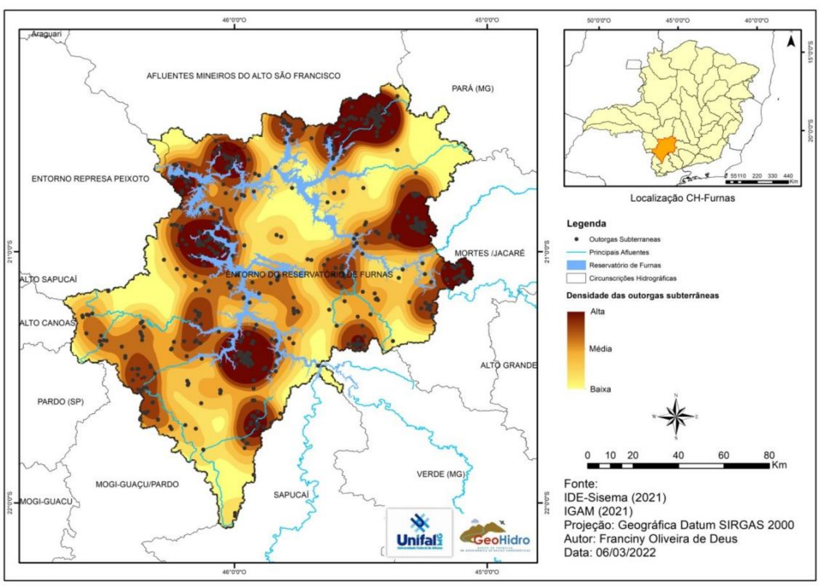

Figure 12. Density of underground grants in CH Furnas Source: The authors (2021)

Data on land cover extracted from IDE-SISEMA (2021), via the website, showed that the municipality of Formiga/MG has extensive eucalyptus plantations and a high concentration of deferred underground grants; to the northwest, there is also a high density of grants in the municipalities of Capitólio/MG, Guapé/MG and São José da Barra/MG, which have scenic landscapes due to the Furnas dam, and therefore have a tourism-oriented economy.

To the south, in the "arm" of the Sapucaí river, it is noted that Alfenas/MG, Areado/MG, Alterosa/MG and Machado/MG have a high density of deferred underground grants, and this fact can contribute to the occurrence of conflicts between user segments, as well as cause water stress in the region.

The regions identified with high density of grants are more susceptible to the emergence of conflicts between multiple users of water resources, for example, the municipality of Formiga/MG can be highlighted. In July 2020, in an attempt to resolve conflicts between user segments, the municipality of Formiga/MG was declared as an area of conflicts through IGAM Ordinance No. 49, October 15, 2019.

It was observed in Figure 13 that the highest flows granted are in the central, north, east and southwest regions in CH Furnas. In the central region there are flows granted between 9.1 and 42.9 $m^3.h^{-1}$ where the municipalities of Campo do Meio/MG, Ilicínea/MG and Boa Esperança/MG stand out, in the area there are extensive plantations of coffee and eucalyptus.

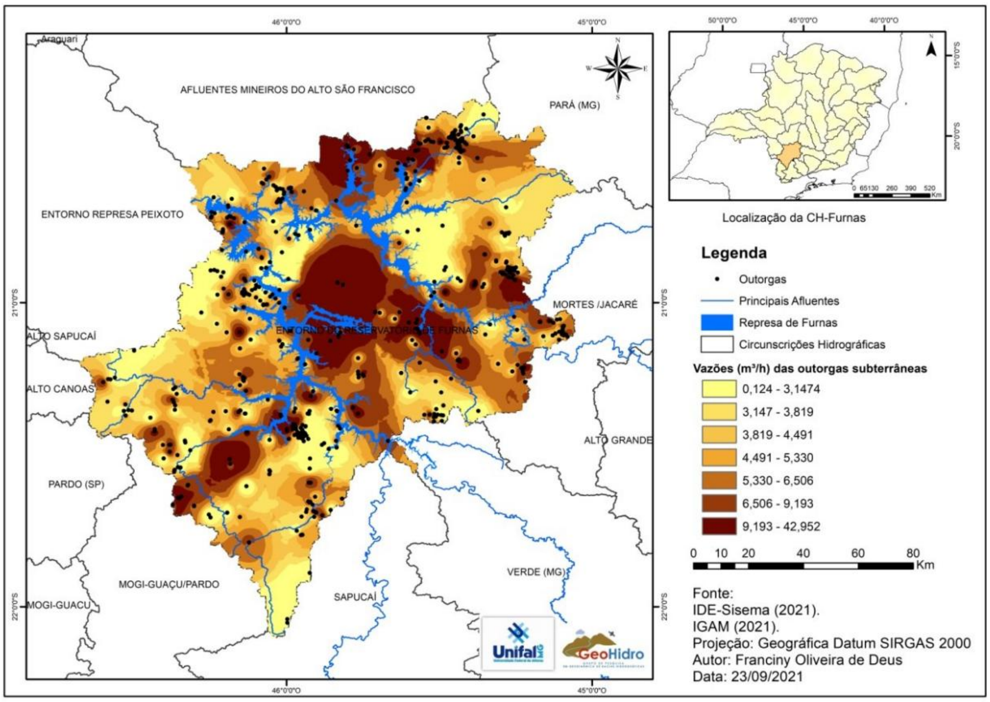

Figure 13. Spatialization of underground flows granted at Furnas CH (2001 to 2020)

