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Proposition and application of a method for the characterization of rural areas in the census sectors from the sanitation point of view

Roberta Vieira Nunes Pinheiro
Master, UFG, Brazil.
robertavnp@gmail.com

Isabela Moura Chagas
Master Student, PPGEAS/UFG, Brazil.
isabelamch@gmail.com

Raviel Eurico Basso
PhD Professor, UFG, Brazil.
basso.raviel@gmail.com

Juliana Dorn Nóbrega
PhD Professor, UFG, Brazil.
junobreg@gmail.com

Nolan Ribeiro Bezerra
PhD Professor, IFG, Brazil.
nolanbezerra@gmail.com

Paulo Sérgio Scalize
PhD Professor, UFG, Brazil.
pscalize.ufg@gmail.com

ABSTRACT
Considering the concept of rurality, the need for methods to contextualize the rural areas and the attendance by sanitation services, the goal of this work was to propose and apply a method of characterization in census sectors (CS) of rural areas. For such, a classification method for rural clusters was built, considering the selected criteria based on the *Programa Saneamento Brasil Rural* (Rural Brazil Sanitation Program) and other technical-scientific literature. The method encompassed three criteria: the identification of clusters and dispersed households, distance from the cluster to the closest urban center (Cucd) and demographic density (Dd). Of all the 115 rural areas in the state of Goiás, it was possible to apply such in 98, as in the remaining 17 the method could not be directly applied, due to the existence of one or more clusters with the presence of households that do not make part of the rural area, that is, non-contiguous households. In a more detailed analysis, four areas were identified where the method could be applied to a group of households. A total of 103 rural areas were numbered, with an average Cucd of 27.7km (SD = 19.42; CV = 0.70), and average Dd of 50.1 inhabitants per square kilometer, in which 118 clusters were detected. Of that total, 6.79% were classified in the CS 1b and 2, 7.77% on 3 and 85.44% on 5 and 7. It was concluded that the method can be applied integrally in a rural area and/or clusters with contiguous households. Lastly, the classification in CS allows for a preliminary analysis of solution propositions for basic sanitation, being them collective and/or individual, centralized and/or decentralized, according to spacial technical criteria.
KEYWORDS: Rural Cluster. Rurality. Rural Sanitation.

INTRODUCTION

The rural areas are marked by great human diversity, with different forms of social organization, represented by farmers, traditional peoples and communities, and individuals with different socio-occupational profiles (BRASIL, 2019a). In Brazil, the National Policy for the Sustainable Development of Traditional Peoples and Communities recognizes and defines them as groups culturally different, able to be categorized as indigenous, *quilombolas*, riparian, Romani people, peoples and communities of African Matrix or T*erreiro*, collectors, artisanal fishermen, babassu coconut breakers and Pomeranians (BRASIL, 2007).

The conceptualization of rural is composed by several areas of knowledge such as economy, from the distances to be covered; demography, from population dynamics; geography, through the reading of space/territory; and anthropology, from the social representations (GALIZONI, 2021). In the last five decades several social, economic, technological and political changes have occurred, such as the digital revolution, the decentralization of responsibilities and public resources and physical connectivity, which influenced and changed the way of life in the rural environment. These changes have motivated the discussion, in several countries, about the concept of rurality and about what differs such environment from the urban one in particular, in the public policies directed towards the social sectors and of infrastructure services, covering the rural sanitation (MEJÍA; CASTILHO; VERA, 2016; LA ROSA; VILLARREAL, 2020; MÉNDEZ, 2020; SÁNCHEZ et al., 2021).

The Rural Brazil Sanitation Program (*Programa Saneamento Brasil Rural,* PSBR) (BRASIL, 2019a), considering the concept of rurality, proposed an alteration in the census sectors (CS), reclassifying the areas in urban clusters (CS 1a) and rural clusters: close to urban (CS 1b, 2 and 4), denser and isolated (CS 3), less dense and isolated (CS 5, 6 and 7) and without clusters, having proximity to a cluster or not (CS 8). This form allows for more homogeneity and reveals peculiarities in terms of collective or individual solutions for sanitation, especially in function of the demographic criteria which rule the principle of economies of scale, demographic density and proximity to urban centers, reinforcing that the adoption of individual solutions does not characterize inadequate access to the sanitation services, if quality and security criteria are followed (ROLAND *et al.*, 2019). This new proposition for the identification of clusters is justified since, according to Laschefski (2021), without additional information, the original classification (IBGE, 2017) does not allow the identification of rural areas for specific measures regarding sanitation.

These areas must be attended by sanitation services, which are essential for the promotion of health, being a right for everyone and duty of the State by the Federal Constitution (BRASIL, 1988). This group of public services is composed by: infrastructure and operational facilities for supplying potable water; sanitary sewage; urban cleaning and solid waste management; drainage and rainwater management. The provision of the aforementioned services is linked to quality, continuity and accessibility to the service, having as principles the universality of access, effective service provision and adoption of methods, techniques and processes which consider the local and regional peculiarities, among others (BRASIL, 2020), which can be influenced by economic, politic, social, institutional and legal factors (ROLAND; REZENDE; HELLER, 2020).

The exercise of such right compels the State to adopt new service models aiming public attendance, with adequate conditions of environmental health, to the indigenous peoples and other traditional populations, as well as rural populations and small communities, through the use of solutions compatible to their socioeconomic characteristics (BRASIL, 2013). Environmental healthiness was defined by Braga, Scalize and Bezerra (2022) as the health situation of a population, influenced by the socioeconomic conditions, education, basic sanitation and the environment in which they live.

According to Brasil (2019a), geographically these populations are also spread in distinct manner: in clusters or dispersed, close or far among each other and close or not to urban areas. Thus, besides a general classification of the Brazilian rural areas by the PSBR, it is extremely necessary to develop a method for individual characterization of these areas with the goal of helping in decision-making for the best sanitation technologies to be implemented and/or practiced.

Facing the presented context and the lack and limitation of universal information for the characterization of the Brazilian rural environment (RIGOTTI; HADAD, 2021), the goal of this work was to propose a method to characterize rural areas in census sectors from the basic sanitation point of view and apply it on rural communities of the state of Goiás.

MATERIAL AND METHODS

Proposition of the method for the characterization of rural areas in census sectors (CS)

The method is applicable for rural areas which present clusters with contiguous households, denoting an integrated area. It was developed considering the PSBR (BRASIL, 2019a) and the discussions conducted regarding the concepts of rurality (MEJÍA, CASTILHO; VERA, 2016; FREITAS, 2021; GALIZONI, 2021) and methods of spatial delimitation of rural areas (HAN *et al.*, 2019; LACHEFSKI, 2021; RIGOTTI; HADAD, 2021). This form of classification proposed by the PSBR has a greater capacity of delineation and representation of the diversity of existing tenures in the rural environment (ROLAND *et al.*, 2019).

