ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 8, nº 1 (2022)

https://doi.org/10.21680/2447-3359.2022v8n1ID25950

Expert analysis of industrial landfills in the municipality of Uberlândia (MG) with the use of geotechnologies

Análise pericial de aterros industriais no município de Uberlândia (MG) com o uso de geotecnologias

Gabriella Dantas Amaral[1]; Raquel Naiara Fernandes Silva[2];

[1] Federal University of Uberlândia (UFU), Uberlândia/MG, Brazil. Email: gabrieladantasl@ufu.br
ORCID: https://orcid.org/0000-0002-4818-4414

[2] Federal University of Uberlândia (UFU), Uberlândia/MG, Brazil. Email: raquelfernandes@ufu.br
ORCID: https://orcid.org/0000-0002-8010-8251

Abstract: The environmental monitoring of industrial landfills stands out for their importance in the context facing the final disposal of waste, as it allows the operational control of these systems and contributes to the minimization of the environmental impacts caused by these units. Therefore, this research aims to use of geotechnologies in conducting expert analyzes in industrial landfills in Uberlândia-MG and it supports decision making through Boolean logic. Careful investigation of these locations is of paramount importance, as it guarantees the minimization of the impacts to the environment arising from this undertaking. The methodology of this work aimed at stipulating the restriction criteria, following the normative guidelines described in ABNT NBR 10157:1987, analyzing landfills that admit industrial waste as to their location through boolean maps with rating about whether it fit or not. The final aptitude map revealed that the industrial landfills in the municipality of Uberlândia are not in a suitable region. Finally, the objectives were achieved with the proposed methodology, but due to the pandemic scenario, all evaluation was done remotely. For future work, is suggested an additional on-site analysis.

Keywords: Environmental monitoring; Industrial landfill; Boolean logic.

Resumo: O monitoramento ambiental de aterros sanitários industriais se destaca pela sua importância diante do contexto de disposição final de resíduos, pois permite o controle operacional desses sistemas e contribui para a minimização dos impactos ambientais provocados por essas unidades. Diante disso, este artigo visa o uso de geotecnologias na realização de análises periciais nos aterros industriais de Uberlândia-MG e tem como apoio à decisão o auxílio da lógica booleana. A investigação criteriosa desses locais é de suma importância, pois, garante a minimização dos impactos ao meio ambiente oriundos deste empreendimento. A metodologia visou a estipulação de critérios de restrição, seguindo as diretrizes normativas descritas na ABNT NBR 10157:1987, analisando os aterros que admitem resíduos industriais quanto à sua localização através de mapas booleanos com classificação de apto ou não apto. O mapa final de aptidão revelou que os aterros industriais do município de Uberlândia não estão em uma região apta. Por fim, os objetivos foram atingidos com a metodologia proposta, porém devido ao cenário pandêmico, toda a avaliação foi feita remotamente. Para trabalhos futuros, sugere-se análises in loco adicionais.

Palavras-chave: Monitoramento ambiental; Aterro industrial; Lógica boolena

Received: 15/07/2021; Accepted: 14/09/2021; Published: 15/04/2022.

1. Introduction

The generation of solid waste has always been present in all activities carried out by man. Due to the population growth, the generation of waste has increased more and more, causing serious environmental impacts. The brazilian legislation is clear about the legal procedures when dealing with the disposal of waste. It is necessary that, when disposing of waste, it receives an environmentally correct final destination. According to Samizava et. al (2008), the practice of environmental sustainability (driven by various sectors of society) produced a greater demand for solving problems related to waste management.

Even with the great contemporary development, there are countless ways of waste disposal. In Brazil, the one that is used the most is still landfill (dumps, sanitary landfills, industrial and controlled landfills). The use of this type is due to the lower cost of installation and operation compared to other methods, such as incineration (CAMERON et al., 1997). However, the effectiveness of landfills has been strongly questioned, because when these are built irregularly, they can cause negative impacts on the environment (RAPTI-CAPUTO *et al.*, 2006; TEIXEIRA *et al.*, 2009).

Just as landfills are prepared to receive domestic waste, the industrial landfill is prepared to receive waste from the most diverse industries. According to CONAMA Resolution nº313/2002, solid industrial waste is all waste that results "from industrial activities and is found in solid states, semi-solid, gaseous - when contained, and liquid - whose particularities make its release into the public sewer system or water bodies that are impracticable, or the demand for this technically or economically unfeasible solutions given the best available technology".

According to ABNT NBR (2004), class I residues are those that, due to their physicochemical and infectious characteristics, pose a risk to public health and the environment. They can be conditioned, incinerated, treated, temporarily stored or disposed of in specific landfills for a certain type. These are residues that have specific characteristics of dangerousness, such as reactivity, flammability, toxicity, pathogenicity and corrosivity.

It is worth mentioning that that residues, diverging in their classes, come from occupations in the various branches of industry, such as chemical, petrochemical, food, paper, metallurgical and others, being quite varied, and can be represented by ash, sludge, oil, alkaline or acid residues, plastics, paper, wood, fibers, rubber, metals, slag, glass and ceramics, among others (NAUMOFF E PERES, 2000).

Thus, aiming at a holistic understanding of industrial landfills and accepted tailings, the Geographic Information System (GIS) aims to process spatial information, being able to efficiently manipulate and store data in order to distinguish the proper relationship between spatial variables, enabling the preparation of reports and maps (RIBEIRO *et. al.*, 2000).

Therefore, the present study aims, through expert analysis with the use of GIS, an important geotechnology, to assess whether the hazardous waste landfills in the city of Uberlândia meet the regulatory requirements described in ABNT NBR 10157:1987 and have environmentally friendly solutions in terms of location.

2. Industrial landfills

For Pinto (2011), the industrial landfill is a correct purpose for industrial waste. In landfills, national and international efficient techniques are used that intend to fully protect the environment, reducing environmental impacts, enabling the controlled disposal of these residues on the ground and preventing damage or risks to public health. Current mechanisms are restricted to confining industrial waste in the smallest area and volume possible (through drainage, geomembranes, effluent treatment and groundwater monitoring wells), wrapping them with a layer of inert material at the end of each working day or when deemed necessary.

Landfills should not be singled out as a common waste storage place, but as a site for geotechnical works that analyze the behavior of the numerous stages of operation and degradation (LOUREIRO, 2003).

In addition, industrial landfills are classified in classes I, IIA or IIB, according to the risk level of the waste to be disposed . Class I landfills can receive hazardous industrial waste; the Class IIA, non-inert waste; and Class IIB, only inert waste (ABNT NBR, 2004).

The waterproofing of the bed and the rainwater drainage system are of vital importance for landfills that accept industrial solid waste. These measures prevent contamination of the soil, surface and infiltrated water.

According to Rocca (1993), the physicochemical phenomena caused by the mixing of incompatible waste are: generation of heat, production of toxic and flammable fumes and gases, fire or explosion, solubilization of toxic substances and violent polymerization. When disposing of industrial waste, it is necessary to consult the compatibility listings published by the environmental control agencies.

3. Boolean logic

For Moreira (2002), the logical combination of input data and thematic maps generated under different criteria, are evaluated through conditional operators providing a scenario or hypothesis. From the 1960s, the multicriteria analysis is used to assist decision making. From different selected parameters, various scenarios and possible results are verified. Boolean algebra makes use of logical tools AND (intersection), OR (union), NOT (negation) and XOR (exclusion) (AMARAL; LANA, 2017). The Venn Diagram displays this algebra (Figure 1).

