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Development of GIS Solutions for the Brazilian Public Administration – A Systematic Review

Desenvolvimento de Soluções SIG para a Administração Pública Brasileira – Uma Revisão Sistemática

José Antonio Teixeira de Oliveira Filho¹; Fabiana Frata Furlan Peres²

¹ State University of Western Paraná – UNIOESTE, Graduate Program in Technology, Management and Sustainability, Foz do Iguacu-PR, Brazil. Email: jatofilho@hotmail.com

ORCID: <https://orcid.org/0000-0002-7596-9751>

² State University of Western Paraná – UNIOESTE, Graduate Program in Technology, Management and Sustainability, Foz do Iguacu-PR, Brazil. Email: fabiana.peres@unioeste.br

ORCID: <https://orcid.org/0000-0002-3937-3432>

Abstract: Geographic Information Systems have evolved in the last thirty years, following the advances of other technologies and becoming a fundamental tool for various tasks, both in the private and public sectors. The characteristics of collecting, storing, retrieving and disseminating spatial data are of great use for the development of actions in the public sector where, not infrequently, difficulties such as lack of investment and labor present themselves as challenges to be overcome. This article presents a systematic literature review identifying scientific production between 2018 and 2022 on Geographic Information Systems developed for the Brazilian public service, its main actors and fields of application. To perform the searches, the indexed databases IEEE Digital Library, ISI Web of Science, Science Direct and Scopus were considered. The searches returned 263 articles, of which 79 were duplicates and 171 did not meet the established inclusion criteria. Thus, 13 articles remained for analysis. The results made it possible to evaluate the popularization of these systems in the governmental sphere and revealed the main fields of application, the most used software and other characteristics regarding the solutions developed in the period.

Keywords: Public service; GIS; Systematic Review.

Resumo: Os Sistemas de Informações Geográficas têm evoluído nos últimos trinta anos, seguindo os avanços de demais tecnologias e se tornando ferramenta fundamental para diversas tarefas, tanto na iniciativa privada quanto no setor público. As características de coletar, armazenar, recuperar e disseminar dados espaciais são de grande utilidade para o desenvolvimento de ações no setor público onde, não raramente, dificuldades como escassez de investimento e de mão de obra se apresentam como desafios a serem superados. Este artigo apresenta uma revisão sistemática da literatura identificando a produção científica entre 2018 e 2022, sobre Sistemas de Informações Geográficas desenvolvidos para o serviço público brasileiro, seus principais atores e campos de aplicação. Para realizar as buscas, foram consideradas as bases de dados indexadas *IEEE Digital Library*, *ISI Web of Science*, *Science Direct* e *Scopus*. As buscas retornaram 263 artigos, dos quais 79 eram duplicados e 171 não atendiam aos critérios de inclusão estabelecidos. Desse modo restaram 13 artigos para análise. Os resultados possibilitaram avaliar a popularização desses sistemas no âmbito governamental e revelaram os principais campos de aplicação, os softwares mais utilizados e as outras características a respeito das soluções desenvolvidas no período.

Palavras-chave: Serviço Público; SIG; Revisão Sistemática.

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1. Introduction

Nowadays, any government needs systems that meet the needs of planning, execution and monitoring of its activities. Regardless of its size - municipal, state or federal - the choice of tools that adapt to their realities, at low cost, becomes essential for a satisfactory service to the demands of society.

Governments have evolved in the use of technology to increase their efficiency in providing services to citizens. This phenomenon has led to the emergence of a series of practices that have become the target of studies, with different terminologies, such as digital governance (KHAN and JOHNSON, 2021), smart governance (SCHOLL and SCHOLL, 2014) and e-government (ARENDSSEN et al., 2014).

Regardless of the terminology for the modernization of procedures, public agencies that work in the planning and execution of actions with geographical characteristics in which the term "where" is an intrinsic attribute to the work, it is imperative to use geospatial tools to achieve strategic objectives.

By having characteristics that allow examining social, economic and political circumstances, Geographic Information Systems (GIS) have effective collaboration in the public sector and therefore in decision making (HAQUE, 2001). The use of GIS can help for example communities, local governments and Non-Governmental Organizations (NGOs) to obtain a better knowledge of the potential of the region (TENIWUT et al., 2022).

Given this scenario, the present work aims to know the scientific production about the development of GIS solutions in the Brazilian public power in the last 5 years. To this end, a Systematic Literature Review (SLR) was conducted to visualize an overview of the development and application of this important tool by the Brazilian public administration.

To avoid misunderstandings about the proposed scenario, we avoided research that only used spatial data manipulation software as support or demonstration of results.

Next, in section 2, the methodological procedures adopted are detailed; then, in section 3, the results are exposed and discussed; and finally, in section 4, the conclusions are presented.

