



Spatial planning of the Bueno Brandão (MG) municipality with emphasis on hydrographic sub-basins

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Received in: 23/10/2023

Accepted in: 25/04/2024

Abstract

Territorial planning must be carried out with the objective of organizing human activities so to promote sustainable development, reconciling human well-being with environmental preservation. In this context, this study was developed with an initial proposal for the spatial planning of the municipality of Bueno Brandão (MG), using the hydrographic sub-basins as environmental planning units. For this purpose, the Geographic Information System software QGIS was used to structure a database composed of hydrographic, altimetric information, municipal limits and spatial distribution of rural clusters and the urban area of the municipality. The Digital Elevation Model, obtained from the Shuttle Radar Topography Mission project, was also used. Google Earth images were used to verify that the areas of population concentration coincided with the limits of the sub-basins. The initial proposal for Bueno Brandão spatial planning resulted in the identification of 43 rural clusters and the delimitation of the urban area, distributed in 12 hydrographic sub-basins.

Keywords: Territorial management. Environmental Planning. SRTM. QGIS. Economic Ecological Zoning.

Introduction

Territorial planning consists of the attempt to put human activities in order, characterizing the space appropriated by a social group according to the economic, social, political and environmental processes that gave rise to it, in order to satisfy its economic, social and environmental demands (BRASIL, 2006; LEONARDI, 2012).

According to Lossardo and Lorandi (2014), the use of natural resources without considering the environmental dimension has generated a series of problems. Faced with these environmental issues, Ross (2006) highlights the growing urgency of a comprehensive physical-territorial planning that contemplates economic, social and environmental aspects.

In this context, environmental planning is carried out to organize a region, aiming at the best performance in relation to its natural vocation (FRANCISCO *et al.*, 2008), to minimize the negative impacts that affect the environment

in which man develops his activities (FLORIANO, 2004), focusing mainly on the conservation and preservation of natural resources. Also noteworthy is the ecological-economic zoning (EEZ), which, according to Leonardi (2012), consists of a technical planning instrument that generates integrated information of a given territory, in order to classify it according to its potential and natural and socioeconomic instabilities.

Ross (2006) also emphasizes the importance of relief and other components of nature in the production process of spaces, considering the potential of natural resources and the fragilities of natural environments due to the possible interferences allowed by technologies, which are increasingly developing. This is important to guide the environmental planning applied to territorial management and to know the environmental dynamics, as well as the social and economic aspects, which is fundamental to improve sustainable development.

The hydrographic basins are the territorial units intended for the implementation of the National Water Resources Policy and the performance of the National Water Resources Management System, according to Federal Law No. 9.433/97 (BRASIL, 1997), and have been increasingly used as environmental planning units, in order to: delimit and recognize the physical environment in a strategic planning vision; apply specific legislation compatible with the local reality; carry out integrated environmental management of the natural physical aspects of the environment with the social groups belonging to it and its economic characteristics; gather environmental and social actions; facilitate identification and establish priorities to mitigate environmental impacts; and evaluate water resources, since their drainage network is a great indicator of the interventions caused in the environment, especially those that are directly linked to the water environment (ALBUQUERQUE, 2012; LOSSARDO; LORANDI, 2014; MORAIS; PIMENTA; SLOVINSKI, 2010; PIRES; SANTOS; DEL PRETTE, 2002; VILAÇA *et al.*, 2009).

The adoption of hydrographic basins as units of planning and spatial planning was proposed by Saunite (2016), in the municipality of Inconfidentes (MG). Likewise, in the municipality of Bauru (SP), the territorial division based on river basins was adopted, resulting in the planning of rural and urban areas within the limits defined by the sub-basins and adjusted according to the road system (BAURU, 2008).

However, many municipalities do not use river basins as planning units for land use planning. In most cases, spatial planning is based on the empirical knowledge of the population, lacking a cartographic definition of the boundaries between population clusters, especially rural ones. This is what happens in the municipality of Bueno Brandão, located in the south of the state of Minas Gerais, object of study of this work.

In the municipality, the only existing form of planning is the municipal division into rural census tracts, carried out by the Brazilian Institute of Geography and Statistics (IBGE). However, this division does not coincide with the residents' perception of rural clusters or identify with the municipality's sub-basins. In addition, there are conflicts regarding the nomenclature of rural clusters, and the use of pseudonyms to identify them is common, based on geographical accidents or constructions present in the population agglomerations. In this scenario, a resident who lives near the boundary between two rural clusters, for example, encounters difficulties in providing their own address.

Defining the territorial planning of Bueno Brandão will benefit the local population, as well as the municipal government, both in the distribution of municipal funds according to the demand, physical size and spatial position of rural clusters, and in the planning of the municipality aimed at sustainable development, since, for this, the public administration must have a georeferenced territorial planning. Another beneficiary of this ordering will be the registry offices, for which having a georeferenced map containing the territorial border and the denominations of rural clusters, also called by the residents of rural neighborhoods, will facilitate the generation of documents and ensure greater reliability to the records.

Given these circumstances, this study was developed with the objective of proposing the initial territorial planning for the municipality of Bueno Brandão (MG), adopting the hydrographic sub-basins as cells of the municipal territorial division in rural clusters, also considering the human occupation in the territory.

Material and methods

The object of study of this work comprises the entire area of the municipality of Bueno Brandão,

which is located in the south/southwest mesoregion of the state of Minas Gerais and in the micro-region of Pouso Alegre (IBGE, 2022) (Figure 1). According to IBGE (2023), the municipality has a territorial area of 356.15 km², an estimated population of 10,911 inhabitants in 2022, a human development index (HDI) of 0.658 and a population density of 30.64 km⁻² in 2022.