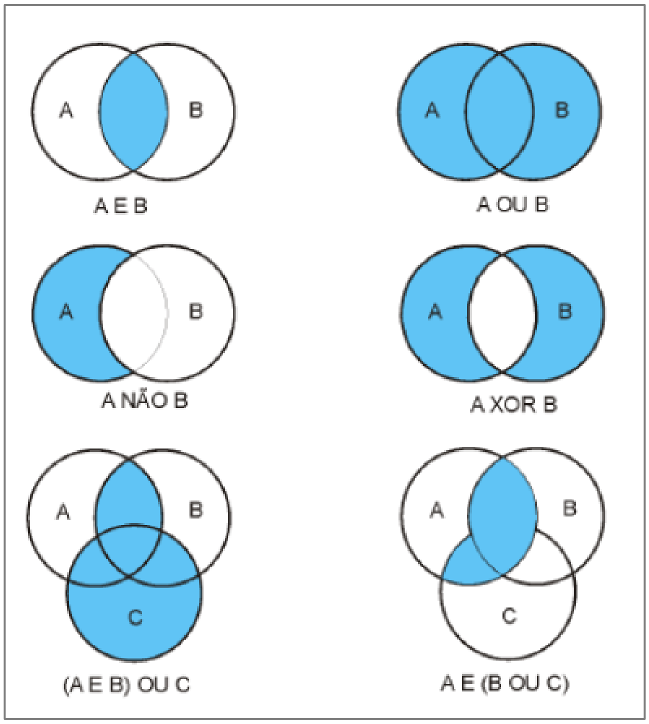


Figure 1 – Venn diagrams.
Source: Amaral; Lana (2017).

Therefore, the information classified as suitable own a Boolean character and eliminates criteria that, due to technical or legal impossibilities, do not fit the desired attributions regarding tolocation.

In order to apply this logic, the classification of parameters was carried out with binary values (0 or 1) that will be presented as suitable (1) and non-suitable (0) regions.

4. Methodology

4.1 Study Area

The municipality of Uberlândia is located in the Triângulo Mineiro and Alto Paranaíba mesoregion, in the state of Minas Gerais, limited by the Universal Transverse Mercator (UTM) coordinate system 7906752,608m and 788392,778m, with an altitude of 843m, positioned at spindle 22S (Figure 2) (IBGE, 2021).

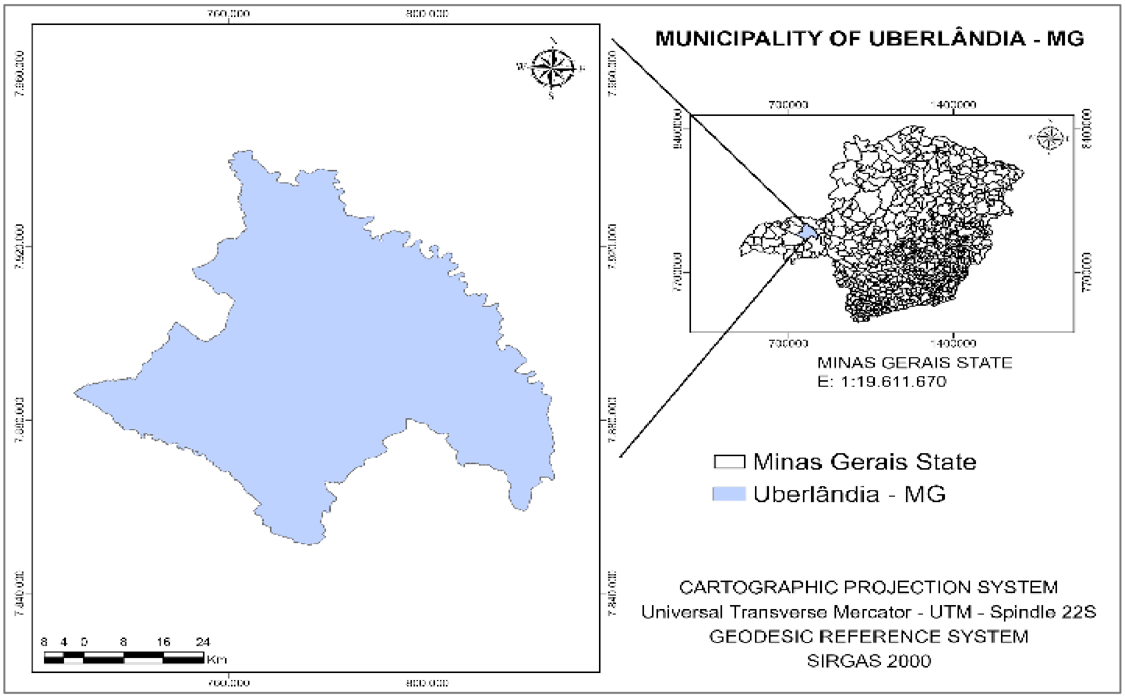


Figure 2 – Location of the municipality of Uberlândia (MG).
Source: Author (2021).

According to the IBGE (2020), the city ranks second among those with the largest populations in the state, comprising about 699,097 inhabitants estimated in 2020, with a territory equivalent to 4,115.2 km^2, where the main economic activities are industries and animal agriculture.

The climate of Uberlândia, according to the classification of K$\ddot{o}$ppen, is of the Aw type, therefore, it has a rainy summer and a dry winter, featuring a total average of annual rainfall of 1342mm (MENDES, 2001).

The region is inserted in the cerrado biome, for Freitas (2009), the biota is described as dominating savanna type vegetation, but include varieties of phytophysiognomies that diverge from grass-predominant fields, sub-shrubs, twisted trunk shrubs, even forest formations.

In addition, the most common soils in the region are latosols, interspersed with cambisols and hydromorphic soils, such as gleysols, where the industrial landfills covered are located. For the Instituto Agronômico de São Paulo (2021), gley soils are mainly present in floodplains or plains/low lands, and, as a limiting factor, it has a high frequency of flooding and long periods of saturation.

The landfills selected for expert analysis are located in the Industrial District of the municipality of Uberlândia (Figure 3). The choice was made because they are the only ones operating in the locality, both belong to private companies and have different waste admission processes, such as, Landfill 1, handles only Class I tailings, while Landfill 2, Class I and IIA. The UTM coordinates of the industrial landfills were obtained through Google Earth, as follows: 7911055,561m and 780634,584m for the landfill that accepts industrial waste 1; 7909606.116m and 782938.800m for landfill 2, both located in spindle 22S (GOOGLE, 2021).