2. Methodology

As explained by Kitchenan (2007), SLR is a means of identifying, evaluating and interpreting available research relevant to a particular issue, subject area or phenomenon of interest. Such a procedure can identify research gaps or even suggest new research topics on a given subject.

An SLR is composed of the planning stages, in which the objectives, questions to be researched and details of the protocol are outlined; conduction, which deals with the identification and selection of studies, with subsequent extraction and synthesis of data; and publication of results. The digital platform Parsifal, available through the link: <https://parsif.al/>, which follows this methodology for the construction of the systematic review in a structured way, was used to carry out the SRL. The SLR sought answers to the questions: "Which public sector developed GIS?" and "Which field of application gathers research on GIS in Brazil?".

To find articles that could reflect the proposed scenario, the following search string was used: "Geographic Information System" AND (Brazil OR brazilian) AND (government OR public), with a time frame of the last five years (2018 to 2022). IEEE Digital Library, ISI Web of Science, Science Direct and Scopus were defined as indexed databases.

For the selection of articles related to the interest, the following inclusion criteria were used: articles describing the development of GIS solutions, databases, web maps or SIGweb and articles that were applied to the Brazilian context. To discard the articles returned by the execution of the search string not aligned with the interest of this SLR, the following exclusion criteria were considered: articles that were not in English or Portuguese; articles that were intended for the private sector; and articles that only used GIS software for spatial analysis or map generation.

In the conduction stage, to visualize the panorama regarding the development and application of GIS in the Brazilian public service and to identify the characteristics exposed in the selected articles, the information presented in Box 1 was extracted.

Data extraction form	
Description	Values
Potential for application by a public company?	Yes
	No
Application in which public level?	Municipal
	State
	Federal
Field of application	Education
	Geology
	Infrastructure
	Environment
	Public Policies
	Health
Type of product developed	Mobile app
	Spatial Database
	WebMap
	Desktop GIS
	WebGIS
Research for a specific public company?	Yes
	No
Software used	ArcGIS
	AutocadMap
	Geoserver
	Google Earth/Maps
	MapServer
	OpenStreetMaps
	PostGIS
	QGIS
	SPRING
	Terraview
	IDRISI

*Box 1 – Data extraction form.
Source: The Author (2023).*

The search string was applied to the databases. The search, considering the time interval of five years, resulted in 263 papers divided among the four databases and distributed as shown in Figure 1. Next, 79 duplicate articles were identified and excluded. The remaining articles (184) had their titles and abstracts read considering the inclusion and exclusion criteria. Those that were excluded for "only using GIS software for spatial analysis or map generation" had their methodology sections read to identify which GIS software was used to enrich the discussion with the collected data.

Only 13 articles did not meet the exclusion criteria and were read in full. Figure 1 presents a flowchart that summarizes the process of conducting the protocol and highlights the results achieved at each stage.

3. Results and discussion

After analyzing the titles and abstracts of the 184 articles and applying the exclusion criteria, 171 articles were rejected. Among those rejected, 72% were because they "only used GIS software for spatial analysis or map generation", i.e., they did not present a GIS solution.

Although some GIS concepts have characteristics that are confused with the functions present in software, GIS are a set of tools to group, store, retrieve, transform and present spatial data from the real world (BURROUGH, 1998). However, it is important to distinguish between the tool that is used and the development of GIS solutions.

Each of the operations present in the GIS concept incorporates different levels of complexity depending on the scope and scale for which the system will be used. In some situations, the GIS solution may involve a geographic database, one or more software packages and the use of programming languages to customize services on the World Wide Web (WWW), for example, to meet the demands of the user. Software that manipulates spatial data brings operations involving the creation of maps by overlaying data stored as tables with details of geographic characteristics symbolized by points, lines

or polygons or raster data sets (e.g. photographs) and their geographic coordinates (FLETCHER-LARTEY and CAPRARELLI, 2016).