To be used as criteria for this method, a literature study was conducted regarding the main characteristics, their relevance for the characterization of rural areas and their specifications from the standpoint of sanitation services provision. The most representative

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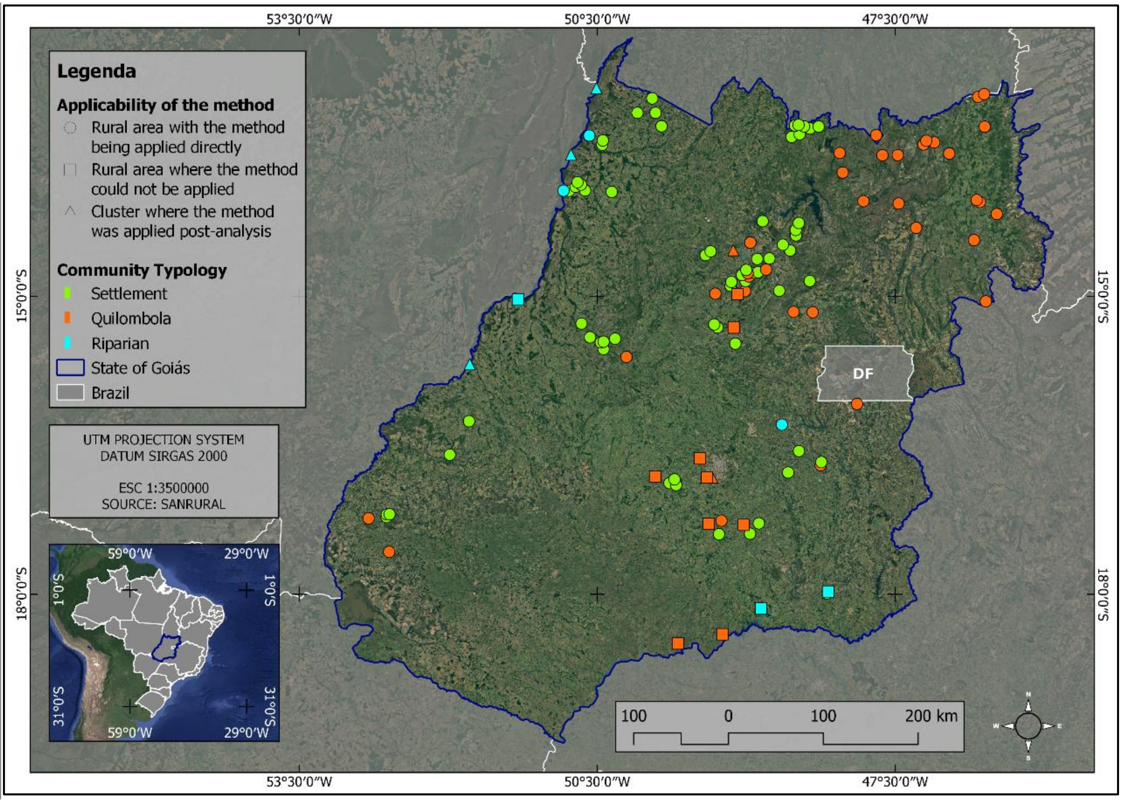
criteria for the spatial characterization of the rural area were selected, organized in value ranges and inserted into a decision flowchart of application.

A specific method for obtaining the values for each criteria was suggested, in each of the clusters, in order to classify them in rural census sectors (1b to 7), making its application possible into any rural area of the same nature.

Application of the proposed method

The proposed method was applied in 115 rural areas, distributed in 43 cities of the state of Goiás, Brazil (Figure 1). They are composed by 53.9% of settlements, 38.3% (44/115) of *quilombola* communities and 7.8% (9/115) by riparian communities.

Figure 1: Geographical distribution of the 115 rural areas, characterized in Census Sectors (CS), Goiás - Brazil



Source: drafted by the authors.

Data were collected while visiting the rural areas in the span from August 2018 to August 2019, and they are catalogued as the following: name and its typology, municipality to which it belongs, total number of inhabitants and amount of households and its geographic coordinates. Adding to this, the delimitation of areas and determination of its distance to the closest urban center were carried out.

In the visit to each community, the collection of the households' geographical coordinates was conducted using the Android and/or iOS geo-referencing apps. The geographical delimitations of the rural areas were obtained from the National Institute for Colonization and Agricultural Reform (*Instituto Nacional de Colonização e Reforma Agrária*, INCRA), or certain ones with the aid of QGIS, defining the comprising perimeter, using the coordinates of the most external households as a limit, and from then, establishing a buffer of 200m to obtain the area. It is important to highlight that in the case of the clusters located in urban centers, only the calculation of the cluster has been maintained without considering a possible insertion of such households in a neighborhood or region.

Regarding location, the smallest distance by road access between each cluster of rural areas and the closest urban center has been obtained. For this step vector, files in the *shapefile* format were used, being for the urban perimeters of municipal headquarters made available by SIEG (2014) considering, still, the existing urban expansions in the Google Satellite images. For the districts, the information available in SIEG (2017) was used, with delimitation of the perimeters' districts based on the Google Satellite Image. In the discussion, it was considered that the access difficulty is greater for distances longer than 60.0 km, according to studies conducted in rural areas of the USA and the European Union (LASCHEFSKI, 2021).

All data were obtained from the Project Sanitation and Environmental Health in Rural and Traditional Communities in Goiás (Project SanRural – https://sanrural.ufg.br/), developed in the Federal University of Goiás (UFG).

In possession of the data, it was possible to describe and characterize the rural areas and the environment to which they belong from sanitation's point of view. The information obtained for the sampling universe were treated and presented, according to each used criteria, and also in accordance to the classification of the clusters in CS. The results were discussed, following the sanitation components (water supply, sanitary sewage, solid waste management and drainage and rainwater management), bringing an overview of the characteristics found in rural communities, studied in Goiás.

RESULTS

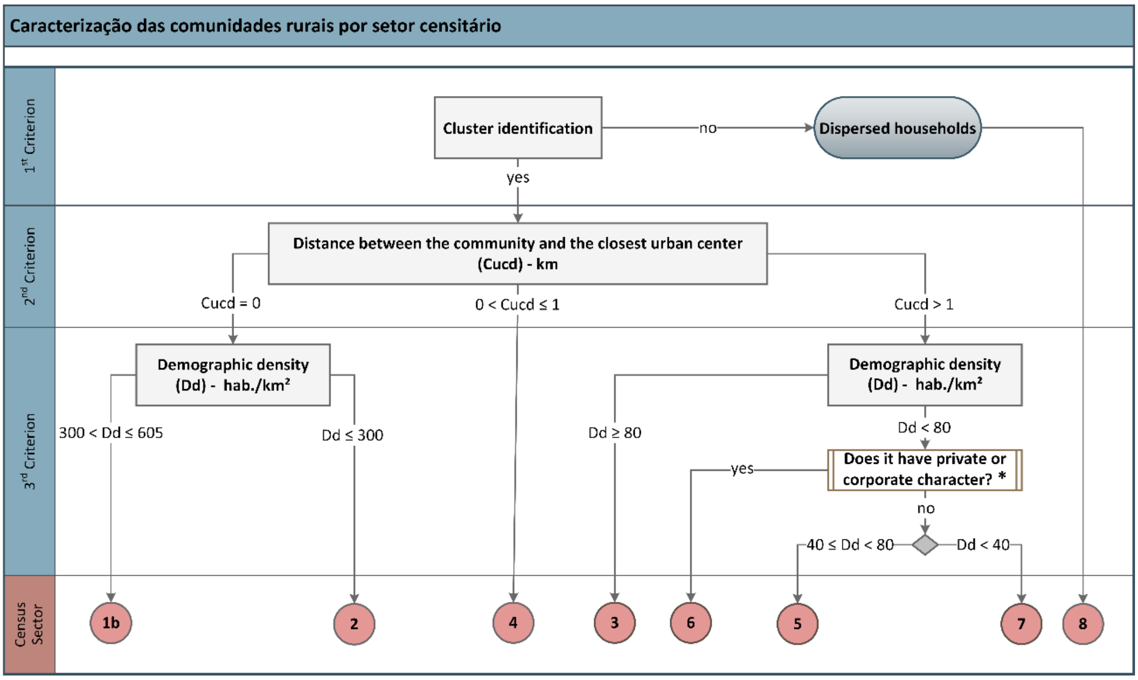
Method for the characterization of rural areas in census sectors

The criteria which can be used for the characterization of rural areas were identified, from the standpoint of sanitation services' provision: accessibility to service centers, neighborhood characteristics (other rural or urban areas), demographic density (RIGOTTI; HADAD, 2021), spatial household distribution, organization into community associations, available water's quality (ROLAND *et al.*, 2019), income, human development index, primary sector employment percentage (LASCHEFSKI, 2021), total amount of inhabitants, their relationship to demographic density, type of land occupation (farming or forestry activity), existing sanitation infrastructures (MEJÍA; CASTILHO; VERA, 2016).