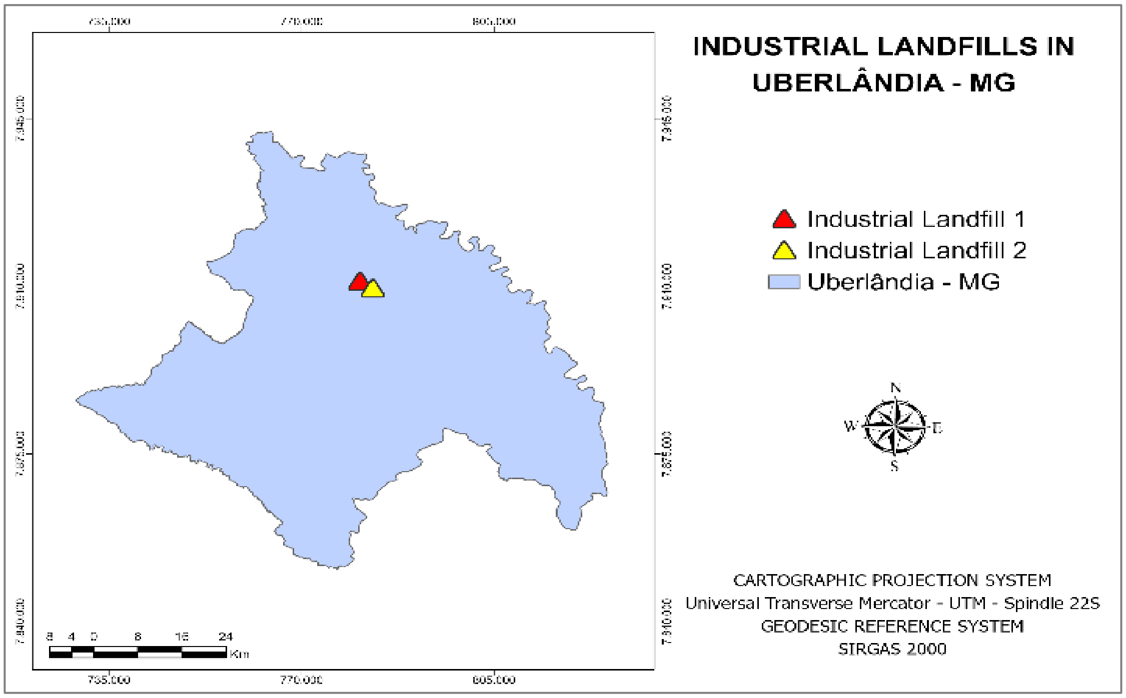


Figure 3 – Location of Industrial Landfills in the municipality of Uberlândia.
Source: Author (2021).

4.2. Methodological procedure

It is important to highlight that the analysis and mapping of the studied areas were developed using ArcGis Pro software from Environmental Systems Research Institute and Quantum Gis (QGis), both GIS cross-platform.

All data used in the study are georeferenced in the Universal Transverse Mercator (UTM) coordinate system, Spindle 22S and in the SIRGAS 2000 reference system.

For the industrial landfill to comply with current regulations and promote the well-being of the population and the environment, it was evaluated based on the criteria of the guidelines described in ABNT NBR 10157:1987 and were representedin Table 2.

In order to clarify the attributions presented in Table 2, a buffer was created, as well as a delimitation of areas of influence, based on established criteria (Table 1).

4.3 Maps

The pedology of the Uberlândia region was obtained and classified according to data provided by the Agricultural Research Company (EMBRAPA, 2021). The map presents the soil spatial distribution discovering information on natural resources and soil types. Therefore, pedological studies are of paramount importance for understanding soil formation factors and their weaknesses.

The slope map of the municipality of Uberlândia was generated using a Digital Elevation Model (DEM), following the premise established in the study by Leal *et.al* (2019), mission-based SRTM (*Shuttle Radar Topographic Mission)*, refined data were obtained from the original spatial resolution, 90 meters, in GRID format for 30 meters. The information was provided by the United States Geological Survey (USGS) and by the Brazilian Institute of Geography and Statistics (IBGE), being classified according to the Brazilian Agricultural Research Corporation (EMBRAPA).

Data for the development of thematic maps of highways and hydrology were obtained from the State Spatial Data Infrastructure Catalog of Minas Gerais (IEDE, 2021).

It is important to mention that for the elaboration of the urban area map, information was obtained by crossing information from the Brazilian Institute of Geography and Statistics with IEDE's spatial data catalogs.

Thus, after structuring and standardizing the thematic maps, decision criteria were developed to achieve the objectives of this study. For this, based on Boolean logic, weights were assigned to the factors considered in this analysis.

In order to make the information constituted through the thematic maps' tangible, the maps of all the parameters investigated above were combined. In the merged map, the terrains that obtained a score of 0 were designated as unsuitable areas, on the other hand, those who obtained a score of 1 were selected and classified as suitable regions.

To implement a landfill, it must meet: from the defense of the environment; to the planning of economic, social and urban development in the region; the guidelines established for the use and occupation of land and the protection of public health (NETO *et. al*., 1985). Therefore, it is possible to analyze areas that, due to technical or regulatory impossibilities are not suitable to be used as final destination for industrial waste.

Therefore, in order to apply Boolean logic, the criteria were classified with binary values (0 or 1), their categorization will be expressed in the following topic.

5. Results and discussion

According to the thematic maps of pedology and slope, shown in figures 4 and 5, it can be inferred that the municipality of Uberlândia presents, in amplitude, soils with well-developed structures such as latosols, detaining, almost predominantly, of flat and smooth-wavy reliefs.

For highway, hydrology and urban area maps, Figures 6 and 7, the regions were delimited according to the guidelines established in ABNT NBR 10157:1987, through the buffer procedure, distances expressed in Table 1.

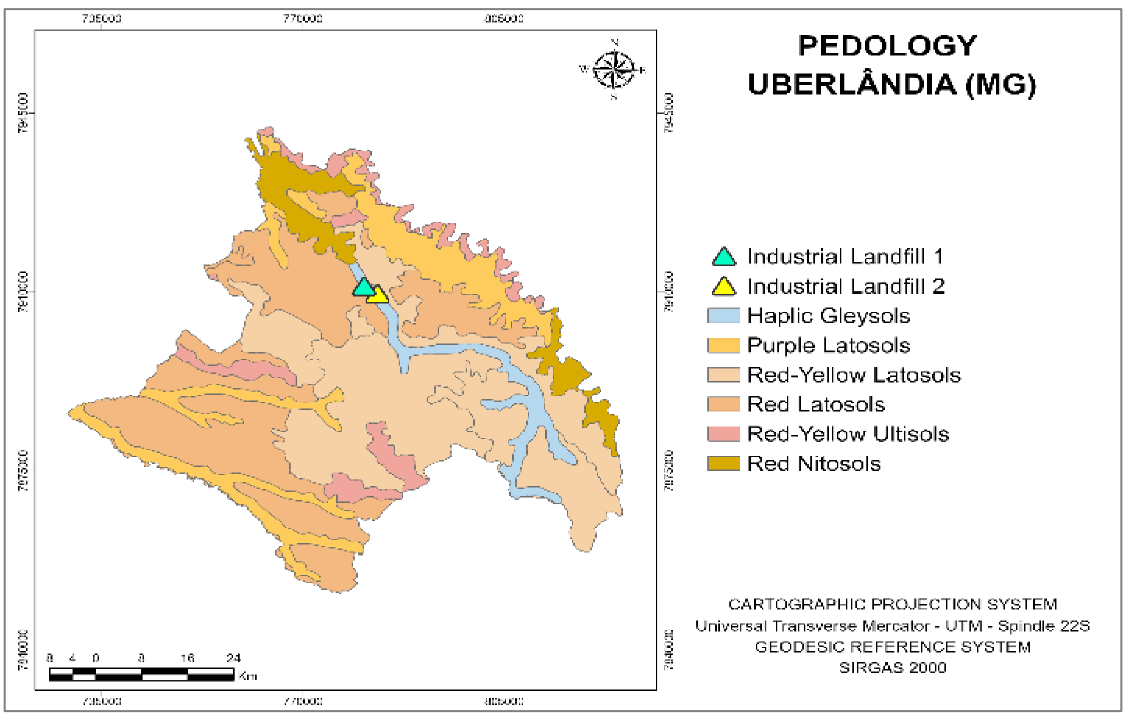


Figure 4 – Pedology of the municipality of Uberlândia – MG.
Source: Author (2021).