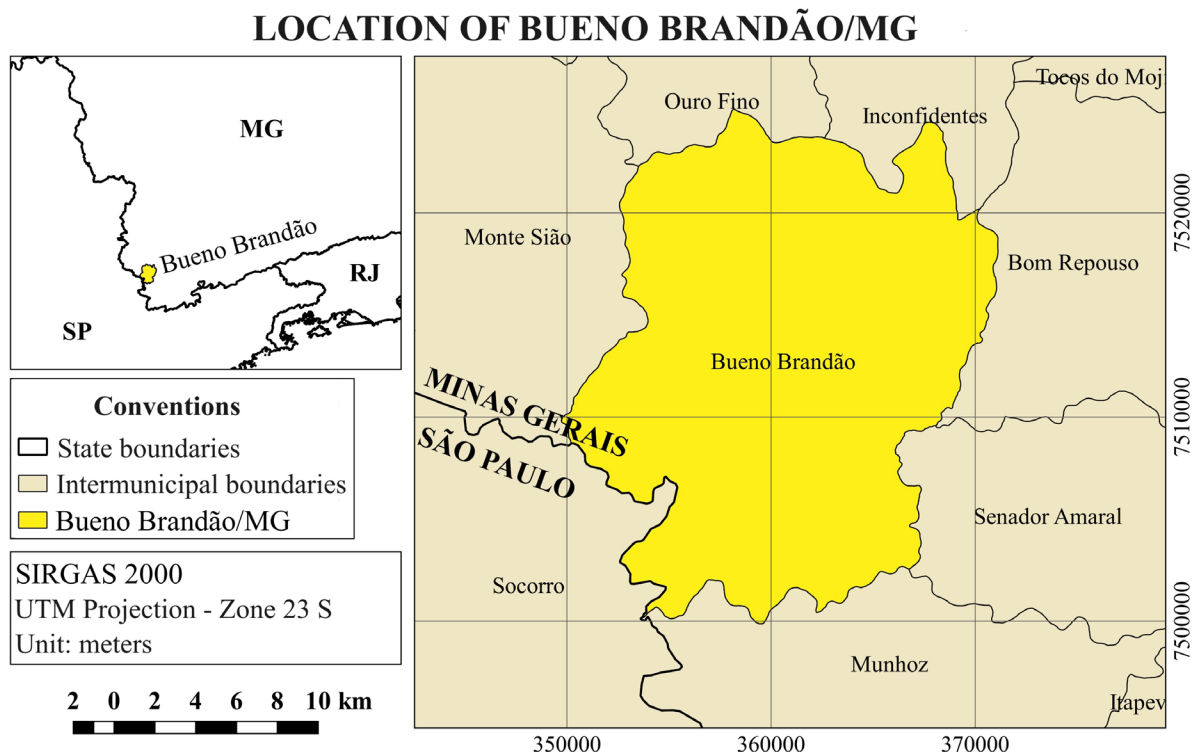
The database used for the initial proposal of the territorial planning of Bueno Brandão is composed of vector and matrix files. To manipulate the information plans and generate this spatial planning proposal, we used QGIS, a free geographic information system (GIS) software, in version 2.18.20.

Regarding the vector files, the information planes referring to hydrography, altimetry, contour lines with a vertical equidistance of 20 m and the Bueno Brandão limits were used. These files were obtained from the official page of IBGE, from the digital files of the Munhoz

(Sheet SF-23-Y-B-IV-1) and Ouro Fino (Sheet SF-23-Y-B-I-3) topographic maps, in which the municipality of Bueno Brandão is contained, both on the 1:50,000 scale, in the cartographic projection UTM (Zone 23 S) and in the geodetic reference system Córrego Alegre, with altitudes referenced to the vertical *datum* of Imbituba (SC).

In addition to these vector data, the information plan regarding the possible centers of rural clusters was included in the project database, consisting of points for identification of each of these clusters (red points identified in Figure 2). The centers were determined using Google Earth, adopting as a reference the Catholic church of each of the clusters, since they are usually located in the center of the rural cluster. In clusters without a Catholic church or in which it was not possible to locate one using Google Earth, a residence located in the center of the cluster or even a tourist reference point was assumed, as is the case of the Serrinha rural cluster, in which the center was identified in “Pico da Serrinha”.

Figure 1. Location of the municipality of Bueno Brandão (MG)



Source: the authors (2024)

It is noteworthy that, before identifying the centers, the name of the rural clusters was determined, using, for this purpose, information provided by the Department of Education of the Municipality of Bueno Brandão, an analogical map prepared in 2000 by the Departments of Infrastructure and Sports, Culture, Leisure and Tourism of the Municipality of Bueno Brandão and, mainly, interviews and research carried out with the local population, since the objective is to propose a territorial planning that can reflect the local reality experienced by the residents.

It should be noted that IBGE (1993) characterizes rural cluster as the locality located in an area not legally defined as urban and characterized by a set of permanent and adjacent buildings, forming an area continuously built with streets recognized or arranged along a communication road. According to the manual of the continuous territorial base of 2018 (IBGE, 2018), the rural cluster can be subdivided into: village – when it is not linked to a single owner and is characterized by the existence of trade and services; rural nucleus – when it is linked to a single owner; and hamlet – when it does not have urban services or equipment and is not linked to a single owner. Although the vast majority of rural clusters in the municipality of Bueno Brandão can be classified as hamlet, there are rural clusters with characteristics of villages, such as the cluster called “Ponte Nova”. Thus, the term rural cluster was adopted as nomenclature for this initial territorial planning of Bueno Brandão, designating what is known by the population of the municipality as a rural neighborhood – agglomerations unrelated to the urban area.