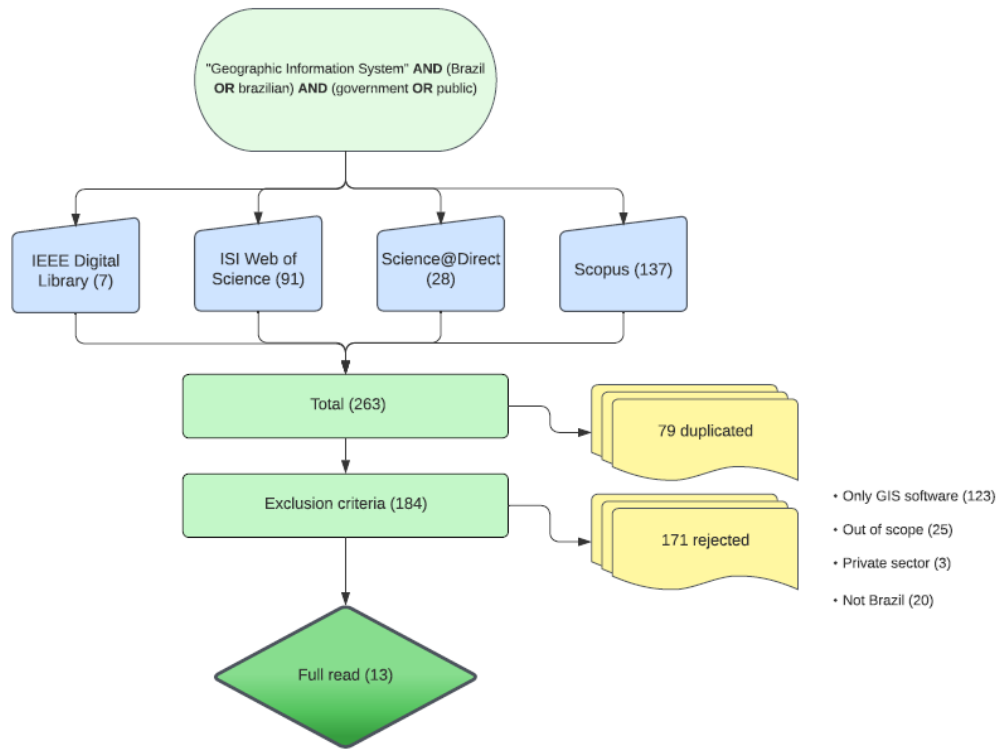


Figure 1 – Review workflow.
 Source: The Autor (2023).

In the distant past, GIS software was accessible only to specialized users. In the last two decades, this has expanded to a range of products available for many different purposes and types of users (HENRICO et al., 2022). This diffusion of software available to an increasing number of stakeholders generates some misconceptions about GIS.

According to DeMers (2005), the definition of GIS as software that manipulates spatial data is very restrictive. Therefore, it is essential that the terms referring to the science of study and the spatial data manipulation software are dissociated, according to the objectives of the work being developed.

This review, for example, seeks to identify work focused on the development of GIS solutions for the public service and not research that has only used spatial data manipulation software as support.

Articles that described "only the use of GIS software for spatial analysis or map generation" were exempted from full reading, however, their methodology sections were read to identify which GIS software was used.

As shown in Figure 2, the most cited software are used for map generation and geoprocessing tools. ArcGIS software was used in 54 papers and QGIS in 39 papers out of 123.

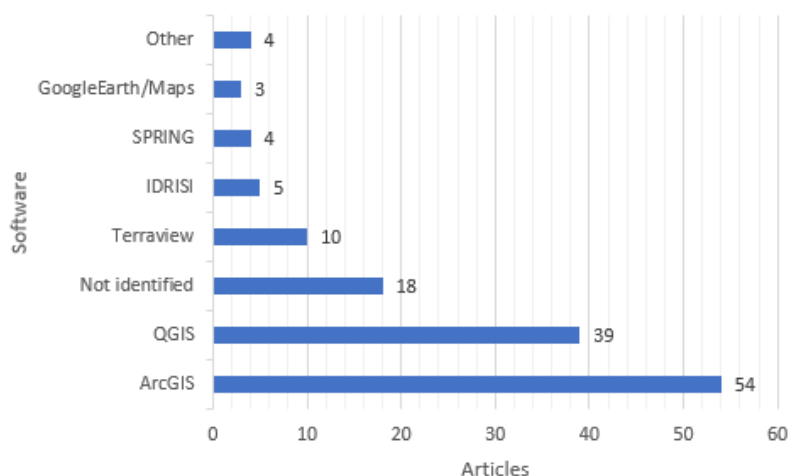


Figure 2 – Software used in the papers excluded for "only using GIS software for spatial analysis and map generation".

Source: The Autor (2023).

Data on the use of geotechnologies by public administrations in Brazil are scarce in the academic literature.

Gavlak and Barroso (2022) show that, in the Brazilian Federal Government, the main applications and public and private actors involved in the use of geotechnologies are not known. The SLR corroborated this reality and only thirteen articles from the databases considered describe the development of GIS solutions, databases, web maps or WebGIS. These articles (Table 1) have been read in full to build the panorama regarding the questions posed as the objective of the study.

