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CARACTERIZAÇÃO DOS RESÍDUOS SÓLIDOS URBANOS DOS MUNICÍPIOS PAULISTAS POR SETOR CENSITÁRIO

RELATÓRIO FINAL DE PROJETO DE INICIAÇÃO CIENTÍFICA

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RESUMO

Esta iniciação cientifica, iniciada em março de 2018, tem como objetivo dar continuidade no projeto intitulado “Caracterização dos resíduos sólidos urbanos (RSU) dos municípios paulistas por setor censitário”. No início deste trabalho, em 2017, foram elaborados modelo de geração e caracterização dos RSU para o Brasil e para os municípios do estado de São Paulo. Porém, no início de 2018 identificou-se a necessidade de se analisar os critérios restritivos que interferem na localização e construção de áreas para aterros sanitários no Brasil e no mundo. Para isso foi realizada uma revisão bibliográfica sistemática das restrições e suas classificações dentro de três vertentes: ambiental, social e econômico. Dentre as informações analisadas dentro do fator ambiental temos declividade, distância de corpos hídricos e pedologia. Do fator social temos uso da terra e distância de centros urbanos. E do fator econômico temos distância de rodovias, aeroportos e fronteiras intermunicipais ou estaduais. Além disso, foram coletadas informações para uma meta-análise a respeito dos softwares utilizados para o mapeamento, dos locais onde foram realizados os estudos, e da resolução espacial utilizadas em cada artigo. Essa revisão permitiu avaliar os fatores de restrições mais comuns utilizados no mundo e principalmente identificar os valores de restrições para cada um dos critérios. Estas informações serão de extrema importância para a próxima etapa do trabalho que será mapear as áreas restritivas para localizações de aterros sanitário em duas escalas diferentes uma regional, tendo como área de estudo o estado de São Paulo e outra mais abrangente tendo como área de estudo o Brasil.

Palavras-chave: Resíduos sólidos, aterros sanitários, meta-análise, áreas restritivas

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SICINPE - Seminário de Iniciação Científica e Iniciação em Desenvolvimento Tecnológico e Inovação do INPE

RSU - Resíduos Sólidos Urbanos

SIG - Sistema de Informações Geográficas

INPE - Instituto Nacional de Pesquisas Espaciais

IBGE – Instituto Brasileiro de Geografia e Estatística

GIS - Geographical Information System

SW – Solid Waste

MSWD – Municipal Solid Waste Management

NIMBY - Not-In-My-BackYard

SUMÁRIO

1. INTRODUÇÃO

Este relatório tem por objetivo apresentar o progresso do projeto de iniciação científica intitulado “Caracterização dos resíduos sólidos urbanos (RSU) dos municípios paulistas por setor censitário”, desenvolvido pela bolsista Anna Isabel Silva Loureiro, no período de março a julho de 2018.

Neste período do projeto foi realizado por meio de revisão bibliográfica a pesquisa e organização das restrições de acordo com os critérios ambientais, sociais e econômicos dos artigos de localização de aterros sanitários utilizando SIG. Com os resultados dessa revisão bibliográfica está sendo elaborado um artigo cientifico o qual está sendo escrito em inglês e encontra-se na integra nesse relatório no Capítulo 3. Este estudo será apresentado na forma de pôster no Seminário de Iniciação Científica e Iniciação em Desenvolvimento Tecnológico e Inovação do INPE (SICINPE 2018), com o intuito de incorporar os comentários e sugestões recebidas pelos avaliadores, pesquisadores e alunos que estarão presentes no simpósio na análise em questão. Vale ressaltar que apesar de não ser obrigatório a apresentação no SICINPE devido ao fato desta bolsa de IC ter se iniciado recentemente em março de 2018 ainda consideramos importante tal fato para receber as sugestões de outros pesquisadores e passar de certa forma este trabalho por revisão antes da submissão do artigo.