Once the names and centers of the rural clusters were defined, the project included, as a *raster* layer, a clipping of the Digital Elevation Model (DEM) of the Shuttle Radar Topography Mission (SRTM) project, in *geotiff* format, with 30 m spatial resolution cells - made available by the North American Space Agency (NASA),

which is part of the United States Geological Survey (USGS) - necessary in the automatic generation stage of the hydrographic sub-basins. According to Vital *et al.* (2010), the use of SRTM data as a basis for geomorphological mapping is an important tool in the differentiation of relief units and landscape sectors and, through SRTM data, the automatic delimitation of watersheds can be performed.

Medeiros, Ferreira and Ferreira (2009) highlight that the operations for automatic generation of hydrographic basins from DEM with GIS computer programs involve the following procedures: elimination of indentations and protrusions of the DEM; production of the flow direction map; elaboration of the accumulated flow map; mapping of the drainage network; and delimitation of the watershed.

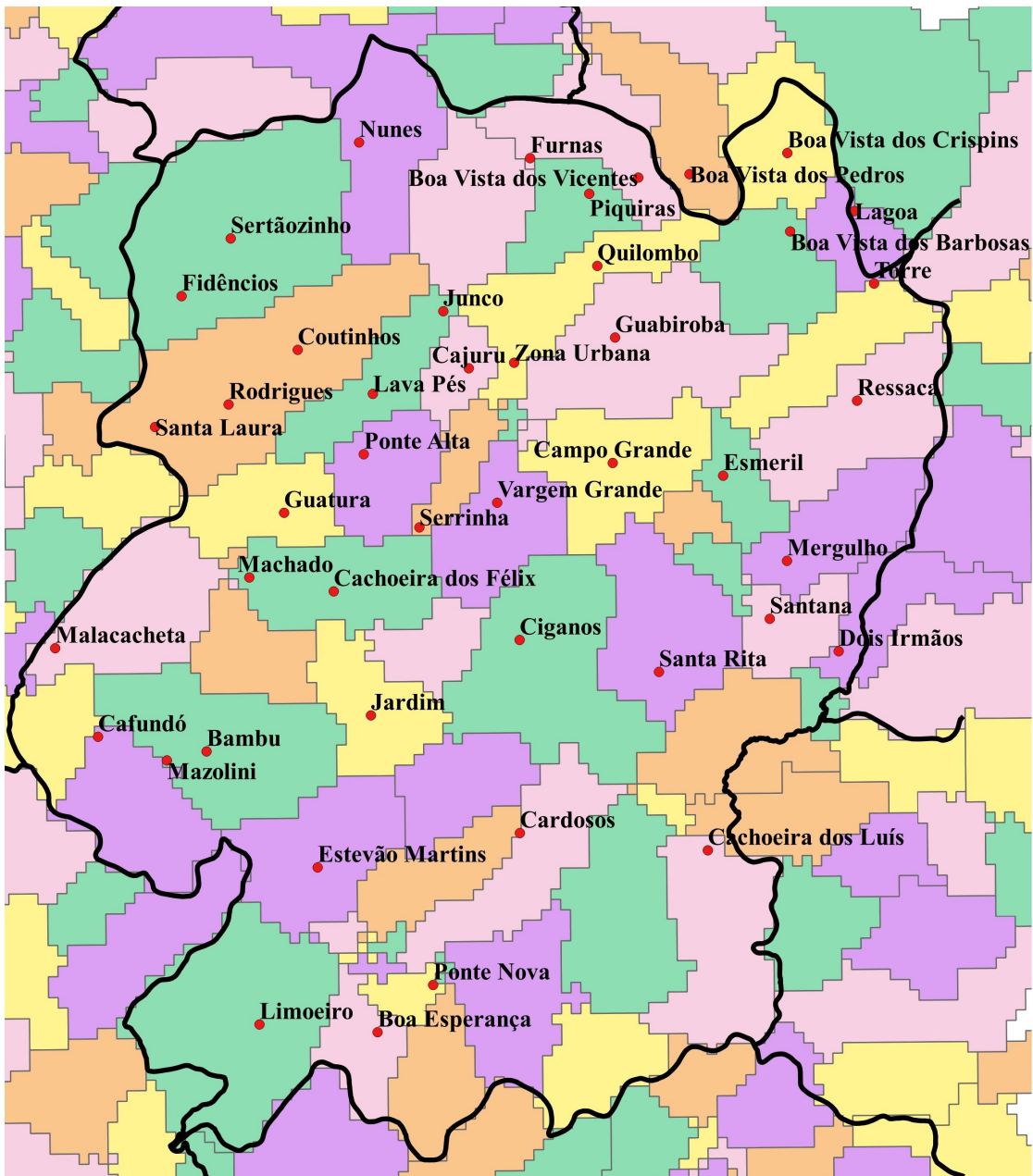
For the automatic generation of the hydrographic sub-basins from the DEM – SRTM in QGIS, the GRASS *plug-in* was enabled and the *r.watershed* – hydrographic basin analysis -command was activated. This tool, developed by Ehlschlaeger and Metz (2017), uses algorithms developed by Ehlschlaeger (1989), Quinn *et al.* (1991), Holmgren (1994) and Metz, Mitasova and Harmon (2011). The minimum size of each sub-basin to be generated (50 cells) was selected and a *raster* file composed of the sub-basins of the area encompassed by the SRTM image was obtained. In Figure 2, the resulting polygons are observed after transforming the *raster* file into a vector.