The criterion of existence of determined urban infrastructure elements (buildings, economic activities, urban equipment, health center, religious temple, among others), adopted by the IBGE (2017), was not included in this study, as such definition does not consider, in a qualitative manner, the way of life of its inhabitants (LASCHEFSKI, 2021). In relation to the use of the neighborhood characteristics criteria, the chosen option was to rule it out, given that the proposition is to make an individual characterization of a rural area possible. As for the total population, it was considered in relation to the cluster area (demographic density) seeking better characterization of the occupation of the studied rural area. The use of two or more criteria for such classification already helps the operationalization and perspective offer analysis of basic services, such as health, education, sanitation and electricity (MEJÍA; CASTILHO; VERA, 2016).

In this way, for the proposed method, three criteria were chosen for the classification of rural communities in CS: 1) Identification of clusters and dispersed households; 2) Distance to the closest urban center (Cucd); 3) Demographic density (Dd). The 2nd and 3rd criteria were used according to recommendation of Rigotti and Hadad (2021), and the 1st criterion served as support for the definition of the other criteria, given that the households in rural areas have no homogeneous spatial distribution, and can present one or more clusters and dispersed households, being considered as an aspect of rurality (ROLAND *et al.*, 2019). These criteria are described in the following items. From these criteria, the rural areas were classified in the census sectors 1b to 8, as seen in the flowchart of Figure 2.

Figure 2: Decision flowchart of classification of rural areas according to the census sectors redefined by the Rural Brazil Sanitation Program



Source: drafted by the authors.
Note: (*) = The analyzed private or corporate character is only considered when Dd < 80 hab./km² (LASCHESKI, 2021).

1st Criterion: Identification of clusters and dispersed households

Based on technical-scientific literature, this criterion was chosen due to its relevance and importance for the choosing of individual and/or collective solution and as support for the application of the other criteria (MEJÍA; CASTILHO; VERA, 2016; ROLAND *et al.*, 2019; GALIZONI, 2021).

The spatial distribution was considered as a criterion to select the type of solution (collective or individual) for water supply to be applied in 15 Brazilian rural communities (RAID, 2017). For places with households which are considered dispersed, alternative solutions were suggested. With the goal of carrying out the proposition of individual or collective sewage technologies in these communities, there was consideration regarding certain criteria, such as water availability, through the identification of the existence of proper water supply for the determination of the use of a bathroom with sanitary flush, and the demographic density (SILVA, 2017).

Initially, one must obtain the coordinates of each household of the rural area to be characterized, which allows the identification of household clusters based on distances, using for such purpose several methods of area regionalization (Complete linkage method; Ward; ClustGeo; SKATER; among others). For the proposed methodology the use of cluster analysis along with K-media method is suggested (HOSKING; WALLIS, 1997; NAGHETTINI; PINTO, 2007), which classifies the household distances within the groups in accordance to the clusters, using the Euclidian distance between one household and the others in the same community (Equation 1).

$$D_{ij} = \sqrt{\left(x_i - x_j\right)^2 + (y_i - y_j)^2} \qquad \text{(Equation 1)}$$

Note: D_{ij} is the distance between household "i" and household "j", x_i, x_j, y_i e y_j are latitudes and longitudes in projected coordinates for each household, respectively.

The descriptive visualization of the distances matrix can be made with the aid of R language and the box-plot graphic, and the number of clusters with the k-means method from the *factoextra* library (KASSAMBRA; MUNDT, 2020). The Cluster grouping can be applied with base on the "stats" library which is available on the CRAN repository (R Code Team, 2021), and with the dendrograms, determining the clusters with similar distances between the households.

For the identification of the clusters, a distance greater than 2.5 km between clusters and/or dispersed households is suggested. Such distance was based in a value established by the World Health Organization (WHO), as a maximum route of 30 minutes for access to potable water source (WHO, 2004), which was extrapolated to conceptualize the condition of dispersion of rural households, with an average marching speed of 140 cm/s (NOVAES; MIRANDA; DOURADO, 2011). Such distance was adopted considering the integration and/or viability of attendance to sanitation services, however, for other services, such distance must be smaller, as seen in a study in China where it was considered that above 2.5 km, such presents extremely low accessibility to farming markets (WANG; ZHOU, 2022).

2nd Criterion: Distance to the closest urban center (Cucd)

The choice for the Cucd criterion was motivated by the possibility of increase of goods and more complex services' offer, such as access to basic sanitation services which exist in urban area, reflecting directly on the way of life and configuration of the rural area (IBGE, 2017). Facing that, the Cucd was conceptualized as the smallest distance of road access between the urban center's perimeter and the closest household to rural area. It can be considered an urban center all the municipal headquarters and districts, which are configured as service centers (BRASIL, 1938; LASCHEFSKI, 2021; AIHW, 2004), establishing the following possibilities: (i) the city's own Municipal Headquarters (MH), (ii) the Own Municipal District (OMD), (iii) Another Municipal District (AMD) and (iv) Another City's District (ACD).

It should be highlighted that the Cucd must consider the road system (AIHW, 2004), justified by the need for transportation, normally through highways, of the collected solid waste until its next step for handling (treatment unit, displacement or final disposal) (BARROS, 2012). The access and transportation also are needed for the other sanitation components (water supply, sanitary sewage and rainwater management) aiming the maintenance of operation of existing infrastructures in the rural area (BRASIL, 2020).

The Cucd can be determined using software such as ArcGIS, Google Earth Engine, QGIS, and several sources of road system data such as Google Road, Bing Maps, Google Satellite. It is suggested, for the determination of Cucd, the use of the road system available on Google Read and/or Google Satellite and the aid of QGIS. After determining the Cucd, the rural cluster should be classified as: in urban area (Cucd = 0 km), next to urban area (0 < Cucd ≤ 1 km) and isolated from urban area (Cucd > 1 km) (BRASIL, 2019a).

3rd Demographic Density (Dd)

According to Roland *et al.* (2019) and Rigotti & Hadad (2021), the Demographic Density (Dd) is a criterion that must always be considered for the classification of rural areas knowing that such places present lower level of density than the urban areas. Thus, the Dd was calculated by the relation between inhabiting population and the area of each rural cluster.

For the clusters located in urban areas (Cucd = 0 km), it was considered as too dense areas those with 300 hab./km² < Dd ≤ 605 hab./km², and areas of low density those with Dd ≤ 300 hab./km². That range was adopted based on IBGE (2017) and Rigotti & Hadad (2021).

For isolated areas (Cucd > 1 km), the areas considered dense were those with Dd ≥ 80 hab./km², and average and low density those with Dd < 80 hab./km². This Dd value was considered more adequate for the Brazilian reality (LASCHEFSKI, 2021), differently from the method of the Organization for Economic Cooperation and Development which uses 150 hab./km² in rural communities in the European Union (RIGOTTI; HADAD, 2021).

In the isolated rural areas, without private or corporate character, the areas considered of average density had 40 hab./km² ≤ Dd < 80 hab./km², while areas with low density had Dd < 40 hab./km². The original value (80 hab./km²) was fractioned for the creation of two new sub-bands, of the same amplitude, making their differentiation possible in clusters of average and low density, being that such density variation, in the CS context is a methodological alternative to try and understand the complexities of rural areas (GALIZONI, 2021).