Na elaboração do artigo apresentado no Capítulo 3 deste relatório, a busca por publicações relevantes foi realizada usando uma meta-análise e um método de revisão bibliográfica para restrições em estudos de localizações de aterros sanitários utilizando SIG. A revisão foi feita na *Web of Science* e nos periódicos SAGE. Para esta última base de dados, fez-se a busca pelas palavras-chave “*landfill e GIS*” e foram encontrados 334 artigos, divididos em 228 artigos inovadores e 18 artigos de revisão. Nesses artigos, foi aplicado o filtro com as palavras “*restriction, constraint and limitation*” e restaram 14 artigos. Após a leitura detalhada desses documentos, seis artigos foram usados em nosso estudo.

Para a base de dados *Web of Science*, foi usada a mesma abordagem relatada anteriormente, e ao buscar-se “*Landfill and GIS*”, 356 artigos foram encontrados, deste total 279 artigos inovadores e 8 artigos de revisão. Após a aplicação do filtro usando as palavras "*restriction, constraint, and limitation*", restaram 26 artigos. Após uma leitura cuidadosa desses documentos, 17 artigos foram levados em consideração em nosso estudo.

Além, destes 23 artigos encontrados nas duas bases de dados citadas anteriormente, foram incluídos 17 artigos encontrados em outras bases de dados relacionados com localização de aterros usando SIG, totalizando, portanto, 40 artigos. Estes artigos foram analisados e as informações retiradas deles foram organizadas e tabuladas. Algumas das informações retiradas para a meta-análise foram: tamanho e localização da área de estudo, software utilizado, resolução especial, além das restrições ambientais, sociais e econômicas ressaltadas em cada um dos artigos.

Este relatório está organizado da seguinte forma. O **Capítulo 2** contém os objetivos do projeto de iniciação científica. |O **Capítulo 3** apresenta o artigo produzido ao longo desse curto período da pesquisa e que documenta o trabalho realizado. O **Capítulo 4** apresenta as considerações finais deste relatório. As referências utilizadas são listadas ao fim deste documento.

2. OBJETIVO

2.1. Objetivo Geral

Os principais objetivos deste projeto são primeiramente identificar padrões na geração e caracterização dos resíduos sólidos urbanos para se elaborarem cenários futuros, especializando os resultados por setores censitários do IBGE e posteriormente identificar as principais restrições dentro dos aspectos ambientais, econômicos e sociais para se dispor estes RSU de forma adequada.

2.2. Objetivos Específicos

1. Elaborar um modelo de geração e caraterização dos resíduos sólidos urbanos através do uso da programação computacional;

2. Desenvolver cenários que levem em consideração tanto a quantidade gerada como a caracterização dos RSU;
3. Espacializar os resultados em setores censitários do IBGE utlizando SIG;
4. Desenvolver cenários de gerenciamento dos RSU, como por exemplo a porcentagem dos RSU que serão tratados e portanto não serão dispostos nos aterros sanitários;
5. Elaborar um modelo para calcular o tamanho das áreas necessárias para dispor os resíduos sólidos urbanos de forma adequada.
6. Analisar as possíveis mudanças ambientais que podem ocorrer com os resultados dos modelos elaborados, levando em consideração cenários propostos.
7. Analisar nas bibliografias nacional e internacional as restrições de acordo com os aspectos ambientais, econômicas e sociais que podem impedir a construção de um aterro sanitário;
8. Espacializar os resultados das restrições a nivel estudual e nacional

3. ARTIGO – A worldwide review of restrictions criteria used in landfill siting

3.1 Introduction

The main purpose of this study is to make a systematic review of restriction criteria used for landfill site selection using Geographical Information System (GIS). Landfill site selection is becoming critical because of population growth, changes in living standards, increased economic activities and the pressure for a sustainable environment.

Generated solid waste (SW) requires adequate treatment in order to minimize water, air, and soil contamination. However, finding a landfill site location is not simple. Issues such as “Not-In-My-BackYard (NIMBY)” syndrome, different local regulations and constraints make finding an appropriate landfill site location very difficult.

Accelerated population growth and changes in lifestyle are the main factors that contributed to the fast growth of SW generation (Eskandari et al. 2015). A landfill is a good option for the disposal of all this SW produced. Landfill efficiency depends on its location, whether it is installed in accordance with the standards and constraints criteria for preserving the soil, water, and air around it.