Table 1 – Selected articles for full reading

ID	Article
1	"Tô de Olho: Geographic information system with public participation for mapping of urban disorders" (HOLANDA <i>et al.</i> , 2019).
2	"Environment for analysis of rural school transportation: A case study in Espírito Santo/Brazil" (PORTO, M.F. <i>et al.</i> , 2017).
3	"Enabling spatial queries in open government data portals" (VASCONCELOS, P. A. F <i>et al.</i> , 2017).
4	"A Smarter sidewalk-based route planner for wheelchair users: An approach with open data" (KOZIEVITCH, N. P. <i>et al.</i> , 2017).
5	"The adoption of the One Health approach to improve surveillance of diseases in Foz do Iguaçu, Brazil" (LEANDRO, A. S. <i>et al.</i> , 2021).
6	"Geographic Information System with Public Participat on IoS System" (DA SILVA, M. R. <i>et al.</i> , 2017).
7	"Comune - An Android Application for Applying Surveys to and Collecting Reports from Public Service Users" (DE BRANCO, W. G. e HOLANDA, M. T., 2017).
8	"The use of information technology in surveillance and denunciations of the use of water resources" (ALVES, A. L. F. <i>et al.</i> , 2018).
9	"Update the legend of the reconnaissance soil map of E.S. state and the implementation of Geobases interface for data usage in GIS" (CUNHA, A. M. <i>et al.</i> , 2017).
10	"Landslide susceptibility mapping for transmission lines: dynamic monitoring, analysis and alerts for extreme natural events" (JUNQUEIRA, A.M. <i>et al.</i> , 2020).
11	"PPGIS as an urban planning tool around airports" (SANTOS, G. S. <i>et al.</i> , 2018).
12	"Tridimensional geotechnical database modeling as a subsidy to the standardization of geospatial geotechnical data" (OLIVEIRA, B. R. <i>et al.</i> , 2021).
13	"Spatial data in the Global South: A case study of alternative land management tools for cities with limited resources" (PEREZ, L. P. <i>et al.</i> , 2017).

Source: The Autor (2023).

The first analysis is made regarding the public level of the application described in each research. As shown in Figure 3, seven (53.85%) analyzed works are aimed at the municipal sphere; five (38.46%) at the state sphere and only one for the federal public service.

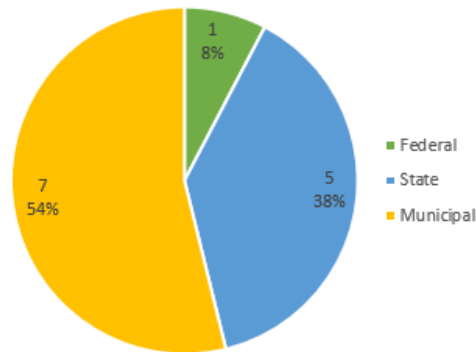


Figure 3 – Public level of implementation.
Source: The Autor (2023).

Although there is no concrete evidence on what exactly influenced the expressive mark of more than half of the articles being aimed at the municipal sphere, it is observed that there was a Brazilian government program of university extension - PROEXT 2007 - MEC / CITIES that may have leveraged the development of solutions at the municipal level. One of the stages of this program was the training of civil servants of Brazilian municipalities in topics related to remote sensing, cartography, global positioning system and GIS (SCHUCH and LOCH, 2011). Staff training and the advancement of free geoprocessing tools may have created this environment of search for solutions developed within city halls.

The investigation on the influence of the PROEXT 2007 - MEC / CITIES program emerges as a possibility for future work, researching the impact of the program on the development of geotechnologies in Brazilian municipalities.

Regarding the field of application, it was identified that the researches directed their efforts to Public Policies, Infrastructure, Geology or Health, distributed among the articles analyzed in the proportion illustrated in Figure 4.

In the application field "Public Policies", most of the works (46%) deal with the creation of mobile applications aimed at public participation, that is, the citizen himself connects directly with the public body to inform about problems or his vision regarding the public administration. Such research explores the concept of Public Participation GIS (PPGIS) which aims to involve the citizens to participate in the production of geographic data. Public institutions provide services to the population and citizens have a great deal of knowledge about where they live or work, with the potential to generate data about such places (DA SILVA et al., 2017).

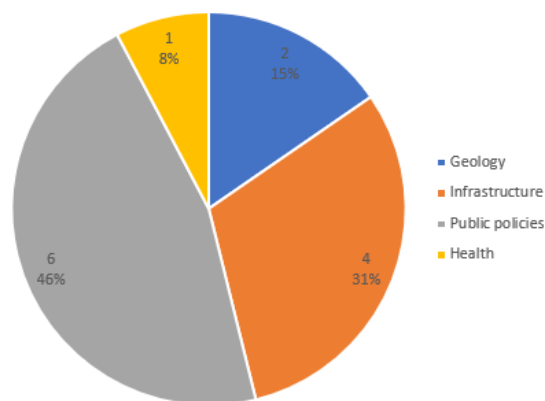


Figure 4 – Field of application.
Source: The Autor (2023).

Following the analysis, Table 2 presents the types of products developed in the papers analyzed. In the context of this SLR, "product" is understood as "software applications developed by the authors to achieve the objectives of the work".

Table 2 shows the predominance of Spatial Database development by eleven of the thirteen papers. The Spatial Database is the storage component of a GIS; it structures and stores data to enable the performance of analysis operations involving spatial data (ELMASRI and NAVATHE, 2015). This result, in a way, was expected, given that the research aims to investigate the development of GIS and, as the basis of a GIS is usually a geographic database, it is normal that this is a product developed by eleven of the thirteen works considered.