Classification in census sectors (CS)

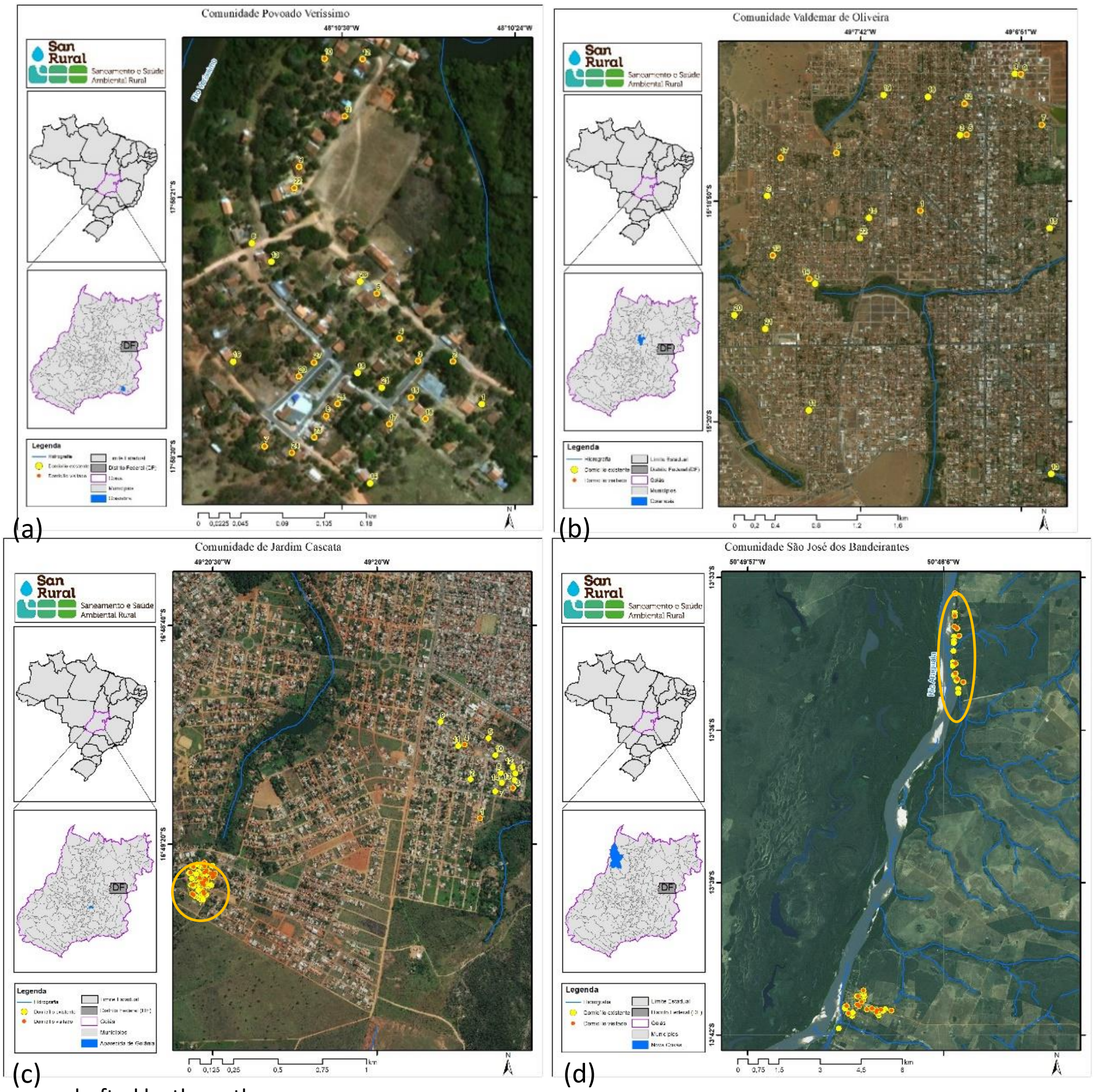
Once the three criteria are determined, the rural areas were classified in: i) SC1b: located within the urban area (Cucd = 0), very dense (300 hab./km² < Dd ≤ 605 hab./km²); ii) SC2: located within the urban area (Cucd = 0), low density (Dd ≤ 300 hab./km²); iii) SC4: located between urban and isolated areas (0 < Cucd ≤ 1 km); iv) SC3: isolated (Cucd > 1 km), dense (Dd ≥ 80 hab./km²); iv) SC6: isolated (Cucd > 1 km), with private or corporate character, average or of low density (Dd < 80 hab./km²); v) SC5: isolated (Cucd > 1 km), without private or corporate character (40 hab./km² ≤ Dd < 80 hab./km²); vi) SC7: isolated (Cucd > 1 km), without private or corporate character, of low density (Dd < 40 hab./km²).

Characterization of rural areas

Identification of clusters and dispersed households

The existence of 5,621 households was found *in loco,* with a total of 16,819 inhabitants within the 115 rural areas. However, 11 *quilombola* and 6 riparian communities did not meet the criterion necessary for direct application, due to the existence of one or more clusters with households that do not make part of the community, that is, with non-contiguous households. That way, the proposed method shows this limitation for direct application in rural areas with the presence of households with another rural area (Figure 3a), or still in urban area (Figure 3b). For these cases, the method must be applied after a detailed analysis, identifying possible existing clusters with contiguous households. In this context, the identification of clusters with contiguous households in the *Quilombola* Communities Jardim Cascata (Figure 3c) and João Borges Vieira, and in the Riparian Communities São José dos Bandeirantes (Figure 3d), Registro do Araguaia and Fio Velasco (Chart 1), the method not being applied in other nine *quilombola* and three riparian communities.

Figure 3: Map with the location of the households of Community Povoado Verissimo (a), Community Valdemar de Oliveira (b), Community Jardim Cascata (c) and Community São José dos Bandeirantes (d)



Source: drafted by the authors.

Chart 1: Description of the amount of clusters and dispersed households of the rural areas in the State of Goiás

Rural Area Name	Typology	Area with non-contiguous households	Quantity (unit.)		
			RA[(a)]	CLU[(b)]	DH[(c)]
Castelo/ Retiro/Três Rios	Q	no	1	4	0
Capela	Q	no	1	3	2
Fazenda Santo Antônio da Laguna	Q	no	1	3	0
Abobreira, Almeidas, Canabrava, Diadema, Sumidouro and Vazante	Q	no	6	2	0
Rafael Machado	Q	no	1	1	2
Buracão, Mesquita and Quilombo do Magalhães	Q	no	3	1	1
Água Limpa (Q), Baco Pari, Boa Nova, Brejão, Cedro, Engenho 2, Extrema, Forte, José de Coleto, Kalunga dos Morros, Mimoso/ Queixo Dantas, Pelotas, Pombal, Porto Leocádio, Povoado Levantado, Povoado Moinho, Povoado Vermelho, São Domingos, Taquarussu and Tomás Cardoso	Q	no	20	1	0
Lagoa do Lago, Landi and Olhos d'Água	R	no	3	1	0
17 de Abril, Acaba Vida, Água Limpa , Água Quente, Aranha, Arraial das Antas II, Boa Esperança, Buriti, Campo Alegre, Cantoneiras, Canudos, Céu Azul, Conceição, Cora Coralina, Dom Roriz, Engenho da Pontinha, Engenho do Bom Sucesso, Florestan Fernandes, Formiguinha, Fortaleza, Gustavo Martins, Independência, Itajá II, João de Deus, José Martí, Julião Ribeiro, Lageado, Lagoa Genipapo, Lagoa Santa, Lagoa Seca, Limoeiro, Madre Cristina, Monte Moria, Mucambão, Nascente São Domingos/Terra Viva, Noite Negra, Novo Horizonte II, Piracanjuba, Pouso Alegre, Presente de Deus, Rio Araguaia, Rio Vermelho, Roberto Martins Melo, Rochedo, Rosa Luxemburgo, Salto para o Futuro, Santa Fé da Laguna, Santa Maria do Crixás-Assu, Santa Rita do Broeiro, Santo Antônio das Areias, São José, São José do Pissarrão, São Judas, São Lourenço, São Salvador, Sebastião da Garganta, São Thiago, Sebastião Rosa da Paz, Serra das Araras, Tarumã, Umuarama and Vitória	S	no	62	1	0
Registro do Araguaia	R	yes	1	3	1
Fio Velasco	R	yes	1	1	1
São José dos Bandeirantes	R	yes	1	1	0
Jardim Cascata and João Borges Vieira	Q	yes	2	1	0
Arraial da Ponte, Itacaiú and Povoado Veríssimo	R	yes	NA	NA	NA
Ana Laura, Balbino dos Santos, Córrego do Inhambú, Goianinha, Nossa Senhora Aparecida, Raízes do Congo, Recanto Dourados, Valdemar de Oliveira and Vó Rita	Q	yes	NA	NA	NA
Total			103	118[(d)]	9

Caption:	Rural area with directly applied method	Rural area with method applied post-analysis	Rural area where it was not possible to apply the method

Note: Rural Area = RA; (b) Cluster = CLU; (c) Dispersed Household = DH; (d) total of clusters considering the 103 rural areas; settlement = S; *Quilombola* community = Q; Riparian community = R; non-applicable = NA.
Source: drafted by the authors.