A well-designed landfill uses an engineering method of SW disposal on land in a way that minimizes environmental hazards by spreading the SW in thin layers, compacting the SW to the smallest practical volume, and applying a cover at the end of each operating day (Eskandari et al. 2015). Appropriate implementation of landfill siting with the right regulations and constraints can avoid undesirable long-term effects (Ahmad et al. 2014).

Landfill siting is becoming increasingly difficult due to growing environmental awareness, decreased amount of governmental and municipal funding with extreme political and social opposition (Sener et al. 2005). Environmental factors are important in order to avoid resources contamination. Social factors are included to try to reduce public opposition to any project. In most cases, the main reason for public opposition is associated with the NIMBY syndrome, which is defined as the opposition by local citizens to the construction and operation of a civil project in their neighborhood. Though needed by the larger community, these projects are considered to be unsightly and dangerous, or many times more likely to lead to decreased property values by the local community (Simsek et al. 2014). As a result, the decision complexity is reduced and more thoughtful decisions are made, leading to an effective landfill location selection and thus minimizing the risk of raising public opposition (Demesouka et al. 2014a).

The economic factor is important once you need to find a place with the good cost-benefit ratio, with ideal distance in order to use existing infrastructures such as roads and power lines. In order to find an ideal landfill site location, GIS models are used. GIS modeling aims to find suitable spatial patterns for upcoming land use based on exact constraints, preferences or predictions of some activity. The spatial nature of modeling of new landfill sites problem involves the use of GIS to expand the traditional frameworks in order to concern equally spatial and attributes data (Abujayyab et al. 2016). GIS enables the manipulation of spatial data by using various spatial operations. These operations help to construct spatial databases for use as criteria or factors (Kara and Doratli 2012).

This article is organized as follows. Section 2 review the main environmental, social and economic criteria for landfill siting. Section 3 presents the research methodology used to conduct this work. Section 4 discusses the results of this research. Section 5 concludes this work.

3.2 Landfill siting

One of the most delicate steps in waste management is the selection of the most suitable landfill site (Zelenović Vasiljević et al. 2012). Landfills are the most commonly used method of waste treatment due to their simplicity in application. Although efficient landfill siting depends principally on the adequacy of the site selection criteria, in the whole process, a large number of factors are involved (Demesouka et al. 2014b).

Landfills are the ultimate waste sinks in every Municipal Solid Waste Management (MSWM) system, even if waste reduction and reuse, recycling and thermal or biological treatment techniques are included in it. Over-population, urbanization and increased waste production during the past, in addition to limited land resources, have not only decreased the lifetime of existing landfills but also aggravated the difficulty of locating new ones. Siting a landfill is a complicated process since it has to combine social, environmental, technical and financial factors (Kontos et al. 2003). In the next sub-items, there are some of the main restrictions.

3.2.1 Environmental criteria

Environmental criteria aim to prevent the contamination of the natural environment and to protect against water resource pollution (Demesouka et al. 2014b)**.** The environment criteria represent the first part in the sustainable development and planning, it embodied the analysis via implementing several criteria, which play a substantial role to select the landfill sites. (Abujayyab et al. 2016).

Depth to groundwater

The groundwater depth is related to the environmental susceptibility for landfill sites since the shallow is the underground water level the highest susceptible is the area if leachate leaking contamination occurs (NASCIMENTO, 2017). In other words, this criterion ensures that the larger the groundwater depth, the lesser opportunity for the contaminant to reach the aquifer and makes a greater opportunity for the vadose zone to get self-purification (Saatsaz et al. 2018).

Distance from groundwater fount, Distance from surface water resources

The purpose of this criteria is increasing the distance to surface water bodies (i.e., rivers, lakes, ponds, and dams) and groundwater resources (i.e., wells, qanāts, and springs) in order to reduce the risk of contamination (Saatsaz et al. 2018).