Due to the spatial resolution of the *raster* file DEM – SRTM, the automatic generation of the hydrographic sub-basins resulted in coarse polygons, whose limits do not follow the hydrography and altimetry of the municipality and, therefore, should not be assumed as delimiters of the rural clusters of Bueno Brandão. Therefore, the delimitation was carried out manually. To this end, a new line vector layer was created in the QGIS and each of the rural clusters was delimited,

using the vector information corresponding to the Bueno Brandão hydrography and hypsometry. To facilitate the perception of the relief, especially the topographic dividers and thalwegs, a color palette ranging from blue – for regions of lower altitude – to red – for higher regions was applied to the DEM – SRTM. In addition to the DEM, the sub-basins automatically generated in the QGIS also helped in the delimitation.

For cases in which the same sub-basin covered two or more rural clusters, the dividing lines between these agglomerations were defined from the topographic dividers and watercourses, dividing a single sub-basin into two or more rural agglomerations, adopting as a criterion the maintenance of existing population clusters. Finally, using Google Earth images, it was verified that the dividing lines defined in the delimitation

Figure 2. Hydrographic sub-basins generated in QGIS from the DEM – SRTM clipping



Source: the authors (2024)

of rural clusters were not overlapped on existing population clusters. In cases of overlap, the dividing lines were adjusted in order to maintain the clusters, since the division of these could cause great inconvenience to the residents.

It is noteworthy that the proposed initial spatial planning did not take into account the urban neighborhoods of the municipality, only the delimitation of the urban perimeter as a whole, since there is no detailed information on urban hydrography and relief on a scale that reliably represents the municipal urban area.

Thus, larger sub-basins were defined integrating the rural clusters and the urban perimeter defined in the initial territorial planning proposal to the drainage network of the municipality of Bueno Brandão (MG) - which constitute the possible municipal planning units.

Results and discussion

From the available information, that is, from the hydrography and altimetry information plans, the sub-basins automatically generated in the QGIS software, the DEM – SRTM and the centers of the rural clusters and the urban area, the initial proposal for the territorial planning of Bueno Brandão (MG) was obtained, carried out manually, resulting in 43 rural clusters/neighborhoods plus the urban perimeter (Figure 3).

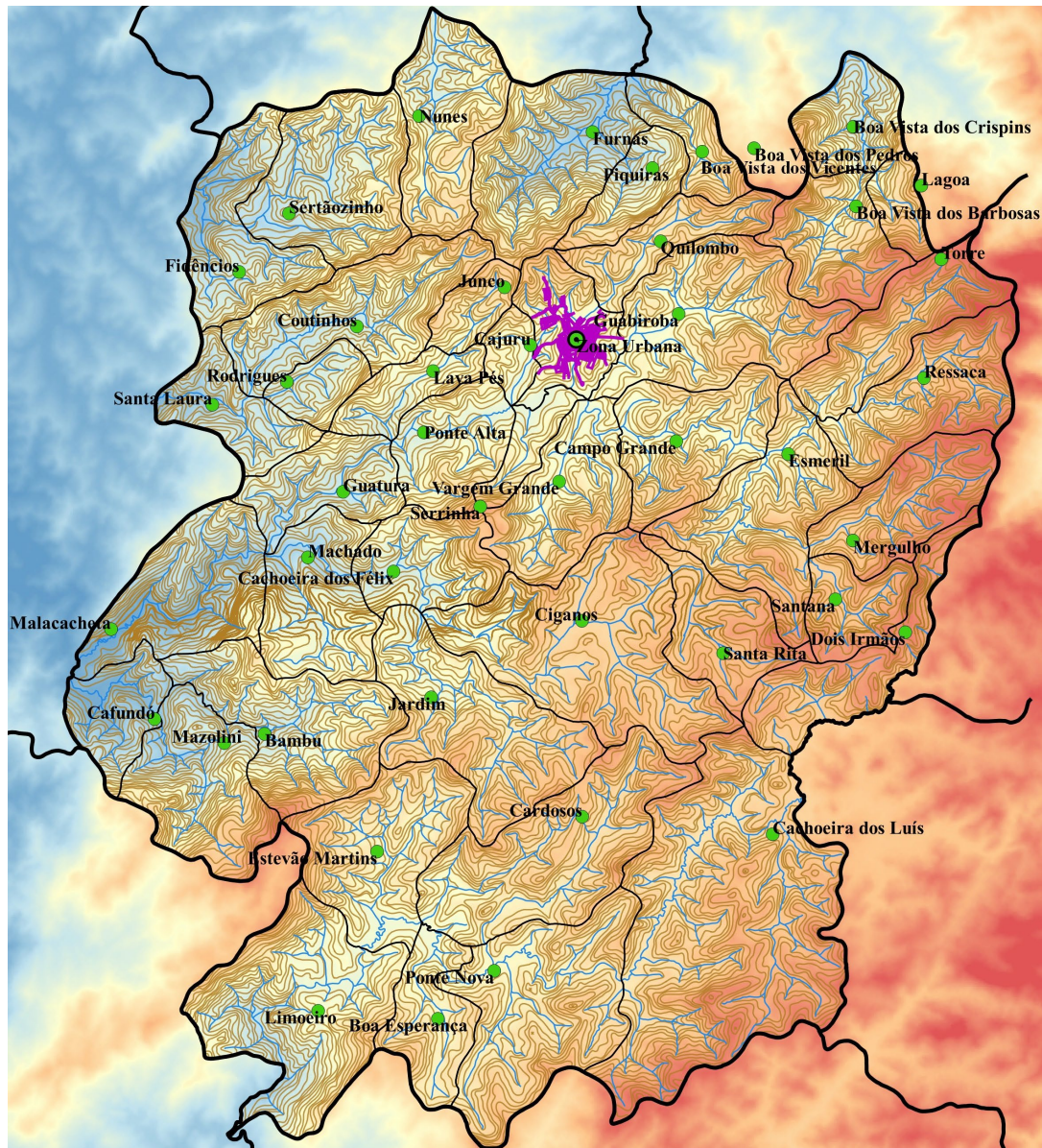
Considering the physical aspects of Bueno Brandão presented in Figure 3, it is possible to observe the delimitation of the rural clusters and the urban perimeter from the hydrographic sub-basins, whose dividing lines are defined from the topographic dividers and, in some cases, from the drainage network. It is also observed that the proposed urban perimeter encompasses all blocks of the municipal urban area, represented in lilac color.