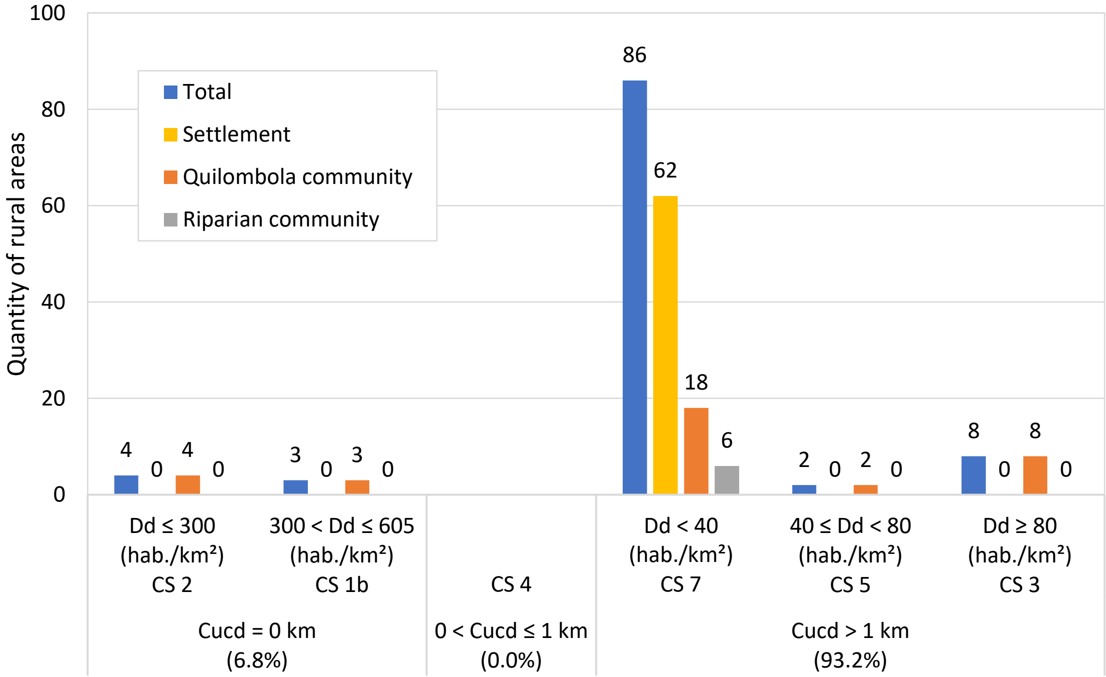
The proposed method was applied, after analysis, on the seven clusters of five rural areas and directly in 98, aided by the decision flowchart (Figure 2). The total was of 103 rural areas with 118 clusters, being that 90.29% (93/103), 5.83% (6/103), 2.91% (3, 103) and 0.97 (1/103) have, respectively, 1, 2, 3 and 4 clusters. The existence of nine dispersed households has been found, which are inserted into five *quilombola* and two riparian communities (Chart 1). The settlements did not present dispersed households. This reality of geographical dispersion has also been reported to the Rural Community of Queimadas-CE, divided into three clusters, where the majority of the households were gathered into a main cluster which had commercial and service provision activities (RAID, 2017).

Distance to the closest urban center (Cucd)

Regarding the 2nd criterion analyzed (Cucd), 6.8%, 0.0% and 93.2% of the studied rural areas were located, respectively, in the bands: Cucd = 0 km; 0 < Cucd ≤ 1 km and Cucd > 1 km (Graphic 1), presenting an average Cucd of 27.7km. That way, the majority (93.2% with Cucd > 1 km) may be influenced by distance or isolation situation. The Cucd interferes in the practice of segregation and incineration of waste in these locations, where distances over 800m from the urban center have their services, such as selective garbage collection, depending on the public authorities, and the commercialization of residues motivated by the initiative of the inhabitants and market in the community's surroundings (HAN *et al.*, 2015).

In this scenario, eight rural areas (7.8%) which can be negatively impacted by the difficulty of access situation have been identified, Cucd ≥ 60 km (75.0% settlements: Cantoneiras, Lagoa Genipapo, Santa Maria do Carixás-Assu, São Judas, Salto Para o Futuro and Tarumã; 12.5% *quilombola* communities: Kalunga dos Morros; and 12.5% riparian: Landi), being that 75.0% of these areas are located in the city of Nova Crixás. These and other 39 rural areas (37.9%) are located at distances superior to 30 km, possibly having the need of implementation of displacement to make possible the provision of solid waste handling services in a collective way (BRASIL, 2019b).

Graphic 1: Distribution of the quantity of rural areas by Cucd band (distance to the closest urban center) and by Dd band (Demographic density), classified in Census Sector (CS)



Source: drafted by the authors.

It has also been verified that 57 rural areas were closer to the municipal headquarters themselves, 25 from districts of the city, 20 from other municipal headquarters, and one from another city's district. Being the Cucd a criterion which impacts the feasibility of the implementation of collective sanitation solutions (MEJÍA; CASTILHO; VERA, 2016), it can be bounding for the provision of these services, reinforcing that the responsibility for the supplying and provision of the collective services pertains to the city (BRASIL, 2019a). That way, the 21 rural areas closest to other headquarters or municipal districts might benefit from the existing structures in these urban centers, however they might have difficulties with the sanitation services' integration. As examples, the *Quilombola* Community Taquarassu is mentioned, which belongs to the city of Campos Belos-GO, but it is closer to the municipal headquarters of Novo Alegre-TO (10.1km), and the Lagoa Santa Settlement, closer to the municipal headquarters of Barro Alto (22.8km), despite belonging to the city of Santa Rita do Novo Destino.

Besides the long distances, it has been found, in four communities (Monte Moria, Novo Horizonte II, Porto Leucádio and Povoado Vermelho), waterway lanes, of permanent form, due to the presence of crossings, which makes the route becomes slower. According to Brasil (2019a), besides the permanent waterway lanes, the temporary ones, with the presence of floodable areas, are also bounding for the implementation and provision of sanitation services. For example, the service of solid waste retrieval might be influenced by the access, measured by the relation between the quantity of roads and its attendance to population (MORAIS *et al.*, 2019). In routes and access with adverse transportation conditions such as waterway, the limiting distance might be reduced to 30 km mentioning, for example, conditions such as the Pantanal and Amazonia biomes (LASCHEFSKI, 2021).