Distance from the fault line, Seismicity, Landslide areas

These criteria consider that faults have an important role in preventing pollution that could be caused by earthquakes or other earth movements (Gorsevski et al. 2012). Also, the risk of an intense seismic event is considered a crucial factor in the evaluation process for candidate sites (Demesouka et al. 2014a). According to (Yıldırım and Güler 2016) SW disposal system should not be constructed in an area of close proximity to historical and active landslides sites since these areas are most subject to recurring catastrophic failures capable of the seriously threatening long-term integrity of the liner and cap system.

Lithology/Geology, Bedrock material, Infiltration, Pedology

The purpose of these criteria is to protect the soil and its resources. From a geological point of view, materials have different suitability for being in landfill sites. It is specified in different studies that each region have a restrictive type of geology and lithology. Soil with fewer infiltration rates is better for a landfill site.

Regional resources for water supply*, *Distance from water generation source

The purpose of these criteria is to ensure the appropriate distance between landfill location and generation sources of water supply. International practice, in addition to European Union directives, dictates that a landfill site must not be adjacent to any water sources due to potential pollution (Kontos et al. 2003).

Protected areas, Environmentally sensitive areas, Forest areas

This criterion ensures that the landfill site should have distance from environmentally sensitive places, protected areas, and forests in order to protect threatened or endangered plants and species from landfill pollution. Moreover, related construction and development of landfill facilities can cause degradation of the surrounding environment (Khoshand et al. 2018).

Slope

The greater earth slopes the greater opportunity for the runoff to reach surface water reservoirs and the lesser to reach groundwater resources (Saatsaz et al. 2018). The slope affects many important landscape processes such as soil water content, erosion potential, runoff rates and velocity of overland and subsurface flow. The slope of the terrain is a crucial factor for generation of surface runoff and therefore the possible transport of pollutants from the landfill on the wider area (Donevska et al. 2012). The slope criterion aims to ensure appropriate landfill construction and operation purposes as well as the stability from material weight (Gorsevski et al. 2012).

Elevation

The best areas for landfills are the places with medium altitude (Donevska et al. 2012). Siting a landfill in a mountainous terrain with high elevations is not feasible on economic terms because of high construction and waste transportation costs (Yıldırım and Güler 2016). Also, elevations are considered as areas with difficult access (Bahrani et al. 2016). The purpose of the criterion is to establish proper elevation for landfill site location.

Coastline

The purpose of this criterion is to protect surface water resources. Landfill sites should be located on areas that are remote from surface water resources (Kara and Doratli

2012). Also, to protect the tourism industry and avoid high land acquisition costs, buffer zones from the coastline and the national borders are assigned (Demesouka et al. 2014b).

Hydrogeology

Hydrogeology includes factors such as permeability, the depth and the homogeneity of the strata beneath the landfill that drives the hydraulic conductivity, the geochemistry and the landfill material reactivity and the type of landfill such as uncontrolled (i.e., waste poses hazards to the environment and human health) or sanitary (i.e., waste is managed via barriers to help protect the environment) (Gorsevski et al. 2012). The purpose of this criterion is to provide long-term environmental safety from landfill siting by avoiding groundwater pollution from landfill leaching and transport of contaminants.

Irrigational canals

Irrigation canals are considered inappropriate for placing a landfill. This criterion aims to minimize the risk of groundwater contamination against the leakage of landfill leachate in irrigation areas (Demesouka et al. 2014a).

3.2.2 Economical criteria

Economical criteria refer to the landfill site feasibility in terms of using the existing municipal infrastructure for the SW logistics. In addition, they refer to the safety regulations regarding the distance between landfill site location and infrastructure, public utilities and industrial sites.

Roads, highways, railways, road accessibility

The main purpose of this criterion is to find a trade-off between logistics requirements and regulatory distance from transportation infrastructures when locating a landfill, which should succeed in a reasonable distance of existing roads in order to reduce the roads construction cost. In a few words, a good road network accessibility can avoid extra costs (Cheng and Thompson 2016). On the other hand, landfills located close to roads negatively impacts tourism, drivers, and passengers with odor, noise, dust, and esthetic problems (Saatsaz et al. 2018).

Powerlines

The purpose of this criterion is to define the distance to avoid seriousness of voltage power resulting from powerlines and to provide electricity for the infrastructure in a landfill site (Chabuk et al. 2016a). Landfills need a suitable distance from power lines to use from them (Bahrani et al. 2016).