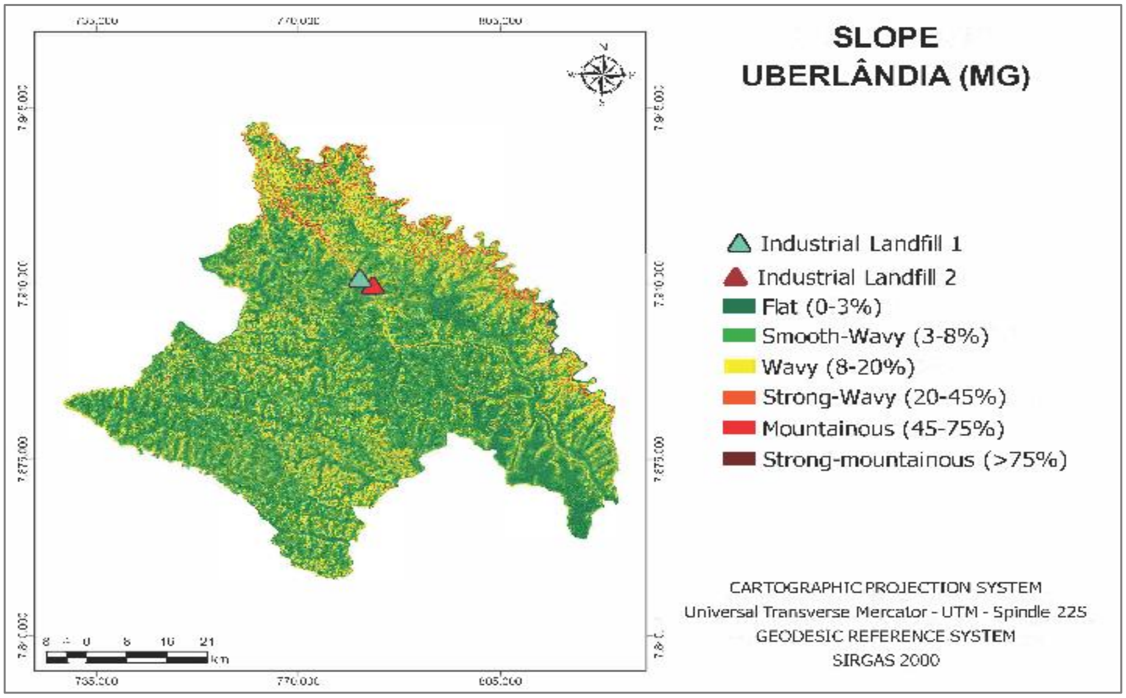


Figure 5 – Slope of the municipality of Uberlândia – MG
Source: Author (2021).

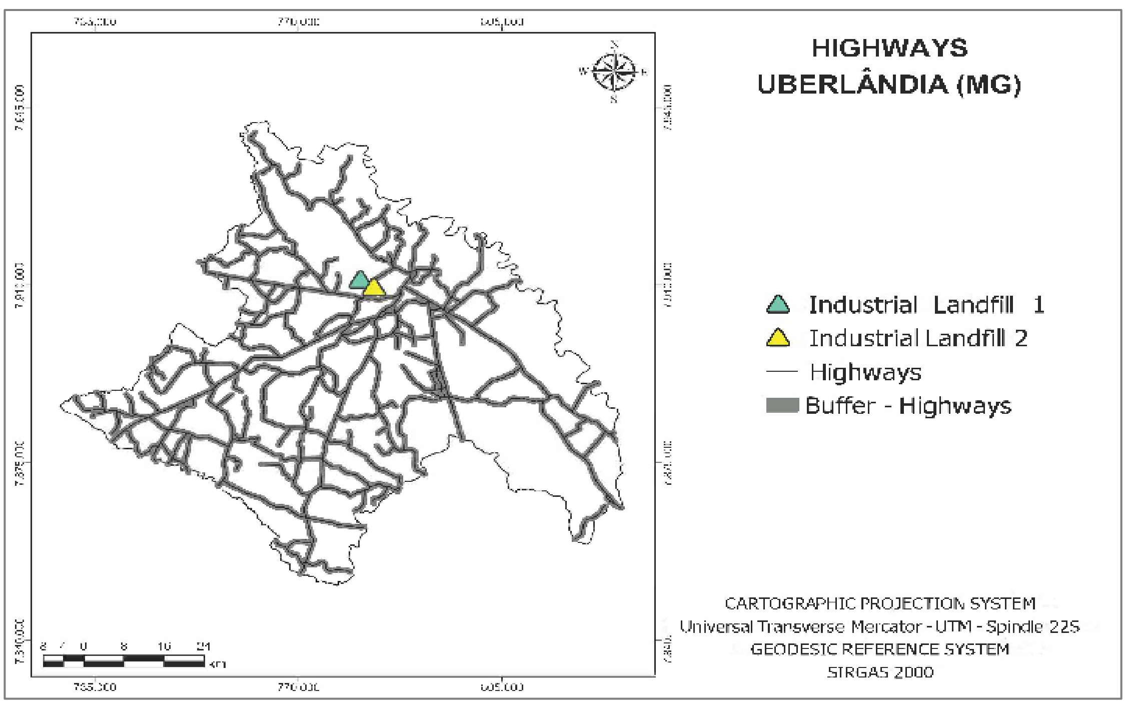


Figure 6 – Buffer of highways in Uberlândia - MG.
Source: Author (2021).

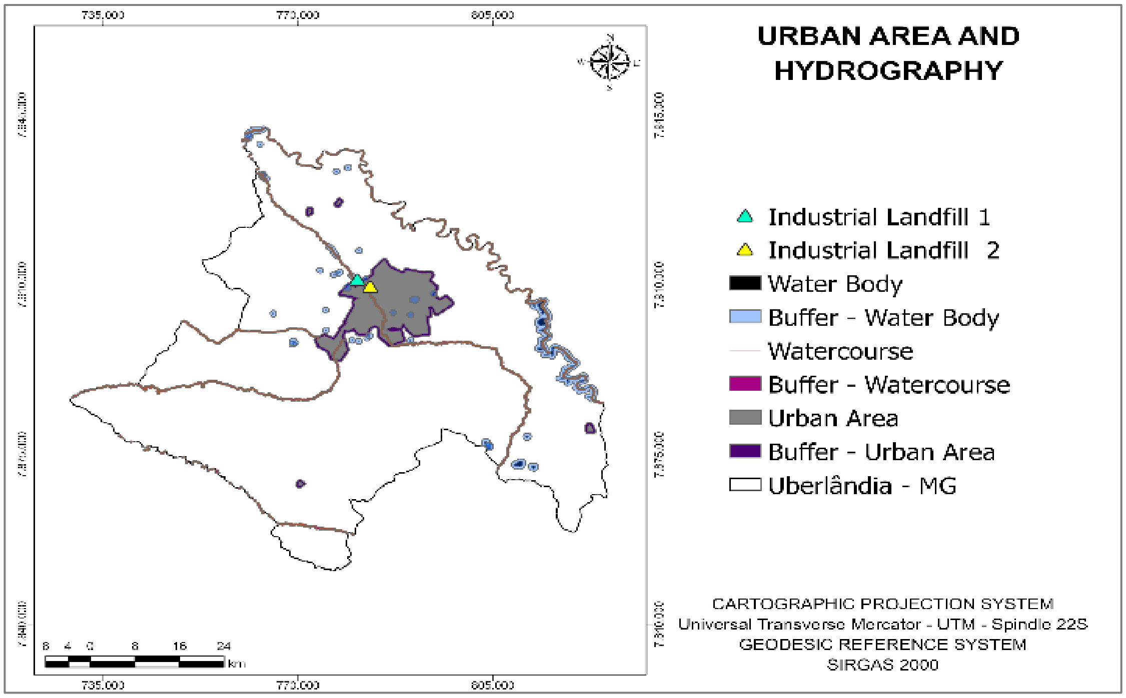


Figure 7 – Buffer of the urban area and hydrology of Uberlândia.
Source: Author (2021).