Demographic Density (Dd)

The Dd average of the main clusters of the 103 rural areas was of 50.1 hab./km^2 (SD = 151.9; CV = 3.3). Considering the 118 clusters, the Dd average was of 45.8 hab./km^2, varying from 2.6 to 1,175.8 hab./km^2 (SD = 142.3; CV = 3.11). The biggest Dd occurred in the *quilombola* community João Borges Vieira of 1,175.8 hab./km^2 (Cucd = 0), being way superior to the next clusters, Dd = 800.0; 530.5 and 250.0 hab./km^2. This community is an extension of the municipal headquarters of Professor Jamil-GO, being covered by all the urban area's sanitation infrastructure.

It has been observed that 93.2% (96/103) of the rural areas have presented a Cucd > 1 km (Graphic 1), with a Dd between 2.7 and 250.0 hab./km^2 (average = 22.9 hab./km^2; SD = 44.8; CV = 1.9), being that 83.5% (86/103) stayed with a Dd < 40 hab./km^2, composed by 100% (62/62) of the settlements (average = 7.5 hab./km^2; SD = 3.9; CV = 0.52), 100.0% (6/6 of the riparian communities (average = 21.5 hab./km^2; SD = 7.8; CV = 0.36) and 51,4% (18/35) of the *quilombola* communities (average = 11.4 hab./km^2; SD = 6.8; CV = 0.59). Of the four rural areas with Cucd = 0 and Dd ≤ 300 hab./km^2, 50.0% (2/4) had Dd compatible to the isolated rural areas and with average density (40 hab./km^2 ≤ Dd < 80 hab./km^2): Communities Cedro and Forte, and 50.0% to the isolated and very dense ones (Dd ≥ 80 hab./km^2): *Quilombola* Communities Mesquita and Vazante, with 142.6 and 200.0 hab./km^2, respectively.

The Dd influences the technical-economic feasibility of sanitation solutions, despite not being able to be analyzed in an isolated way. Rural areas with high Dd (CS 1b, 2, 3 and 4) have greater rates of attendance of collective and centralized solutions, especially water supply, while more isolated areas (CS 5, 6 and 7) have an attendance deficit and greater proposition of individual and/or decentralized solutions (ROLAND *et al.,* 2019). For the supplying of water, a high Dd favors the adoption of collective solutions, with the distribution through water distribution network. For average and low Dd, the coexistence of supplying networks and wells, springs and cisterns has been identified, which prevents an exact determination of supplying quality and quantity. The sanitary sewage solutions tend to follow the expansion of water supply, but with lower attendance and prioritization rates (ROLAND *et al.,* 2019). For the handling of solid waste in rural areas, Han *et al.* (2019) identified that high or average Dd favor the collective service provision, with a centralized treatment, while low Dd motivates the implementation of decentralized treatment methods or mobile units.

Census sectors classification

The proposed method allowed for the classification of 103 rural areas, among the 115 studied areas, in five census sectors (Chart 2). It is needed to reinforce that for those communities with more than one cluster and/or presence of dispersed household, the method was applied more than once, being adopted for the CS definition the cluster with greater number of households.

Chart 2: Description of the rural areas studied in the State of Goiás, according to their typology and classification in census sector (CS)

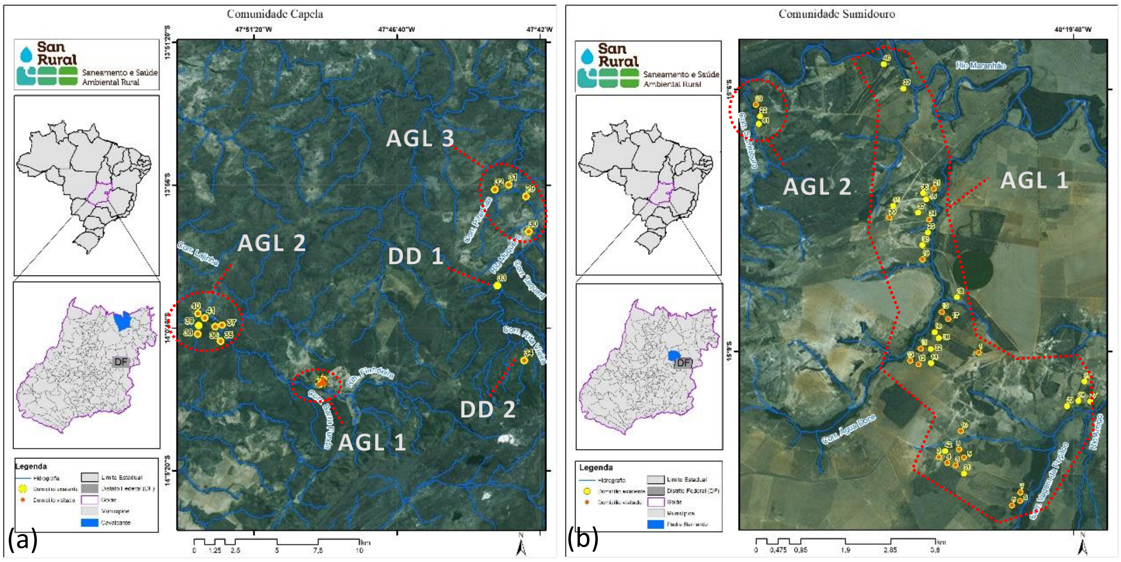
Description	CS[1]	Qty	Rural area name	Typology
Close to urban	1b	3	Boa Nova, Jardim Cascata and João Borges Vieira	*Quilombola*
	2	4	Cedro, Forte, Mesquita and Vazante	*Quilombola*
Isolated and denser	3	8	Capela, Baco Pari, Engenho II, Extrema, Mimoso/ Queixo Dantas, Povoado Levantado, Povoado Moinho and São Domingos	*Quilombola*
Isolated and less dense	5	1	Brejão	*Quilombola*
	7	19	Abobreira, Água Limpa (Q), Almeidas, Baco Pari, Buracão, Canabrava, Castelo/Retiro/Três Rios, Diadema, Fazenda Santo Antônio da Laguna, José de Coleto, Kalunga dos Morros, Pelotas, Pombal, Porto Leucádio, Quilombo dos Magalhães, Rafael Machado, Sumidouro, Taquarussu and Tomás Cardoso	*Quilombola*
		6	Fio Velassco, Lagoa do Lago, Landi e Olhos D'água, Registro do Araguaia and São José dos Bandeirantes	Riparian
		62	17 de Abril, Acaba Vida, Água Limpa (N), Água Quente, Aranha, Arraial das Antas II, Boa Esperança, Buriti, Campo Alegre, Cantoneiras, Canudos, Céu Azul, Conceição, Cora Coralina, Dom Roriz, Engenho da Pontinha, Engenho do Bom Sucesso, Florestan Fernandes, Formiguinha, Fortaleza, Gustavo Martins, Independência, Itajá II, João de Deus, José Martí, Julião Ribeiro, Lageado, Lagoa Genipapo, Lagoa Santa, Lagoa Seca, Limoeiro, Madre Cristina, Monte Moria, Mucambão, Nascente São Domingos/ Terra Viva, Noite Negra, Novo Horizonte II, Piracanjuba, Pouso Alegre, Presente de Deus, Rio Araguaia, Rio Vermelho, Roberto Martins Melo, Rochedo, Rosa Luxemburgo, Salto para o Futuro, Santa Fé da Laguna, Santa Maria do Crixás-Assu, Santa Rita do Broeiro, Santo Antônio das Areias, São José, São José do Pissarrão, São Judas, São Lourenço, São Salvador, São Sebastião da Garganta, São Thiago, Sebastião Rosa da Paz, Serra das Araras, Tarumã, Umuarama and Vitória	Settlement

Source: Drafted by the authors.
Note: (1) no rural area presented cluster classified on CS 4, 6 or 8.

Thus, the obtained result was of 6.8% classified on the census sectors defined as rural close to urban (CS 1b and CS 2), 7.8% as isolated and denser rural (CS 3) and 85.4% as isolated and less dense rural (CS 5 and 7). None of those was classified in CS 4, 6 and 8. The prevalence of communities inserted in CS 7 (83.5%) happened due to the isolation characteristics (Cucd > 1.0 km) and low density (Dd < 40.0 hab./km²) identified (Graphic 1). The communities classified in CS 1b, 2, 3 and 5 were all of the *quilombola* typology.