In Figure 4, it can be seen that the proposed urban perimeter covers an area larger than the

perimeter currently designated by the Municipality of Bueno Brandão. This expansion incorporates an extensive region of native vegetation near the Mirante do Cristo, an important local tourist spot. It is noteworthy that the inclusion of this area of native vegetation in the urban perimeter can bring numerous benefits to the municipal government; for example, this area could be used to create a municipal park, providing significant advantages to the municipality under the three guidelines that make up the sustainability tripod. First, from a social point of view, the creation of a leisure space would offer a recreational area for local residents, promoting their quality of life and well-being. In addition, from an environmental point of view, maintaining this extensive area of native vegetation of the Atlantic Forest biome would be crucial. This would contribute to the conservation of local biodiversity and the protection of natural ecosystems, serving as a refuge for the fauna and flora of the region. Finally, from an economic perspective, the existence of a municipal park would attract tourists to the city, boosting the tourism sector and generating additional income for the local community. The increased flow of visitors would not only promote the local economy, but also strengthen Bueno Brandão's tourist identity, expanding its opportunities for long-term sustainable development.

It is noteworthy that the rural cluster Boa Vista dos Pedros is located totally outside the municipality of Bueno Brandão, spatially belonging to the municipality of Inconfidentes (MG). Therefore, this neighborhood was not included in the territorial planning proposed for Bueno Brandão. In this same aspect, the case of the rural cluster Lagoa stands out: the sub-basin that defines it is divided between the municipalities of Bueno Brandão and Inconfidentes, so that the main agglomeration of the residences of this neighborhood is located in Inconfidentes, as well as the Catholic church itself, initially taken as the center point of the rural cluster. In view of this situation, the Lagoa neighborhood was

Figure 3. Delimitation of rural clusters and the municipal urban perimeter. In blue, the hydrography is represented; in brown, the contour lines; in lilac, the urban area; and, colored by the color palette from blue to red, the DEM – SRTM image



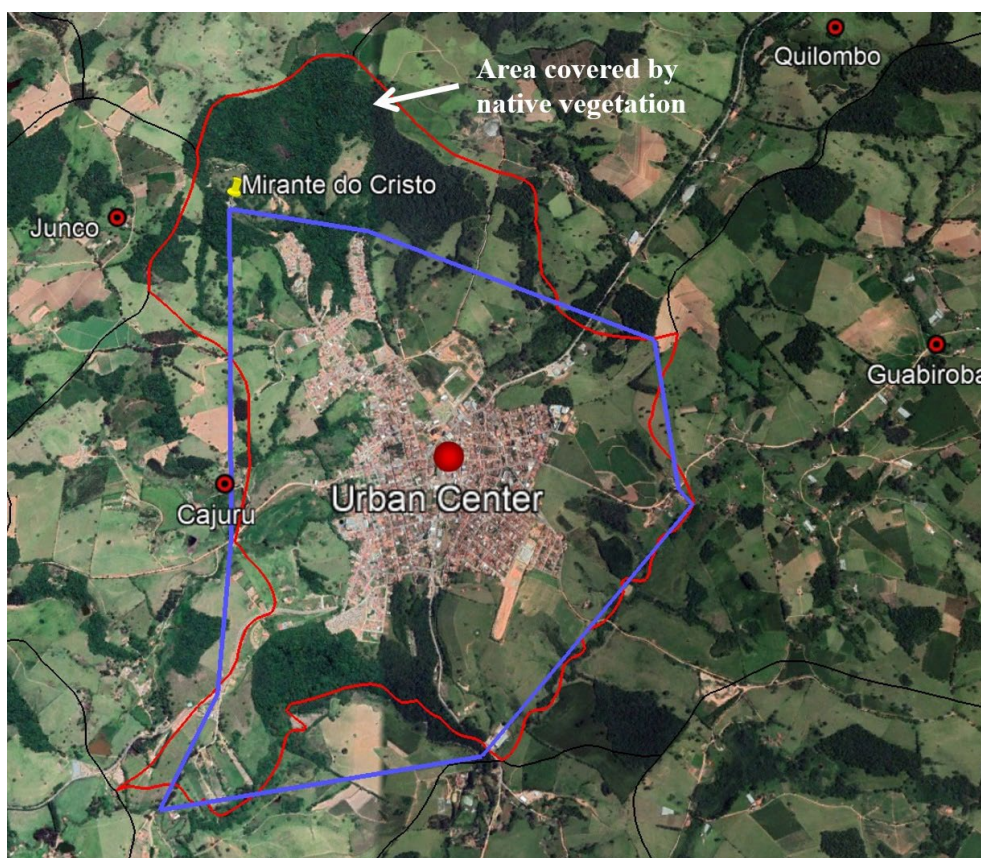
Source: the authors (2024)