To assign binary logic, set as zero (0) the criteria that did not fit the normative guidelines, ABNT NBR 10157:1987, for the optimal functioning of the industrial landfill and one (1) for those who did fit. Their determinations are shown below (Table 2).

Table 1 – Criteria and analysis values.

Maps	Classes	Grades
Pedology	**Latosol**	**1**
	Gleysol	0
	Ultisol	0
	Nitosol	0
Slope	< 3%	0
	3 - 8%	**1**
	8 - 20%	**1**
	> 20%	0
Highways	**> 500m**	**1**
	≤ 500	0
Hydrography	**> 200m**	**1**
	≤ 200	0
Urban Area	**> 500m**	**1**
	≤ 500	0

Source: Author (2021).

The information listed above are the relevant expert parameters for the study. Therefore,these landfills located at a minimum distance of 500 meters from highways and urban areas; 200 meters of a course and water body; positioned on latosol soils and with a declivity between 3% to 20% are established in a suitable region, in accordance with current normative guidelines.

Industrial landfills or locations that receive other types of waste they must not be located near courses or bodies of water, in order to preserve safety and minimize contamination (SNSA, 2008). The landfill must be located outside the marginal protection strip of any water body and respecting the minimum distance of 200 m (ABNT NBR 10157:1987).

In analog to the distance of water resources, the best situation occurs when landfills are far from highways and urban areas, because these ends up developing a better social role (SNSA, 2008). A minimum distance from highways, 500 meters, is recommended, to avoid environmental impacts, such as noise, odors and landscape modification in the region (ABNT NBR 10157:1987).

According to Ker (1997), latosols are considered soils deep and with good structure, however, it can be said that regions with latosols has low rates of fragility.

It is recommended that landfills be in locations with a slope greater than 1% and less than 20%, as low slopes facilitate waste and soil handling operations (SILVA, 2011).

As reported by Lopes and Silva (2020), the demonstration of a logical flowchart that follows the proposed objectives to obtain the final analysis, provides better detail in the distribution of criteria and classification of the proposal. Therefore, the following flowchart was generated for this research (Figure 8).

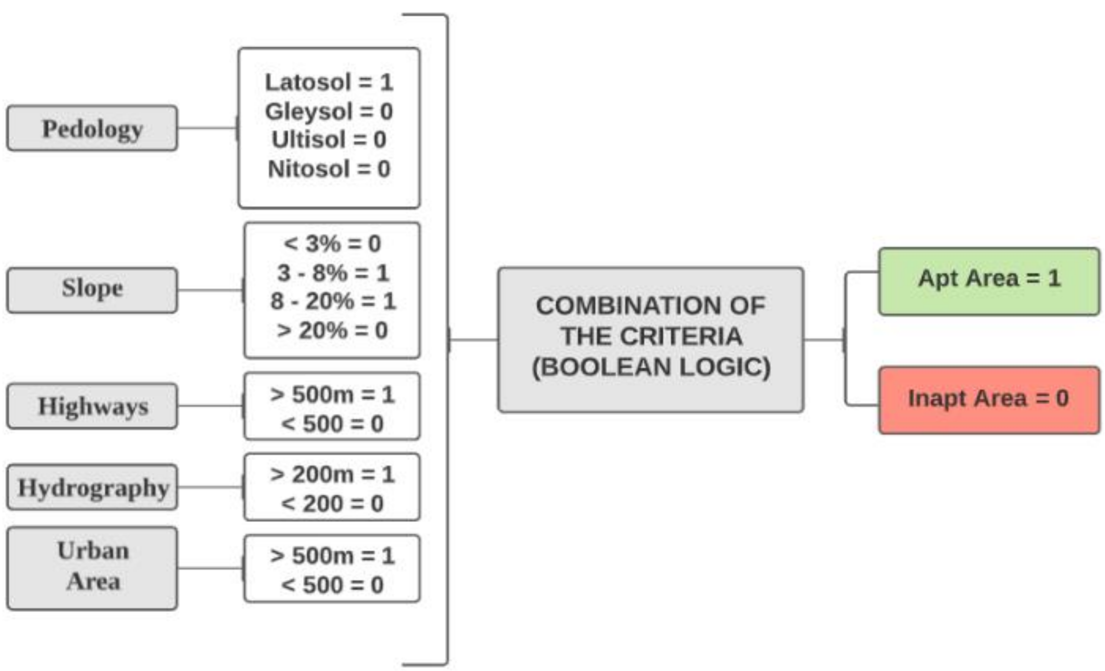


Figure 8 – Logical flowchart.
Source: Author (2021).

The way the buffer was done and itsdimensions are specified in Table 1, for highway criteria, hydrography and urban area, these were classified as unfit, as they were self-limiting.

Table 2 – Values for defining areas of influence

Maps	Buffer (m)
Highways	500
Hydrography	200
Urban Area	500

Source: Author (2021).

To verify the suitability of where the industrial landfills in the city of Uberlândia are installed, parameters were standardized by joining all those that had grade 0 and grade 1 in their respective features' tables and, with aid of joining tools, plus the combination and clipping of ArcGis software, it was possible to determine if your location is in accordance with the established terms (Figure 9).