The census sectors must be evaluated in group with their criteria, in the choice of technological sanitation solutions for rural areas. There are adequate, low-cost and sustainable solutions, usually decentralized, which can be applied for the treatment of superficial water (PETER-VARBANETS *et al.,* 2009) or subterranean spring (THOMAS *et al.*, 2022), for the sanitary sewage (LOURENÇO; NUNES 2020), for the handling of solid waste (HAN *et al.,* 2015) and also for the drainage and rainwater management (TAVANTI; BARBASSA, 2012). It is necessary to emphasize the importance of this individual analysis for each rural area, for the sake of the selection of applicable sanitation solutions. Thus, it has been observed in the rural areas with more than one cluster, that nine were *quilombola* and one was a riparian community (Table 1). Among them, two (Capela and Sumidouro) presented different classifications among their clusters. The *Quilombola* Community Capela (Figure 4a) has three clusters, one near to the municipal headquarters of Cavalcante ($Cucd_3$ = 37.6 km) and two close to the municipal headquarters of ($Cucd_1$ = 43.1 km and $Cucd_2$ = 36.1 km). The main cluster of these communities has presented Dd = 159.5 hab./km², while the others have presented 6.7 and 2.6 hab./km², yet having two other dispersed households. The *Quilombola* Community Sumidouro (Figure 4b) has two clusters at the distances of 3.9 and 14.5 km from the municipal headquarters of Padre Bernardo, presenting Dd_1 = 4.6 hab./km² and Dd_2 = 39.3 hab./km².

Figure 4: Map of the location of households from the Capela Community, Cavalcante-GO (a) and Sumidouro Community, Padre Bernardo-GO (b)



Source: Drafted by the authors.
Note: Cluster = AGL (CLU); dispersed household = DH (DD).

Freitas (2021) reinforces that the PSBR defines guidelines and strategies for sanitation in rural areas, aiming towards the universalization of access to water supply, sanitary sewage, solid waste retrieval and rainwater drainage services, with equity, integrality and sustainability. Such process must be conducted considering the diversity and peculiarities of these areas, allowing for the adoption of adequate techniques.

A fundamental condition for the success of sanitation projects is that it must offer solutions that answer to the existing demands of the rural area. The families must know and participate on the choice regarding technical options and available service levels, taking into consideration their cultural aspects (MEJÍA; CASTILHO; VERA, 2016).

CONCLUSIONS

The present work has allowed the following conclusions:

- The classification of rural areas in census sectors makes it possible to conduct a preliminary analysis for the proposition of basic sanitation solutions, which can be collective (centralized or decentralized) or individual;
- The proposed method makes the CS classification possible, through criteria for the identification of clusters and/or dispersed households, passible of application in a rural area as a whole and/or in clusters with contiguous households, including dispersed households;
- The application of the method also reinforces the concept of rurality and permitted the classification of seven *quilombola* rural areas, which would not be in the original classification;
- From the 103 rural areas where the method was applied, 118 clusters have been delimited, being that 10 communities have presented from 2 to 4 clusters, which can be a hindrance in the implementation of sanitation services, as it would be similar to attend to several communities within the same area;
- The average Cucd was of 27.7 km (SD = 19.42; CV = 0.70), with eight rural areas with Cucd ≥ 60 km, 75.0% settlements, 12.5% *quilombola* and 12.5% riparian, all with Dd < 7.5 hab./km^2, with the exception of Riparian Community Landi, with 24.7 hab./km^2, bringing obstacles for the access to public services for these small isolated areas;
- All the settlements and riparian communities were classified into CS 7 (Cucd > 1 km and Dd < 40 hab./km^2), which can hinder the universalization of sanitation services;
- The *quilombola* communities have presented a Dd between 2.6 and 1,175.8 hab./km^2, evidencing the possibility of greater variety of sanitation solutions for these traditional peoples;
- All the studied rural areas were classified in five census sectors: CS 1b (2.91%), CS 2 (3.88%), CS 3 (7.77%), CS 5 (0.97%) and CS 7 (84.47%), and none at CS 4, 6 and 8.

Lastly, it is strongly recommended that a form to classify communities with non-contiguous households is studied.

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Appendix 1: Census Sector (CS), demographic density (Dd), distance from the municipal headquarters and distance to the closest urban center, of the studied clusters of agricultural reform settlements

City Name	Rural Area/Cluster Name	Clustered Area (km²)	Dd (hab./km²)	Distance from the municipal headquarters (km)	Distance to the closest urban center (km)	CS
Faina	17 de abril	14.3	6.6	26.6	9.0	7
Niquelândia	Acaba Vida	75.3	3.3	82.1	41.5	7
Niquelândia	Água Limpa	10.1	6.1	12.4	12.4	7
Minaçu	Água Quente	23.2	5.5	41.4	21.9	7
Niquelândia	Aranha	10.3	6.6	64.4	56.3	7
Faina	Arraial das Antas II	0.7	27.2	41.8	39.8	7
Piracanjuba	Boa Esperança	17.6	8.4	18.4	18.4	7
Silvânia	Buriti	3.3	15.4	12.8	5.9	7
São Miguel do Araguaia	Campo Alegre	57.9	4.9	32.2	32.2	7
Nova Crixas	Cantoneiras	30.3	4.4	84.1	84.1	7
Palmeiras de Goiás	Canudos	110.9	9.4	16.4	8.9	7
Minaçu	Céu Azul	14.8	4.4	57.3	37.3	7
Niquelândia	Conceição	18.8	8.3	7.0	7.0	7
Faina	Cora Coralina	2.2	10.9	43.1	25.2	7
Minaçu	Dom Roriz	51.4	5.8	48.4	28.5	7
Santa Rita do Novo Destino	Engenho da Pontinha	3.0	10.0	42.7	32.1	7
Niquelândia	Engenho do Bom Sucesso	9.3	10.9	14.9	14.9	7
Nova Crixas	Florestan Fernandes	19.3	8.0	15.4	15.4	7
Mineiros	Formiguinha	7.7	5.2	63.2	34.6	7
Piranhas	Fortaleza	19.6	5.0	21.8	21.8	7
São Miguel do Araguaia	Gustavo Martins	23.0	7.3	42.0	42.0	7
Santa Rita do Novo Destino	Independência	25.0	6.2	44.7	28.6	7
Goianésia	Itajá II	4.5	11.4	33.3	9.5	7
Silvânia	João de Deus	3.4	17.1	25.2	25.2	7
Niquelândia	José Martí	19.0	6.3	14.4	6.3	7
Niquelândia	Julião Ribeiro	8.5	5.3	58.0	16.5	7
São Miguel do Araguaia	Lageado	8.2	6.4	37.5	37.5	7
Nova Crixas	Lagoa Genipapo	31.3	3.7	92.5	92.5	7
Santa Rita do Novo Destino	Lagoa Santa	8.4	9.7	38.9	22.8	7
Santa Rita do Novo Destino	Lagoa Seca	11.0	8.9	37.7	13.9	7
Faina	Limoeiro	12.2	6.2	5.1	5.1	7
Goiandira	Madre Cristina	8.1	5.2	19.8	19.8	7
São Luíz do Norte	Monte Moria	4.9	6.9	19.3	19.3	7
Minaçu	Mucambão	34.1	3.2	56.9	37.2	7
Piranhas	Nascente São Domingos	28.7	5.8	28.6	28.6	7
Minaçu	Noite Negra	98.1	2.9	53.4	33.7	7
São Luíz do Norte	Novo Horizonte II	19.4	7.9	20.9	20.9	7
Piracanjuba	Piracanjuba	2.4	10.5	11.6	11.6	7
Mineiros	Pouso Alegre	2.3	8.2	61.4	32.7	7
Goianésia	Presente de Deus	51.5	7.8	33.3	11.5	7
São Miguel do Araguaia	Rio Araguaia	35.3	6.5	47.6	47.6	7
Niquelândia	Rio Vermelho	40.0	4.6	39.5	31.5	7
Minaçu	Roberto Martins Melo	26.8	8.9	46.0	26.3	7
Professor Jamil	Rochedo	9.8	8.5	16.7	16.7	7
Faina	Rosa Luxemburgo	4.2	11.3	38.9	36.8	7
Niquelândia	Salto para o Futuro	18.1	6.2	59.7	60.0	7
Barro Alto	Santa Fé da Laguna	10.2	10.3	30.0	30.0	7
Nova Crixas	Santa Maria do Crixás-Assu	23.5	6.8	69.1	69.1	7
Niquelândia	Santa Rita do Broeiro	6.2	8.8	24.2	24.2	7
Faina	Santo Antônio das Areias	9.9	6.2	4.7	4.7	7
São Miguel do Araguaia	São José	29.1	4.7	15.1	15.1	7
Faina	São José do Piçarrão	2.3	15.6	17.4	17.4	7
Nova Crixas	São Judas	33.3	3.7	71.9	71.9	7
Uruaçu	São Lourenço	6.5	7.6	42.4	42.4	7
Minaçu	São Salvador	76.7	5.5	40.4	20.8	7
Silvânia	São Sebastião da Garganta	19.0	5.9	50.3	28.8	7
Santa Rita do Novo Destino	São Thiago	13.0	7.4	49.5	33.4	7
Uruaçu	Sebastião Rosa da Paz	23.3	2.7	26.3	26.3	7
Mineiros	Serra das Araras	8.4	5.5	59.9	31.4	7
Nova Crixas	Tarumã	12.5	6.1	76.3	76.3	7
São Miguel do Araguaia	Umuarama	56.7	5.7	29.0	29.0	7
Goianésia	Vitória	36.8	4.7	11.5	11.5	7