Table 2 – Type of product developed.

Product	Article ID													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
Mobile app	■					■	■	■						4
Spatial database	■	■	■	■	■	■	■	■		■		■	■	11
Desktop GIS				■	■					■		■		4
WebGIS	■	■		■		■		■	■	■	■			8
WebMap													■	1

Source: The Autor (2023).

Another product developed by more than half of the papers analyzed (eight papers) is the WebGIS. A WebGIS brings the functionalities of a traditional desktop GIS to the internet. The web environment is more intuitive and does not require a great deal of specialized knowledge for operation. Geospatial information can be accessed through a browser and can be used even by tablets and smartphones (FARGHER, 2018).

Some papers (four) reported the development of desktop GIS and another four the development of mobile applications. For the use of desktop GIS, the user needs to have a specific software installed on his computer and it is necessary that he knows how to operate it, usually requiring time for this training. In the case of mobile applications, the user has the functionalities of a WebGIS but in a specific program for the native operating system of their device.

Another product identified in the research, developed by a work, was the WebMap. A WebMap is a map that is accessed via a browser and can be static, interactive or animated depending on how it is presented. Static maps are simply an image of a map in PNG or JPEG format. Interactive maps allow the user to interact with the image, selecting objects and/or searching for features, for example, and animated maps are those that move when selected or for a specific period, as in weather forecast maps used by news programs (DENT et al., 2008).

To develop solutions in the geosciences field, it is necessary to use software that enables the organization, editing and dissemination of spatial data. To visualize the reality found regarding the main software used, the systems present in the selected articles were listed in Table 3. System software such as operating systems, compilers and programming languages were not listed.

Table 3 – Software used in the survey.

Software	Article ID													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	
ArcGIS									■	■				2
AutocadMap		■												1
Geoserver	■							■						2
GoogleEarth/Maps								■					■	2
MapServer											■			1
OpenStreetMaps	■			■				■						3
PostGIS	■	■	■	■	■	■	■	■		■	■	■		11
QGIS				■	■							■	■	4
SPRING							■							1

Source: The Autor (2023).

As shown in Table 3, the most used software in the development of the research products analyzed was the PostGIS extension of the PostgreSQL database manager, followed by the QGIS desktop software.

GIS need to manage spatial data, and for that, they use Database Management Systems (DBMS) for integrity control, access concurrency, transaction management, among other tasks. PostgreSQL is a free and open-source object-relational database manager that, through its PostGIS spatial extension, can store, access and analyze geographic data in vector format (FERREIRA, 2003).

Given the traditional lack of financial resources of Brazilian public agencies, it seems natural to use free tools to perform work activities, especially those involving the development of applications for specific purposes. This explains the fact that seven of the nine softwares present in the articles are free, except for the platforms ArcGIS¹, by ESRI and AutocadMAP², by Autodesk.

Of the thirteen articles analyzed, eight developed GIS solutions that demonstrated potential for application in the public sector and five deal with GIS solutions developed and already applied in some public agency. The thirteen papers have characteristics and focus on improving services provided by the public authorities to the population. Table 4 presents the main characteristics and contributions of the articles analyzed.

The works of Holanda et al., (2019), da Silva et al., (2017), Branco and Holanda (2017) and Santos (2018) deal with the development of applications for mobile devices that allow the public to approach the government; they focus on the direct participation of society.

The work of Santos et al. (2018) presents a survey on the opinion of the population regarding the noise level near airports. With access via browser, the user visualizes a map containing the street layout, noise curves, satellite images and zoning and land occupation in the municipality of São José dos Campos-SP and can indicate their level of annoyance and comments, if preferred. In this way it was possible to identify the levels of annoyance of the population.

¹ Desktop GIS application that supports data visualization, advanced analysis, and authoritative data maintenance in 2D, 3D, and 4D. Supports data sharing across a suite of ArcGIS products, such as ArcGIS Online and ArcGIS Enterprise. (Available at: <https://www.esri.com/pt-br/arcgis/products/arcgis-pro/overview>).

² 2D and 3D software to draw, design and automate projects in the mechanical, electrical, engineering, architecture and mapping areas. (Available at: <https://www.autodesk.com.br/products/autocad/overview?term=1-YEAR&tab=subscription>).

Table 4 – Summary of selected articles.