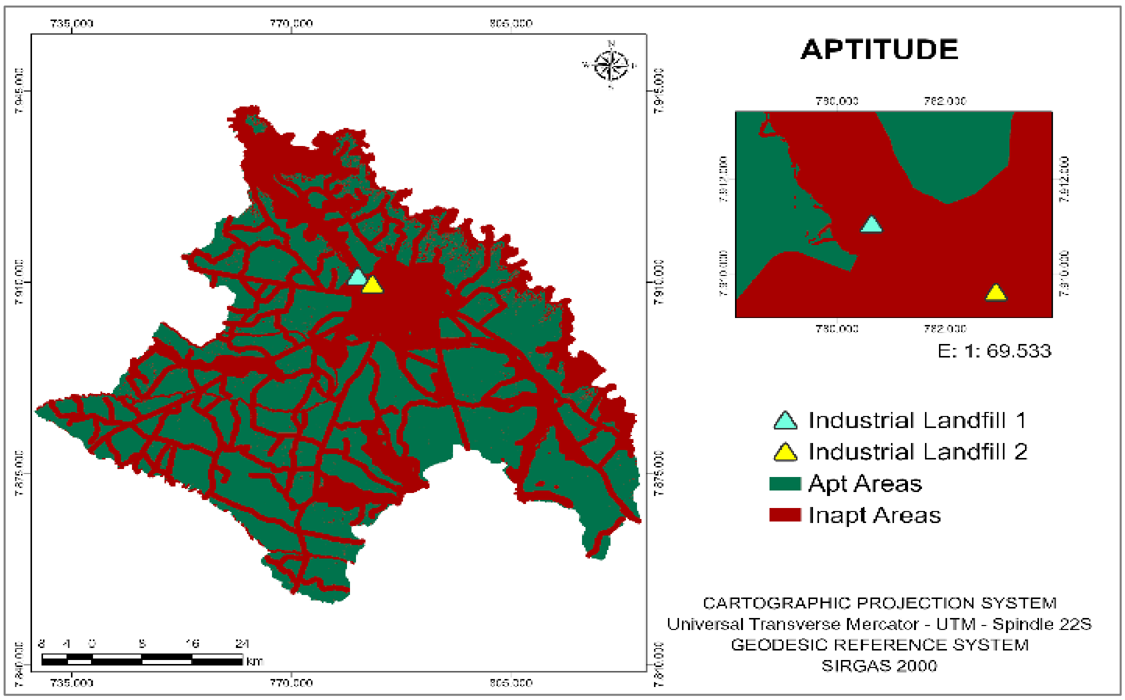


Figure 9 – Aptitude map for expert analysis of industrial landfills in the city of Uberlândia – MG. Source: Author (2021).

When analyzing the aptitude map of the municipality of Uberlândia, it can be understood that both industrial landfills are located in an inappropriate region. In order to base in grounds the diagnosis granted, a previous study was requested, based only on visual analysis, aiming to corroborate with the present work (Figure 10). In this work, the criteria of pedology, water mass, watercourse, urban area and highways were verified. Multi-criteria analysis tools were not applied.Only proposed the overlapping of the features mentioned above, in order to visually understand the result achieved.

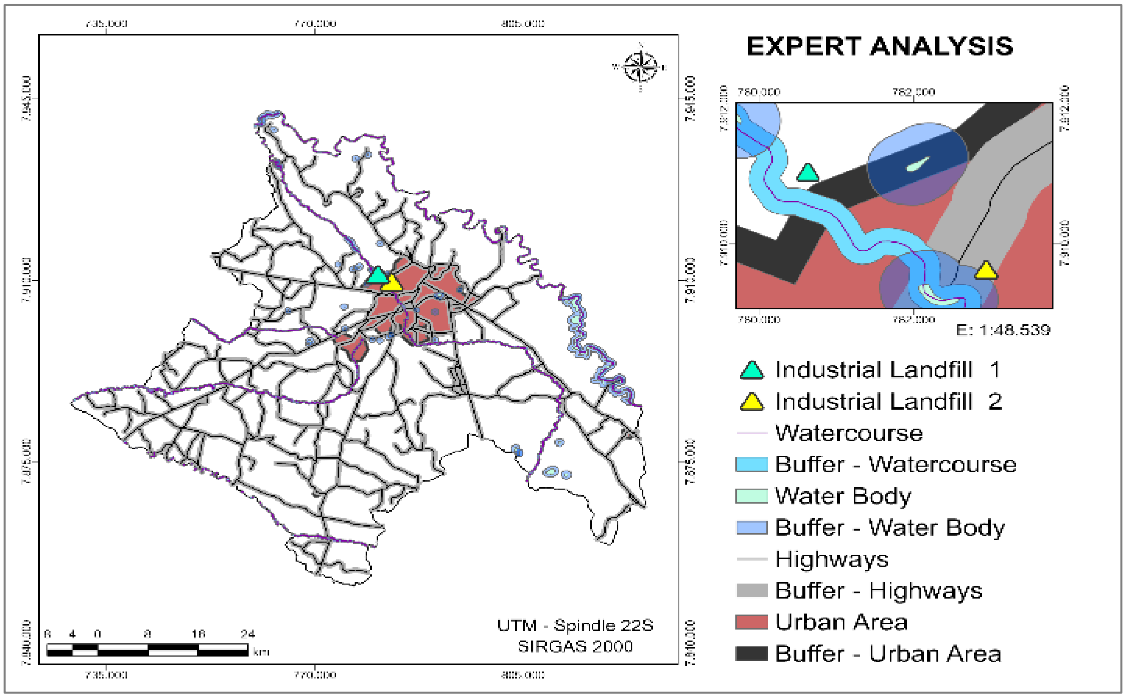


Figure 10 – Expert analysis of industrial landfills in Uberlândia.
Source: Author (2021).

According to Lopes and Silva (2020), landfills are relevant in the current context for solving part of the problems caused by the excess of waste generated in large cities, highlighting the need for a viable and environmentally correct disposal.

The assessment and expertise of areas with dangerous developments constitute an important environmental planning mechanism, because companies that are located or mounted in unfavorable regions can be harmful to the environment and society (BORN, 2013).

It is important to highlight that the Geographic Information System in cooperation with Boolean modeling and the availability of georeferenced data made the evaluation of industrial landfills in the city of Uberlândia possible.

As noted in the generated thematic maps, areas of unsuitable suitability are concentrated in regions of greater soil fragility. Oliveira Neto (2011) confirms this observation by ensuring that gleysols regions, which are hydromorphic soils, have limitations due to the presence of groundwater and high risk of frequent flooding.

It was found that the industrial landfill 2 is installed close to the highways, watercourse, which is not in accordance with the guidelines set out in the ABNT NBR 10157:1987. However, the industrial landfill 1 is located at a suitable distance from the urban area, highways and hydrology operations, however, when it comes to the pedology parameter, this does not fit the intended assignment, as can be seen in Figure 11 in details.

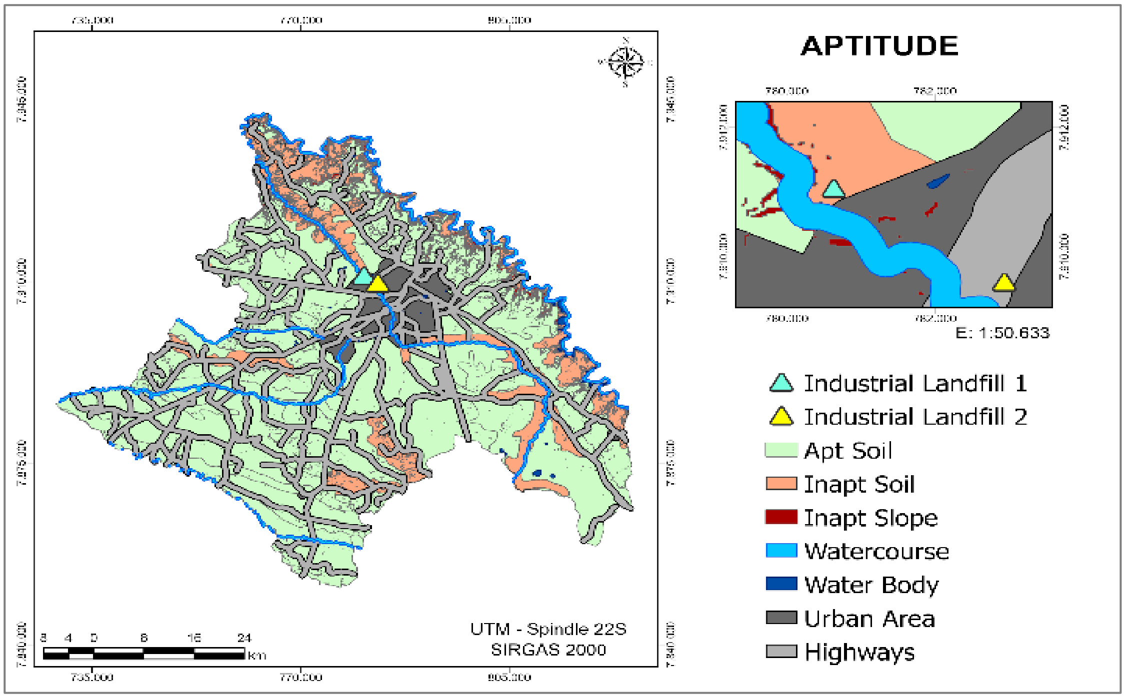
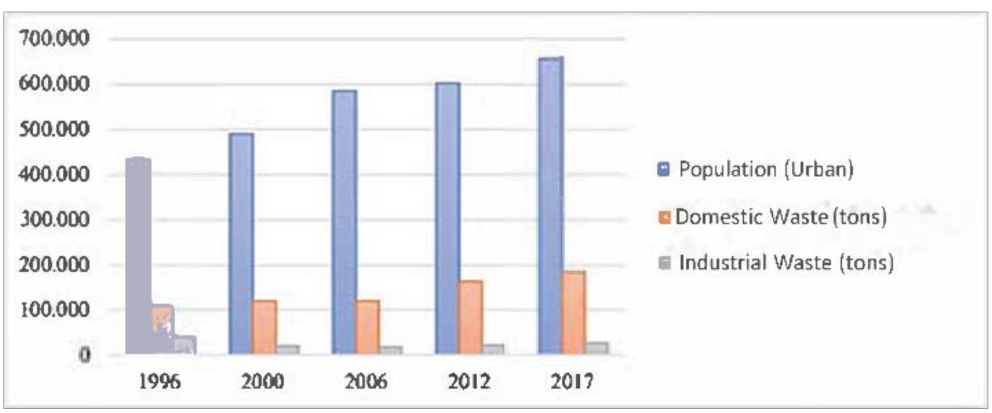