Source: The authors - (2021)

In the north, the towns of Formiga/MG and Pimenta/MG also have expressive rates of flow granted, Formiga/MG with 339.5 $m^3.h^{-1}$ and Pimenta with 119.9 $m^3.h^{-1}$, with agricultural plantations, as well as, to the east in Campo Belo/MG and southwest in the town of Divisa Nova/MG, where sugar cane, corn, beans, potatoes and soybeans are mainly produced, while permanent crops include the production of arabica coffee, which is the municipality's main income-generating product, and the production of grapes (ALAGO, 2021).

The municipality of Alfenas/MG is also in an area that stood out in granted flow, with 233.84 $m^3.h^{-1}$. The municipality concentrates activities related to production and services related to coffee, as well as several agricultural properties, warehouses and export companies (SANTOS, 2011).

Therefore, it was noted that the density of grants is not always related to the higher flows granted, i.e. in regions with a low density of grants there may be higher volumes abstracted.

4 Final considerations

The effective management of water resources is essential for the preservation of this resource, for this, it is necessary that the master plans of the watersheds are updated in order to diagnose and plan the uses of water resources.

The absence, as well as the inconsistencies detected in the underground grant data, represent a major limitation in the management of water resources and, to prevent this from happening, it is essential that the management bodies collect and process such data appropriately, as they will be used for the real planning of the use of water resources, whether underground and/or surface.

The user segment Human Consumption/Public Supply is the one with the highest number of underground permits granted at CH Furnas, and this demonstrates the need to promote effective public policies in the management of water resources, with the aim of managing and planning the use of underground water, according to the availability of each region.

Responsibly managing the use of groundwater resources is fundamental to avoid future problems of water scarcity and the establishment of conflicts between user segments, since it was noted through the comparison between CH Furnas PDRH and data from 2001 to 2020 that there was a considerable increase in groundwater consumption in the region.

In general, the municipalities with the highest quantities granted were those with the highest population contingents, however, it was observed areas with few grants granted in smaller municipalities, but with higher flows consumed, being identified with the class of coverage and use by agricultural plantations. It was also detected areas that suffer greater pressures for the use of water resources, especially Alfenas/MG and Formiga/MG.

In this context, in order to avoid scenarios of water scarcity and conflicts between users, it is necessary to monitor the areas identified with greater uses of groundwater resources.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] ALAGO. Associação dos municípios do Lago de Furnas. Cultura e lazer dos municípios do entorno do lago de Furnas. Disponível em: https://www.alago.org.br/alago.asp. Acesso em 5 de setembro de 2021.

[2] ANA. Agência Nacional de Água e Saneamento Básico. Conjuntura Recursos Hídricos Brasil, 2020.

[3] ANA. Agência Nacional de Água e Saneamento Básico. Regulação e Fiscalização. Disponível em: https://www.gov.br/ana/pt-br. Acesso em 18 de julho de 2021.

[4] BOMFIM, L. F. C. Mapa de domínios/subdomínios hidrogeológicos do Brasil em Ambiente SIG: concepção e metodologia. In: XVI Congresso Brasileiro de Águas Subterrâneas. 2010, São Luís. Anais. São Paulo: Revista Águas Subterrâneas, 2010. 18p.

[5] BRASIL, Leis. etc. (1997). Política Nacional de Recursos Hídricos: lei 9.433 de 8 de janeiro de 1997. Dispõe sobre a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos e dá outras providências. Diário Oficial da República Federativa do Brasil, Brasília, 9 de jan.1997.

[6] BRANQUINHO, S. E; VIERA. S. N. A paisagem e a produção do espaço no entorno do lago de Furnas, Sul de Minas Gerais. GEOPAUTA, vol. 4, núm. 4, pp. 113- 139, 2020. Universidade Estadual do Sudoeste da Bahia. https://doi.org/10.22481/rg.v4i4.6943

[7] EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. Mudanças de Uso da Terra em Bacias Hidrográficas. ISSN 1517-2627. Dezembro, 2011.

[8] FILHO, F. J. M. Qualidade das águas subterrâneas rasas do aquífero barreiras: estudo de caso em Benevides – PA. Dissertação. Universidade Federal do Pará, 113 pg. 2018. .

[9] GOETTEN, W. J. Avaliação da Governança da Água Subterrânea nos Estados de São Paulo, Paraná, Santa Catarina e Rio Grande do Sul. Blumenau. 2015. 317f. Dissertação (Mestrado em Engenharia Ambiental) - Engenharia Ambiental, Fundação Universidade Regional de Blumenau.