Note: Demographic density = Dd; Census Sector = CS.

Appendix 2: Census Sector (CS), demographic density (Dd), distance from the municipal headquarters and distance to the closest urban center, of the clustered *quilombola* and riparian communities

City Name	Rural Area/Cluster Name	Clustered Area (km²)	Dd (hab./km²)	Distance from the municipal headquarters (km)	Distance to the closest urban center (km)	CS
Nova Roma	Abobreira – Clu 1	4.0	23.1	59.9	46.0	7
Nova Roma	Abobreira – Clu 2	0.2	32.6	68.1	39.3	NA
Faina	Água Limpa	5.6	10.6	23.5	20.3	7
Silvânia	Almeidas – Clu 1	7.1	15.9	51.3	38.1	7
Silvânia	Almeidas – Clu 2	1.2	7.4	59.2	46.0	NA
Posse	Baco Pari	1.9	104.2	14.1	14.1	3
Professor Jamil	Boa Nova	0.6	530.5	0.0	0.0	1b
Campos Belos	Brejão	1.2	50.0	10.7	10.7	5
Mineiros	Buracão	1.5	9.6	53.0	24.4	7
Flores de Goiás	Canabrava – Clu 1	41.6	6.9	154.4	56.8	7
Flores de Goiás	Canabrava – Clu 2	7.5	4.4	147.0	49.4	NA
Cavalcante	Capela – Clu 1	0.4	159.5	63.3	43.1	3
Cavalcante	Capela – Clu 2	3.9	2.6	37.6	37.6	NA
Cavalcante	Capela – Clu 3	2.7	6.7	64.2	36.1	NA
Simolândia	Castelo, Retiro and Três Rios – Clu 1	8.9	8.7	32.1	32.1	7
Simolândia	Castelo, Retiro andTrês Rios – Clu 2	0.5	20.8	18.7	18.7	NA
Simolândia	Castelo, Retiro and Três Rios – Clu 3	1.8	11.1	13.5	13.5	NA
Simolândia	Castelo, Retiro and Três Rios – Clu 4	5.6	12.0	21.8	21.8	NA
Mineiros	Cedro	4.3	41.3	0.0	0.0	2
Teresina de Goiás	Diadema – Clu 1	1.3	16.0	49.5	49.5	NA
Teresina de Goiás	Diadema – Clu 2	7.9	8.2	42.8	42.8	7
Cavalcante	Engenho 2	2.2	219.1	24.8	24.8	3
Iaciara	Extrema	0.9	160.6	6.7	6.7	3
Barro Alto	Santo Antônio da Laguna – Clu 1	3.4	6.4	28.5	28.5	7
Barro Alto	Santo Antônio da Laguna – Clu 2	0.8	13.3	35.7	35.7	NA
Barro Alto	Santo Antônio da Laguna – Clu 3	1.4	11.9	37.8	37.8	NA
São João D'Aliança	Forte	1.2	75.4	79.3	0.0	2
Aparecida de Goiânia	Jardim Cascata	0.3	800.0	0.0	0.0	1b
Uruaçu	João Borges Vieira	0.3	1175.8	0.0	0.0	1b
Colinas do Sul	José de Coleto	1.1	26.1	68.1	38.5	7
Cavalcante	Kalunga dos Morros	9.2	7.5	68.1	68.1	7
Cidade Ocidental	Mesquita	2.4	142.6	0.0	0.0	2
Mimoso de Goiás	Mimoso/Queixo Dantas	0.6	122.2	62.0	54.4	3
Monte Alegre de Goiás	Pelotas	7.6	13.0	41.1	41.1	7
Santa Rita do Novo Destino	Pombal	20.8	7.4	48.1	21.8	7
São Luíz do Norte	Porto Leocádio	3.0	13.2	19.9	19.9	7
Iaciara	Povoado Levantado	0.4	151.2	9.7	9.7	3
Alto Paraíso de Goiás	Povoado Moinho	0.7	250.0	11.2	11.2	3
Minaçu	Povoado Vermelho	0.9	690.0	33.8	33.8	7
Nova Roma	Quilombo do Magalhães	6.6	2.9	27.2	27.2	7
Niquelândia	Rafael Machado	13.9	3.7	56.2	31.8	7
Cavalcante	São Domingos	2.3	112.6	55.6	55.6	3
Padre Bernardo	Sumidouro – Clu 1	0.2	39.3	14.5	14.5	NA
Padre Bernardo	Sumidouro – Clu 2	23.6	4.6	3.9	3.9	7
Campos Belos	Taquarussu	3.5	22.0	22.5	10.1	7
Barro Alto	Tomás Cardoso	6.6	15.3	14.3	14.3	7
Divinópolis de Goiás	Vazante – Clu 1	1.8	200.0	27.7	0.0	2
Divinópolis de Goiás	Vazante – Clu 2	0.4	15.4	37.0	0.0	NA
Nova Crixas	Colônia dos Pescadores	2.2	28.6	103.9	23.6	7
São Miguel do Araguaia	Fio Velasco	0.7	18.6	92.0	45.1	7
São Miguel do Araguaia	Lagoa do Lago	2.2	19.0	53.4	27.5	7
Nova Crixas	Landi	2.2	24.7	82.8	82.8	7
Gameleira de Goiás	Olhos D'Água	0.8	29.6	26.5	26.5	7
Montes Claros de Goiás	Registro do Araguaia – Clu 1	1.6	8.8	69.4	10.5	7
Montes Claros de Goiás	Registro do Araguaia – Clu 2	0.3	26.6	70.1	1.7	NA
Montes Claros de Goiás	Registro do Araguaia – Clu 3	0.4	15.8	73.0	5.2	NA

Note: Cluster = Clu; Non-applicable = NA; Demographic Density = Dd; Census sector = CS.