Figure 11 – Detailed suitability map.
Source: Author (2021).

In relation to other Minas Gerais municipalities, Uberlândia is ahead in terms of the urban solid waste disposal structure (USW), having opened its first landfill on July 1995 and its second on October 2010. Due to the high volume of waste received, the landfill, inaugurated in 1995, and scheduled to close in 2013, ended its activities three years earlier (MORAIS, 2013).

With the help of information obtained through the Municipal Basic Sanitation Plan of Uberlândia (2018), there is an increase of 52% of the resident population between 1996 and 2017 and, consequently, a 68% increase of domestic waste destined for landfills. In relation to industrial waste, there was a drop of 62% in 2017 compared to 1996, due to the implementation of new enterprises responsible for treating industrial waste in the municipality (Graph 1).



Graph 1 – Description of the graph with Population data and numbers of domestic and industrial tailings.
Source: Municipal Basic Sanitation Plan of Uberlândia (adapted by the author) (2018).

According to IBGE (2020), there was a 61% increase of inhabitants compared to 1996. Therefore, it can be said that there was an exponential increase in the number of residents in the city during this interval, therefore, leading, to urban growth and, consequently, to discarded waste (Figure 10).

The increase in population density causes, among other factors, soil and slope depreciation, since the lack of protection in the soil causes an increase in the flow velocity of fluids, such as rainwater, enhancing its impacts and, a leading to erosion by decay, pollution and vegetation suppression.

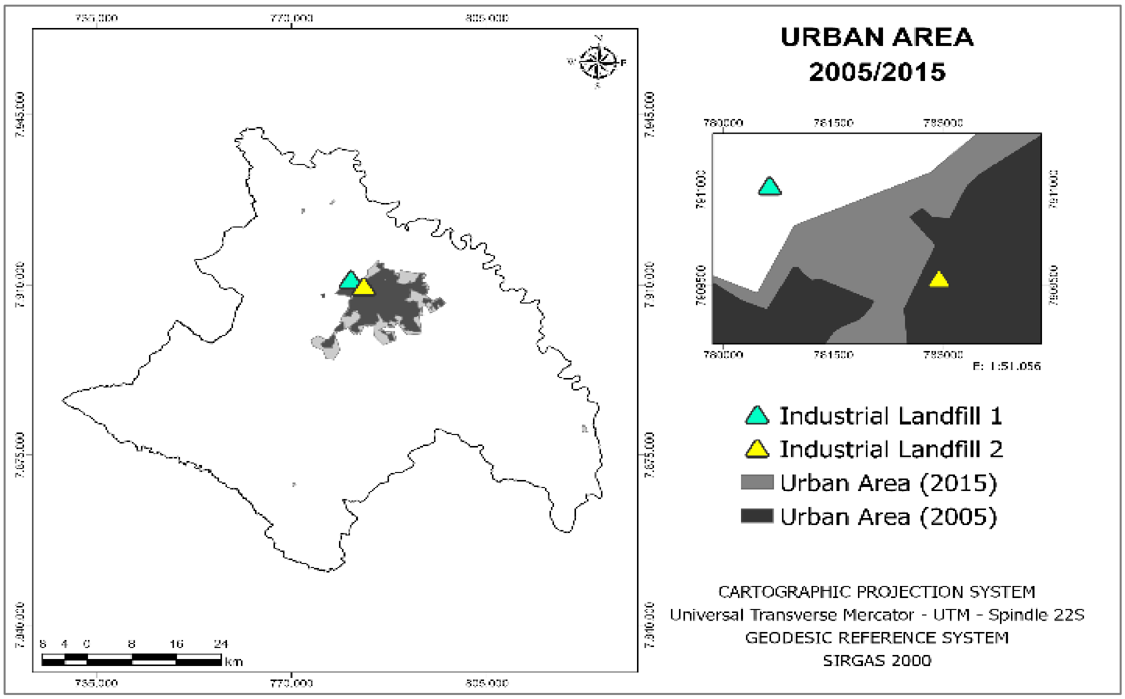


Figure 12 – Comparison between urban grids from 2005 and 2015.
Source: Author (2021).

However, as the first landfill was built in 1995, it is assumed that it has complied with the current normative guidelines, however, with the increase in the number of residents and its resulting impacts, made its current location unsuitable.

6. Final considerations

One can affirm that the established goals were met, according to the proposed methodology, However, it is important to stressthat the assessment was carried out remotely, due to the pandemic scenario, that is, on-site analyzes were not performed. Therefore, the visit to the installation site is essential, in order to prove the result obtained

Thus, it was determined in the conclusion that the landfills that admit hazardous waste in the city of Uberlândia do not currently comply with, the regulatory requirements regarding location. The guidelines established in relation to road distances, hydrology and urban mass were not met in the case of industrial landfill 2, and for landfill 1 the soil characteristics were infringed.

However, further analysis such as soil thickness, soil permeability, groundwater resources, landfill waterproofing and your treatment process should also be carried out.

Finally, geotechnologies proved to be a practical and reliable tool, the aid of ArcGis and QGIS software, along with their respective joining instruments, combination, clipping and calculations, contributed to determining whether the landfills that allow industrial waste in the municipality of Uberlândia comply with current regulatory guidelines. In addition, the databases made available for free, by the Brazilian Agricultural Research Corporation (EMBRAPA) and the Brazilian Institute of Geography and Statistics (IBGE), brought conviction to the end of the article.