Article	Public Level	Application Field	Developed Product	Tools Used	Status	Features	Contribution
1	Municipal	Public policies	Mobile app Spatial DB	Geoserver OpenStreetMaps PostgreSQL/PostGIS	Potential for implementation	Popular participation; informing urban disorder: physical, social and public.	Assist municipalities to identify and correct infrastructure, safety and social welfare problems.
2	State	Infrastructure	Spatial DB WebGIS	AutoCADMap PostgreSQL/PostGIS	Implemented	Platform for rural school transport administration.	It enables the state government to manage rural school transport, from visualization, calculation of best routes and even operation costs.
3	Federal	Public policies	Spatial DB	PostgreSQL/PostGIS	Potential for implementation	Application designed to enable spatial queries on government portals.	Improvement of open data portals of any level for the localization of geospatial data.
4	Municipal	Infrastructure	Spatial DB GIS Desktop WebGIS	OpenStreetMaps PostgreSQL/PostGIS QGIS	Potential for implementation	Wheelchair-friendly route planner based on accessibility principles.	Assist municipalities to identify and correct accessibility issues and make the system available to wheelchair users.
5	Municipal	Health	Spatial DB GIS Desktop	PostgreSQL/PostGIS QGIS	Implemented	Platform for organizing the operations of the Zoonosis Control Centre.	It enables action planning of the municipal agency and mapping of occurrences.
6	Municipal	Public policies	Mobile app Spatial DB	PostgreSQL/PostGIS	Potential for implementation	Popular participation; mapping the opinion of the population related to public services.	It allows municipalities to evaluate urban services and facilities based on users' scores.
7	Municipal	Public policies	Mobile app Spatial DB	PostgreSQL/PostGIS Spring	Potential for implementation	Popular participation; mapping the opinion of the population related to public services.	Municipalities can register targeted opinion polls to find out how the population is evaluating services.
8	State	Infrastructure	Spatial DB WebGIS	PostgreSQL/PostGIS	Implemented	Water resources surveillance system.	It allows the responsible agency to monitor and supervise the use of water, including the possibility of complaints from the population.
9	State	Geology	WebGIS	ArcGIS	Implemented	Specific geographic interface on soils in the state's system.	Avoid duplication of efforts and financial resources in survey, cadastre and state soil database maintenance activities.
10	State	Infrastructure	GIS Desktop WebGIS	ArcGIS PostgreSQL/PostGIS	Potential for implementation	Dynamic landslide monitoring system	Allows energy companies to monitoring landslides in transmission line areas.
11	Municipal	Public policies	WebGIS	ManServer PostgreSQL/PostGIS	Potential for implementation	Participatory system for the population to report noise levels near airports.	Municipalities practicing social welfare and public health actions in areas close to airports.
12	State	Geology	Spatial DB GIS Desktop	PostgreSQL/PostGIS QGIS	Potential for implementation	3D database as a subsidy for the standardization of geotechnical data.	It enables the competent agencies to standardize and disseminate geotechnical data in a centralized manner.
13	Municipal	Public policies	Spatial DB WebMap	GoogleEarth/Maps QGIS	Implemented	Generation of digital maps for localities that do not have a base map.	Allows small municipalities to regularize land ownership in areas that do not have mapping.

Source: The Autor (2023).

The article by Fernandes et al., (2017) brings an application designed to enable spatial queries in government open data portals. With the perception that open data portals only perform literal searches that make the search process time-consuming, the authors propose a model to make it possible to search and return geographic data on these portals. A model of a geographic database was developed that serves as the basis of the system and manages the search and return of the information sought.

Kozievitch et al., (2017) present a route planner for wheelchair users. The shortest distance is not always the best way for a wheelchair user to move from one point to another. The authors developed a geographic database model that contains criteria and restrictions that consider the conditions of the sidewalks and ramps that exist on the route, for example. In this way, the developed GIS traces the best route based on accessibility principles.

Junqueira et al., (2020) developed a dynamic landslide monitoring system in regions containing transmission lines. By grouping all the information in a geographic database, it was possible to develop a susceptibility map model that serves as the basis for monitoring. A web platform was developed for monitoring and alerts, with access by registered users.

The article by Oliveira et al. (2021) brings the modeling of a three-dimensional database as a subsidy for the standardization of geotechnical data. Using the Object Modeling Technique for Geographic Applications (OMT-G) model, the authors present the geographic database and the developed GIS, containing the location of the boreholes and soil data, with the presentation of 3D geotechnical sections of areas in the Federal District (DF). The authors indicate the need to create geospatial databases compatible with the spatial data infrastructure of the Federal District and the National Spatial Data Bank for the dissemination of this information.

Porto et al., (2017) researched a GIS environment for rural school transportation management in the state of Espírito Santo. Aiming at a better use of public resources, a partnership between the Universidade Federal de Minas Gerais (UFMG) and the Government of the State of Espírito Santo decided to develop a GIS platform from a geographic database containing data of students, schools, roads, vehicles, routes and stopping points.

Figure 5 shows a screen of the system, which allows the definition of the best route considering the location of the students, the schools, the vehicles and the available roads.