[10] GODOY, M. J. A reestruturação produtiva e territorial nos municípios de pequeno porte do entorno do Lago de Furnas (MG): (re)funcionalização, transformações e novas dinâmicas. 2017. 140 f. Dissertação (Mestrado em Geografia) – Departamento de Geografia, Universidade de Brasília, Brasília, 2017.

[11] GUTIÉRREZ, R. A. Comitê Gravataí: Gestão participativa da água no Rio Grande do sul. Lua Nova, n. 69, p. 79-121, 2006. https://doi.org/10.1590/S0102- 64452006000400005

[12] HIRATA, R. et al. A revolução silenciosa das águas subterrâneas no Brasil: uma análise da importância do recurso e os riscos pela falta de saneamento. São Paulo: Instituto Trata Brasil. 2019.

[13] IBGE. Instituto Brasileiro de Geografia e Estatística. Disponível em: https://cidades.ibge.gov.br/brasil/panorama Acesso em 26 de março de 2022.

[14] INMET. Instituto Nacional de Meteorologia. Climas. Disponível em: https://portal.inmet.gov.br/. Acesso em 18 de março 2022.

[15] IGAM. Instituto Mineiro de Gestão das Águas. Outorgas. Disponível em: www.igam.mg.gov.br. Acesso em 20 de maio 2021.

[16] IGAM. Instituto Mineiro de Gestão das Águas. Gestão e situação das águas em Águas em Minas Gerais. Belo Horizonte, 2019.

[17] IGAM. Instituto Mineiro de Gestão das Águas. Plano Diretor de Recursos Hídricos da Bacia Hidrográfica do Entorno do lago de Furnas, 2013.

[18] LEITE.C.C.A. Qualidade da água e uso e cobertura do solo em bacias contribuintes do Lago de Furnas (MG): implicações na balneabilidade. Dissertação. Universidade Federal de Minas Gerais, 103 pg. 2020.

[19] LEMOS JÚNIOR, C. B. A implantação da Usina hidrelétrica de Furnas (MG) e suas repercussões: estudo sobre a territorialização de políticas públicas. LEMOS JÚNIOR, C. B. A implantação da Usina hidrelétrica de Furnas (MG) e suas repercussões: estudo sobre a territorialização de políticas públicas.

[20] MARTÍNEZ, M.M., SILVA, S.L.J., LOPES, N. G.Avaliação de Vulnerabilidade das Águas Subterrâneas no Município de Santa Cruz do Sul, RS/Brasil. ISSN 1982- 8470 Agro@mbiente On-line, vol.2, no. 1, jan/jun, Boa Vista. 2008.

[21] MINAS GERAIS. Deliberação Normativa Conjunta CERH-COPAM/MG n° 5, de 20 de setembro de 2017. Disponível em http://www.siam.mg.gov.br/sla/download.pdf?i dNorma=8151. Acesso em 26 de Julho de 2021.

[22] MINAS GERAIS. INSTITUTO MINEIRO DE GESTÃO DAS ÁGUAS. Portaria Igam nº 48, de 04 de outubro de 2019.

[23] MINAS GERAIS. Política Estadual de Recursos Hídricos. Lei nº 13.199 de 29 de janeiro de 1999.NOGUEIRA, G. I. "Base Legal de Águas Subterrâneas e Identificação das Áreas Potenciais de Conflito para Uso em Minas Gerais", Universidade Federal de Minas Gerais, Belo Horizonte, 53p., 2010.

[24] RAMOS, S. L. M., MARTINS, C. J., Abordagem preliminar do uso da água subterrânea em minas gerais através do instrumento de outorga. XII Congresso Brasileiro de Águas Subterrâneas, Belo Horizonte, pg. 14, 2002.

[25] REBOUÇAS, A.C., BENEDITO,B. TUNDISI, J.G. Águas Doces do Brasil: Capital Ecológico, Uso e Conservação. São Paulo : Ed.Escrituras,1999.

[26] SANTOS, F. H. O desenvolvimento econômico de Alfenas e região através do agronegócio do café na região competitiva do sul de minas. Universidade Federal de Alfenas, I Jornada de História Regional José Pedro Xavier da Veiga, p. 15, 2011.

[27] SCOLFORO, J. R. & Carvalho, L. M. T. Mapeamento e Inventário da Flora nativa e dos Reflorestamentos de Minas Gerais. Lavras: Editora UFLA. 288 p.il., 2006.

[28] SCOLFORO, J. R. & Carvalho, L. M. T. Mapeamento e Inventário da Flora nativa e dos Reflorestamentos de Minas Gerais. Lavras: Editora UFLA. 288 p.il., 2006.

[29] SISEMA. Sistema Estadual de Meio Ambiente e Recursos Hídricos, 2018. Relatório. Disponível em:
http: www.meioambiente.mg.gov.br Acesso em 10 de set. de 2021.

Contribution by authors

Franciny Oliveira de Deus performed the data processing, the cartographic base, researched the topic addressed, wrote the essay. Marcelo de Oliveira Latuf contributed to the selection of the study area, conceived the methodological script, assisted in the acquisition and processing of tabular data, and evaluated the writing, as well as cartographic and statistical products.