Acknowledgements

The authors are grateful to the Brazilian Institute of Geography and Statistics (IBGE), to the Brazilian Agricultural Research Corporation (EMBRAPA) and to the Minas Gerais State Spatial Data Infrastructure (IEDE), for the concession of the databases used in the elaboration of the research, to the ESRI company for the student license provided to use the ArcGis software and to the QGIS community for such wealth of information provided free of charge.

References

ABNT NBR 10.157: Aterros de Resíduos Perigosos – Critérios para Projeto, Construção e Operação. Rio de Janeiro, 1987.

________ NBR 13.896: aterros de resíduos não perigosos – critérios para projeto, implantação e operação – procedimento. Rio de Janeiro, 1997.

________ NBR 10.004: Resíduos Sólidos - Classificação. Rio de Janeiro, 2004.

AMARAL, D. G. P.; LANA, C. E. Uso de geoprocessamento para indicação de áreas favoráveis à construção de aterro sanitário no município de Ouro Preto (MG). *Caderno de Geografia*, v. 27, n. 49, p. 368, 2017.

BORN, V. *Avaliação da aptidão de áreas para instalação de aterro sanitário com uso de ferramentas de apoio à tomada de decisão por múltiplos critérios*. Lajeado, 2013. 103f. Thesis (Environmental Engineering Course Conclusion Paper). Univates University Center, Lajeado-RS, 2013.

CAMERON, K. C.; D. I, H. J.; MCLAREN, R .G. Is soil an appropriate dumping ground for our wastes?. *Australian Journal of Soil Research*, 35:995-1035, 1997.

CONAMA, Resolução nº313, de 29 de outubro de 2002, do Conselho Nacional do Meio Ambiente-CONAMA. *Dispõe sobre o Inventário Nacional de Resíduos Sólidos Industriais.* Brasília, 2002.

EMBRAPA. *Infraestrutura de Dados Espaciais da Embrapa*. Available in: http://inde.geoinfo.cnpm.embrapa.br/. Accessed on: 08/20/2021.

FREITAS, R. F. *Diversidade e sazonalidade de abelhas Euglossini Latreille (Hymenoptera:apidae) em fitofisionomias do bioma cerrado em Uberlândia, MG*. Uberlândia, 2009. 65f. Thesis (Masters in Ecology and Conservation of Natural Resources). Postgraduate Program in Ecology and Conservation of Natural Resources, Federal University of Uberlândia, Uberlândia-MG, 2009.

GOOGLE. *Google Earth website.* Available in: http://earth.google.com. Accessed on: 23/04/2021.

IBGE, Instituto Brasileiro de Geografia e Estatística. *Pesquisa Populacional por municípios: censos anteriores, censo 2020 e projeções futuras.* IBGE, 2020.

INDE. Infraestrutura Nacional de Dados Espaciais – INDE. *Dados vetoriais geomorfológicos e pedológicos*. Disponível em: http://www.inde.gov.br. Acesso em: 30/04/2021.

INSTITUTO AGRONÔMICO (IAC). *Gleissolos*. Available in: http://www.iac.sp.gov.br/solossp/pdf/Gleissolos.pdf. Accessed on: 17/09/2021.

KER, J.C.M. Latossolos do Brasil: Uma Revisão. *Geonomos*, v. 5, n.1, p. 17-40. 1997.

LOPES, R. C.; SILVA, R. N. F. Uso de lógica booleana na triagem de áreas aptas para a implantação de aterro sanitário no Município de Campina Verde, Minas Gerais, Brasil. *Revista Brasileira de Gestão Ambiental e Sustentabilidade*, v. 7, n. 16, p. 487–499, 2020.

LOUREIRO, S. M. *Seleção de Áreas para Implantação de Aterros Sanitários – Critérios e Metodologias*. Solid Waste Management, Civil Engineering Program, COPPE/UFRJ, janeiro, p. 46.

LEAL, J. M.; AQUINO, C. M. S; SILVA, F. J. L. T. Uso do mapa de Declividade e do Modelo Digital de Elevação na análise do relevo do município de São Miguel do Tapuio – Piauí. *Revista de Geociências do Nordeste*, v. 5, n. 2, p. 97–107, 2019.

MENDES, P. C. *A gênese espacial das chuvas na cidade de Uberlândia (MG)*. Uberlândia, 2001. 86f. Thesis (Masters in Geography) – Federal University of Uberlândia, 2001.

MORAIS, C. F. de. *Tratamento alternativo para resíduos sólidos urbanos:* uma proposta para a cidade de Uberlândia – MG. Uberlândia, 2013. 120f. Thesis (Masters in Geography). Postgraduate Program in Geography, Federal University of Uberlândia, Uberlândia-MG, 2013.

NAUMOFF, A. F.; PERES, C. S. Reciclagem de matéria orgânica. In: D'ALMEIDA, Maria L. O.; VILHENA, André. *Lixo Municipal: manual de gerenciamento integrado*. São Paulo: Atlas, 2000, p.93-123.

NETO, P. P. C. *Resíduos Sólidos Industriais*. São Paulo, SP: Série Atlas, 1985.

OLIVEIRA NETO, J. T. *Determinação de áreas favoráveis à implantação de aterro sanitário de resíduos sólidos urbanos para o Município de Piumhi-MG*. Monograph (Specialization in Geoprocessing). Institute of Geosciences, Federal University of Minas Gerais, Belo Horizonte-MG, 2011.

PINTO, D. P. de S. *Contribuição à avaliação de aterros de resíduos industriais.* Rio de Janeiro, 2011. 162f. Thesis (Masters in Civil Engineering). Alberto Luiz Coimbra Institute, Federal University of Rio de Janeiro, Rio de Janeiro, Rio de Janeiro-RJ, 2011.

RAPTI-CAPUTO, D.; SDAO, F.; MASI, S. Pollution risk assessment based on hy- drogeological data and management of solid waste landfills. *Engineering Geology*, 85:122-131, 2006.

RIBEIRO, C.; VARELLA, C. A. A.; SENA, D. G. Jr.; SOARES, V. P. Sistemas de Informações Geográficas. In: BORÉM, A. et. al. *Agricultura de Precisão.* Viçosa, 2000, p.380-407.

ROCCA, A. C. C. Resíduos Sólidos Industriais. São Paulo: CETESB, 1993. 234p.

SAMIZAVA, T. M.; KAIDA, R. H.; IMAI, N. N.; NUNES, J. O. R. SIG aplicado à escolha de áreas potenciais para instalação de aterros sanitários no município de Presidente Prudente – SP. *Revista Brasileira de Cartografia*, São Paulo, p. 43-55, 2008.

SILVA, N. L. S. *Aterro Sanitário para resíduos sólidos urbanos RSU - Matriz para Seleção da Àrea de Implantação.* Feira de Santana, 2011, 57f. Thesis (Final Course Work in Civil Engineering). State University of Feira de Santana, Feira de Santana-BA, 2011.

SNSA - Secretaria Nacional de Saneamento Ambiental. Rede Nacional de Capacitação e Extensão Tecnológica em Saneamento ambiental – ReCESA. *Resíduos sólidos: projeto, operação e monitoramento de aterros sanitários: guia do profissional em treinamento: nível 2.* Ministério das Cidades. Secretaria Nacional de Saneamento Ambiental (org) – Belo Horizonte: ReCESA, 2008. 120 p.

UBERLÂNDIA. *Plano Municipal de Saneamento Básico.* Available in: http://servicos.uberlandia.mg.gov.br/uploads/cms_b_arquivos/20610.pdf. Accessed on: 14/04/2021.