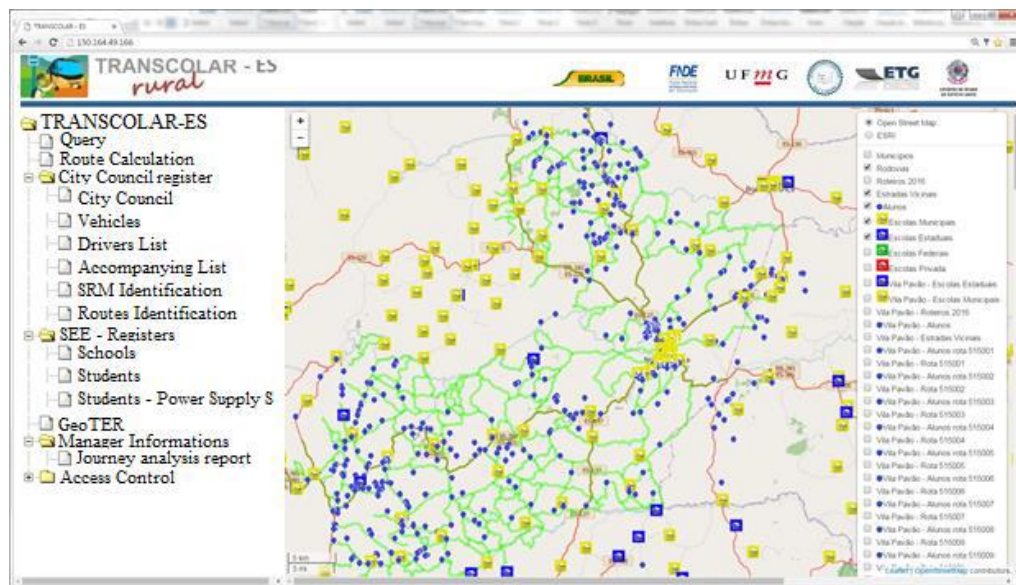


Figure 5 – Transcolar ES System.

Source: Porto et al., (2017).

Leandro et al., (2021) demonstrate in their article the modernization of procedures at the Zoonosis Control Center of Foz do Iguaçu (CCZ-Foz), which was called the One Health method. This method consists of reorganizing the research forms, the field teams, developing a geographic database, fed with all the activities conducted by the teams for action planning and the adoption of a desktop GIS to produce daily updated maps and spatial analysis of occurrences with infected animals.

Alves et al. (2018) brings a project with the Executive Agency for Water Management of the State of Paraíba (AESAs) for the inspection of water use. A geographic database was developed, a cell phone application for inspectors to record the information observed in the field and a WebGIS called Geoportais for management of the inspection system, including management of complaints received over the internet. Figure 6 shows a screen of the system.

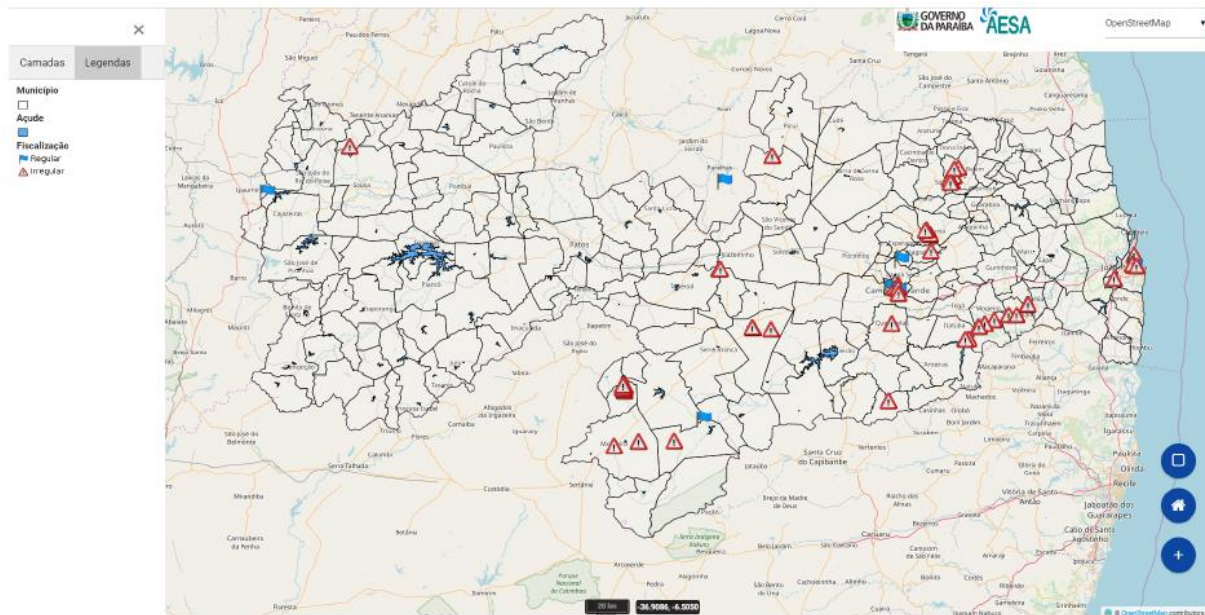


Figure 6 – Geoportais AESAs.
Source: Alves et al., (2018).