incorporated into the territorial planning proposal, but its center point was changed, which began to be identified by a residence in the center of a small agglomerate located in the portion of the sub-basin that delimits the rural cluster, located in the municipality of Bueno Brandão. These described cases are illustrated in Figure 5.

In view of the divergence between the delimitation of the municipalities – according

to the IBGE database – and the limit materialized by the population and recognized by the municipal government, it is necessary to carry out a collaborative study between the municipal governments of Bueno Brandão and Inconfidentes, in order to determine a viable solution. It is suggested to consider changing the intermunicipal limit, previously defined by the IBGE, so that these rural clusters are included

Figure 4. In red, urban perimeter proposed from the sub-basins. In blue, urban perimeter currently adopted by the City Hall of Bueno Brandão (MG)



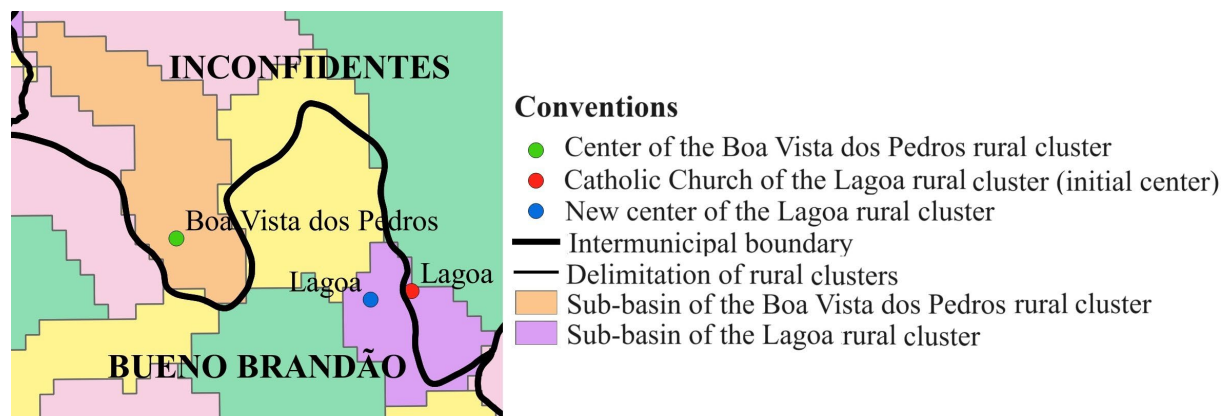
Source: the authors (2024)

in the territory of the municipality of Bueno Brandão, according to the identification of the resident population.

The final product of the territorial planning proposed for the municipality of Bueno Brandão

(MG), with emphasis on sub-basins, is shown in Figure 6. Integrating the rural clusters, popularly known as rural neighborhoods, and the urban perimeter of Bueno Brandão into the municipality's drainage network, it was observed