In Cunha et al., (2017) contributions to the Geobases system (Integrated System of Geospatial Bases of the State of Espírito Santo) are addressed, with the construction of a specific geographic interface on soils, allowing the inclusion and availability of various data on soil attributes over time.

Perez et al. (2017) address a partnership between the Universidade do ABC and the Ministry of Cities to implement the Federal Land Regularization Program "Papel Passado" in two hundred Brazilian municipalities. With applicability and practical implementation through a pilot project, the study brings real data regarding the development of a simplified procedure for generating georeferenced databases on free platforms for later use in the land regularization program.

Figure 7 illustrates the map of the blocks of the entire urban area of Buritirana determined by applying the methodology described in the article.

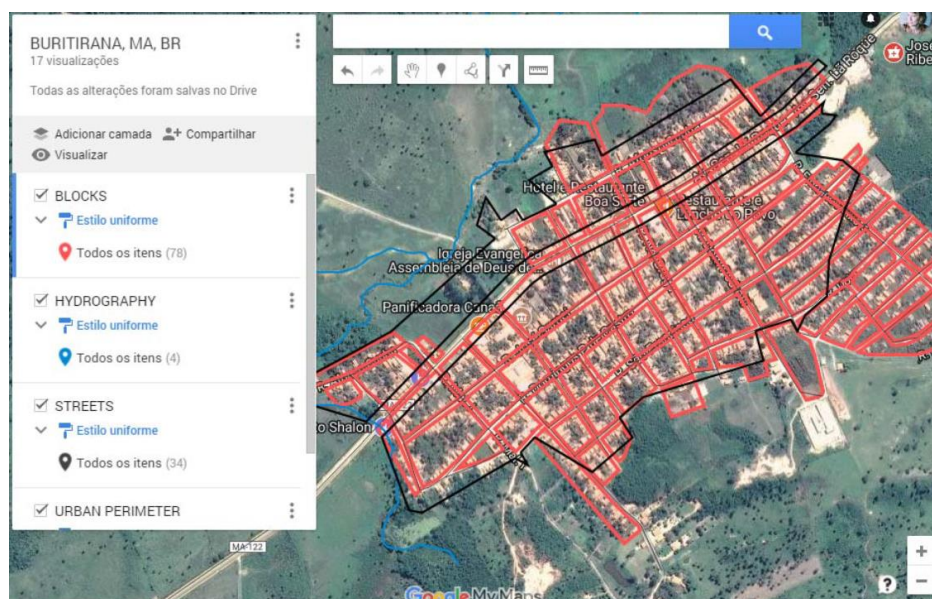


Figure 7 – Preparation of a base map.

Source: Perez et al., (2017).

4. Closing Remarks

Analyzing the results of the SLR regarding the development of GIS solutions separately by public level, it was noticed that GIS has been more studied in municipal instances, despite a small difference for works at the state level. The smaller number of works focused on the federal level corroborates that described by Gavlak and Barroso (2022), who in their research identified that the Federal Government prioritized the purchase of ready-to-use software instead of investing in the development and customization of free software between the years 2011 and 2019, which partly covers the time extract of this work. Even with this preference, there are several solutions, described in articles identified in this SRL, that could be suitable for use in agencies operating at the federal level using free and open-source tools.

Regarding the field of application, Public Policies and Infrastructure stand out. The SLR showed that GIS solutions, mainly based on popular participation, have the potential to be implemented by public authorities and could be used to increase society's participation not only to evaluate services, but also to assist in decision-making and planning, assisting in the process of public hearings, for example. In the field of Infrastructure, two works with application by public agencies were identified, one in the transportation sector and the other for water resources management, which is surprising due to the small number, despite the structural importance of these sectors.

It is also worth mentioning the software used in the research analyzed by the SLR. The use of PostgreSQL and its spatial extension PostGIS allied to QGIS software appears more frequently among the studies, which highlights the usability of free and free tools by public agencies that have a history of little investment power and scarcity of labor, especially in city halls.

A situation that caught our attention and is worth discussing, even though it is not the focus of this review, was the number of articles that cited the use of GIS software for spatial analysis and map generation and not for the development of some dedicated GIS solution. In these articles ArcGIS was the most used software (44%), followed by QGIS (31%). This situation demonstrates the versatility of GIS software and its potential for use by various fields of application, corroborating what was presented during the review regarding the expansion of geotechnologies in recent times.

Despite the expansion in the use of geotechnologies in various sectors, the Brazilian public sector presents timid numbers of publications, even with the increasing supply of tools available. Although initiatives with great potential for implementation have been perceived, it was surprising that only 5 articles presented effective application in some public agency.

The panorama evidenced by SLR contributes to bring data previously not known about the Brazilian reality regarding the development of GIS solutions for the public sector, since little is found in the literature on this subject.

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