Figure 5. Case study of the Lagoa and Boa Vista dos Pedros rural clusters



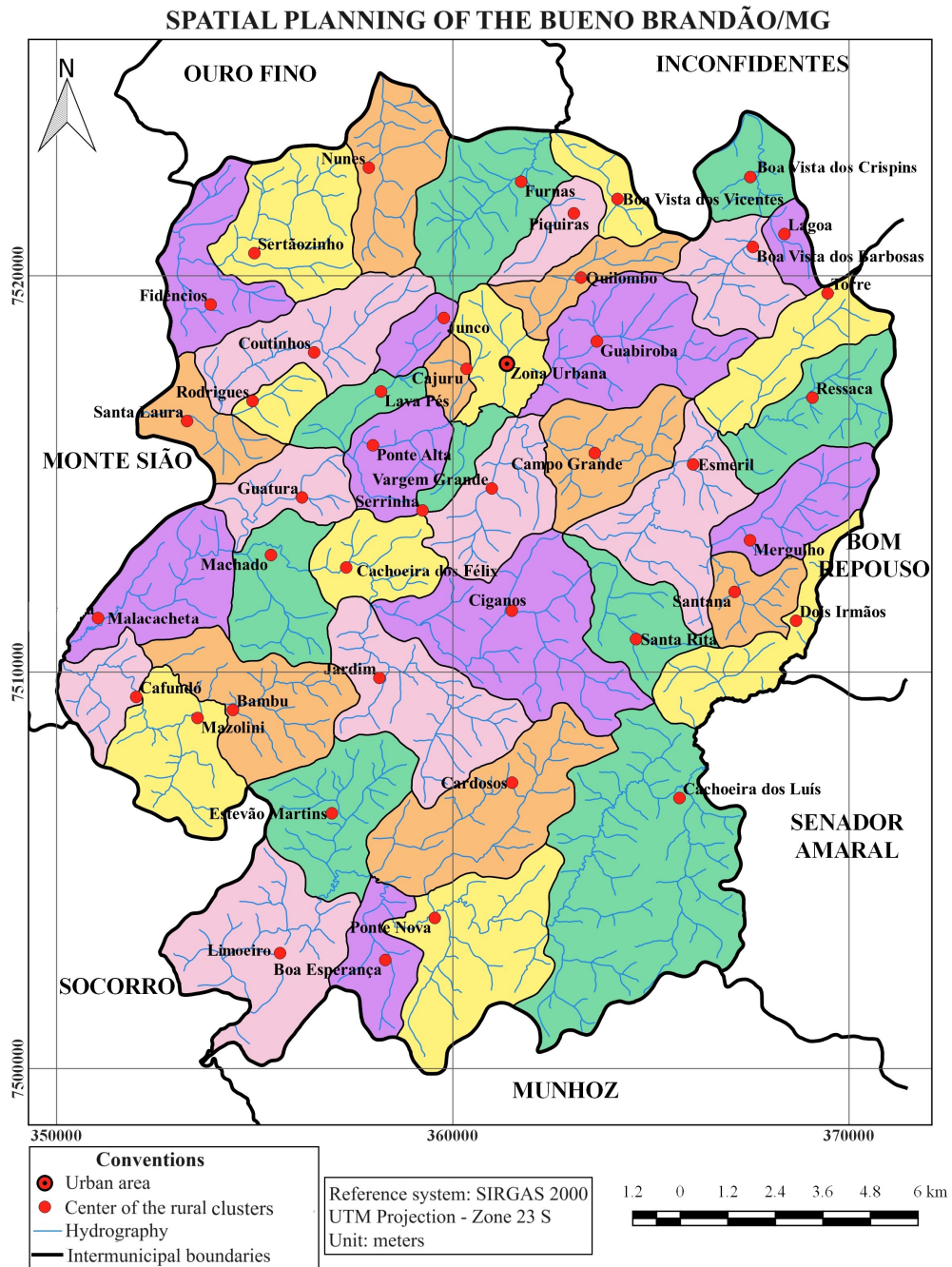
Source: the authors (2024)

that, in most cases, two or more rural clusters are part of the same larger sub-basin, as shown in Table 1. These sub-basins were named after the main existing watercourse, the same methodology adopted by Souza, Sobreira and Prado Filho (2005). The sub-basins presented in Table 1 define the possible environmental

planning units of the municipality of Bueno Brandão (MG), represented in Figure 7.

The delimitation of environmental planning units is relevant since, in order to propose environmental planning or even to carry out an EEZ for the municipality of Bueno Brandão, it is necessary to analyze which rural clusters must

Figure 6. Initial proposal for spatial planning in Bueno Brandão (MG)



Source: the authors (2024)

Table 1. Integration between rural clusters and the urban area and sub-basins to which they belong.

Hydrographic sub-basin	Tributaries	Rural clusters (neighborhoods)
Ribeirão dos Leites or Boa Vista	Ribeirão dos Leites or Boa Vista	Boa Vista dos Crispins, Boa Vista dos Barbosas, and Lagoa
Rio das Antas	Rio das Antas, Córrego da Torre, Córrego do Mergulho, Córrego da Vargem Grande, Córrego da Barba de Lima, and Córrego Fundo	Torre, Ressaca, Mergulho, Santana, Esmeril, Campo Grande, Vargem Grande, Guabiroba, Quilombo, Zona Urbana, Serrinha, Cajuru, Ponte Alta, Guatura, and Malacacheta
Córrego dos Dois Irmãos	Córrego dos Dois Irmãos	Dois Irmãos
Córrego do Retiro	Córrego do Bom Jardim and Córrego do Retiro	Bamboo, Mazolini, and Cafundó
Córrego da Cascavel	Córrego do Marco, Córrego dos Ciganos, and Córrego da Cascavel	Santa Rita, Ciganos, Jardim, Cachoeira dos Félix, and Machado
Córrego da Guatura	Córrego da Guatura	Lava Pés and Junco
Córrego do Bamburral or da Barreirinha	Córrego do Bamburral or da Barreirinha	Coutinhos, Rodrigues, and Santa Laura
Ribeirão dos Três Cruzeiros or Sertãozinho	Ribeirão dos Três Cruzeiros or Sertãozinho	Sertãozinho and Fidências
Ribeirão do Mandu or dos Nunes	Ribeirão do Mandu or dos Nunes	Nunes
Córrego das Furnas or Pitanga	Córrego das Furnas or Pitanga	Piquiras and Furnas
Córrego da Piquira	Córrego da Piquira	Boa Vista dos Vicentes
Rio da Cachoeirinha	Rio da Cachoeirinha, Córrego do Cardoso, and Córrego do Sino	Estevão Martins, Cardosos, Cachoeira dos Luís, Ponte Nova, Boa Esperança, and Limoeiro

Source: the authors (2024).

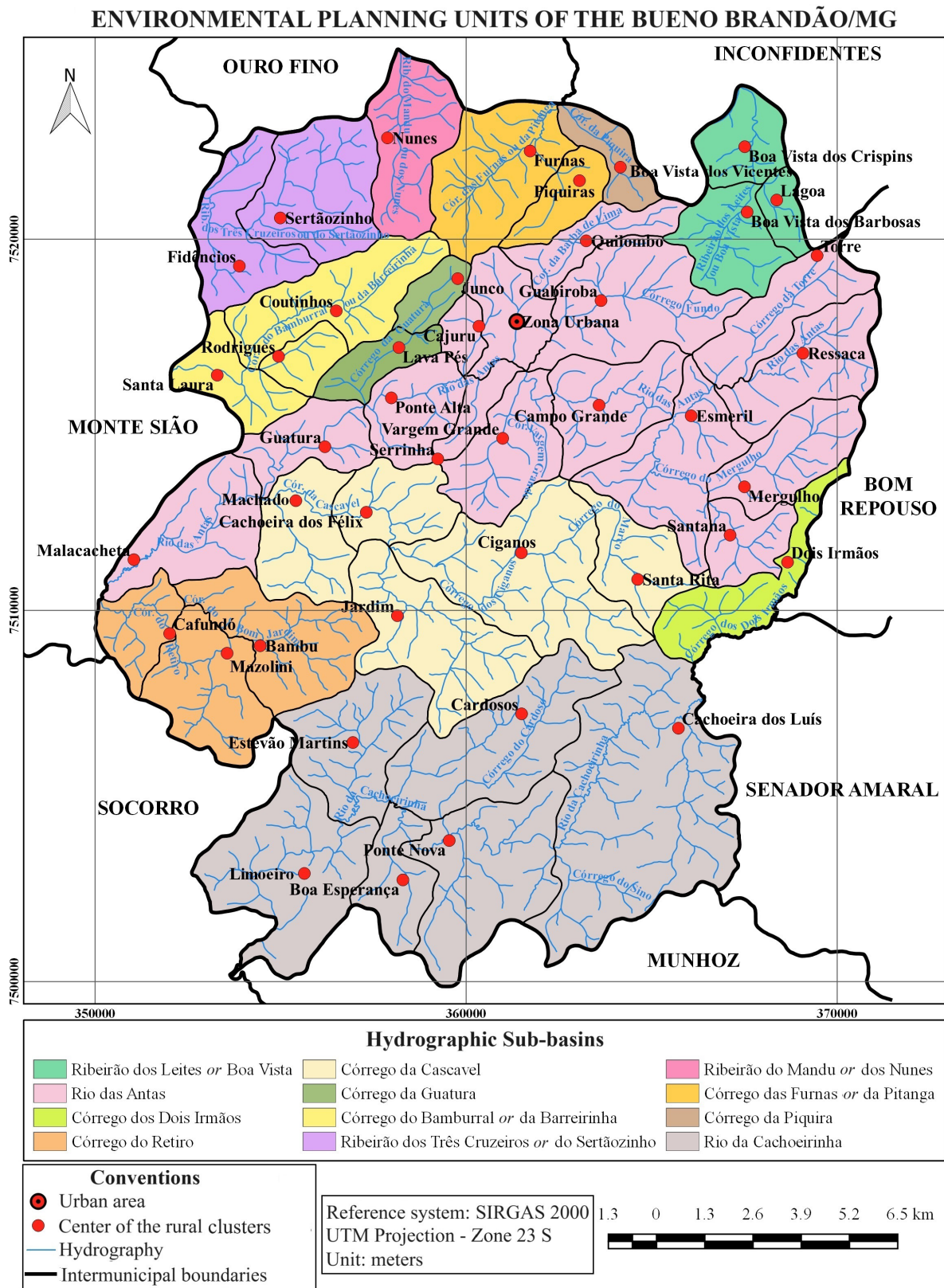
be planned together, which is determined through the sub-basins in which they are contained, which will be used as planning units. Thus, each sub-basin defined in Table 1 is proposed as a unit, whose planning can take place independently, since each one will be destined for a specific purpose according to its potential, which is determined by its natural characteristics and the form of human occupation in the place.

For example, in order to propose development goals that value environmental conservation in the municipality of Bueno Brandão, the Boa Vista dos Crispins neighborhood must be treated together with the Boa Vista dos Barbosas and Lagoa neighborhoods, that is, these three rural clusters must be considered as a single planning unit, since the sub-basin of Ribeirão dos Leites or Boa Vista has its sources in Boa Vista dos

Barbosas and Lagoa and any change made in the headwaters of the basin will directly affect its main watercourse, which drains to Boa Vista dos Crispins.

It is important to highlight that, in order to carry out and validate this initial proposal for municipal spatial planning, it is necessary to hold an *on-site* conference, which will be the object for future work. Only through field research with local residents can the population's perception of the names and limits of rural clusters be verified, thus integrating environmental planning with social well-being and avoiding conflicts of location among residents. In addition to the survey of these possible conflicts, during the *on-site* conference, it will be essential to consider the properties located near or adjacent to the dividing line between the urban and rural areas

Figure 7. Possible environmental planning units based on the sub-basins of the municipality of Bueno Brandão (MG)



Source: the authors (2024)

of the municipality, in order to avoid situations in which a single property is divided between these zones. Only after field research and reassessment of the proposal, the initial spatial planning proposed in this study may be submitted to the municipal government of Bueno Brandão, which so far does not have such a planning plan.

In addition, given the results achieved, it is proven that the use of free software and data for the elaboration of proposals for municipal territorial planning is an effective alternative, which helps the planning and management of municipalities.

Conclusions

The initial territorial planning for the municipality of Bueno Brandão (MG) was developed adopting free data and software. Forty-three rural clusters—referred to locally as rural neighborhoods—were defined, and the municipal urban area was delineated with a proposed new urban perimeter for the municipality. This study also resulted in the proposal of 12 sub-basins that cover the entire municipality, which can be adopted as municipal environmental planning units in future studies, providing the basis for outlining guidelines for medium and long term actions, aiming at the preservation, conservation and improvement of the environmental quality of these areas.

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