Airports

The purpose of this criteria is to ensure proper landfill site distance from the airport because of possible uncomfortable environmental effects such as odor, noise, and dust (Saatsaz et al. 2018) as well as avoiding the presence of birds that feed from landfill site material and may cause aircrafts accidents. (Arkoc 2013) considers as an environmental criterion.

Gas pipelines, Oil pipelines

The purpose of this criteria is to avoid hazards related to gas or oil leakage underneath the landfill site. A distance between the landfill and gas and oil pipelines are adopted to avoid a serious impact of spontaneous fires that result from combustion of solid waste on the gas pipelines (Chabuk et al. 2016a).

Ownership, Size, Average landfill depth

The purpose of this criteria is related to landfill site cost. The ownership of land directly affects the site value, so it is preferable a public ground construct a landfill and there are a minimum size and depth that must be followed.

Presence of public utilities

The purpose of these criteria is to guarantee the availability of public utilities, such as water and electricity in order to avoid additional investment costs for landfill sites. The presence of public utilities, such as electricity and water systems in the proximity of the candidate landfill sites make it more suitable (Kontos et al. 2003).

Distance from industries

The purpose of these criteria is to guarantee a safe distance between the landfill and industries. The more distances from the industries, the more suitable the land and vice versa (Bahrani et al. 2016).

3.2.3 Social criteria

Social criteria refer to factors that contribute achieving public acceptance at the realization phase of the landfill site project. The public can pose difficulties and restrictions to the project.

Archaeological and cultural interest sites

This criterion aims to protect the national cultural inheritance, which includes various palaeontological, archaeological and historical sites (Kontos et al. 2003). Potential landfill sites should be assessed in relation to potential impacts on historical and archeological sites (Bahrani et al. 2016).

Distance from urban areas, Distance from villages, Settlements, Residential areas, Distance from the waste generation source

The purpose of these criteria is to provide acceptable distance for a landfill taking into consideration waste logistics and welfare of residents. The proposed area should be close enough to the city for convenient dumping and affordable transportation costs but should be far enough away to not cause health or environmental problems (Aksoy and San 2017). The landfill that is too far away from the waste generation source will increase the transportation costs and clean-up times which are very important in disaster recovery (Cheng and Thompson 2016). The closer to the dense population settlements, the lower the operating cost will be (Donevska et al. 2012). The landfill is considered to have a significant impact on those living within close proximity to the site, due to excessive noise, traffic, odor, litter, and scavengers (Ghobadi et al. 2013).

Land Use and Land Cover, Agricultural areas

These criteria aim to guarantee that the landfills are not located in productive or underdeveloped areas. The protection of development prospects is achieved by avoiding the location of landfills in forests, agricultural areas of high productivity or areas under development (Demesouka et al. 2014b). Land use is also an important criterion to resolve public conflicts and disputes of the acceptance of unwanted site of landfill facilities (Aydi et al. 2013) (Demesouka et al. 2014b). (Güler and Yomralıoğlu 2017) considers land use as an environmental criterion and says that forest areas are not suitable for landfill siting.

Natural monuments, parks and recreation areas

This criterion aims to protect natural monuments, parks and recreation areas assuring appropriate distance from landfill sites.

3.3 Literature review methods

The search for relevant publications was performed using a meta-analysis and a review method for landfills sites restrictions in the Web of Science and SAGE Journals. For the later, we search for “Landfills and GIS” words and found 334 articles, divided into 228 research and 18 review articles. From the total, we looked for “restriction, constraint, and limitation” words and 14 articles remained, after a detailed reading of these documents, six articles were used in this analysis. For the Web of Science database, we used the same approach described before, and when we searched for “Landfills and GIS” words, 356 articles were found, from this total 279 are research and eight review articles. After filtering using the words “restriction, constraint, and limitation”, 26 articles remained and after a careful reading, 17 articles were taken into consideration in this study. We also included 17 articles found in other databases and online related to the landfill siting using GIS (**Erro! Fonte de referência não encontrada.**).

3.3.1 Search methodology

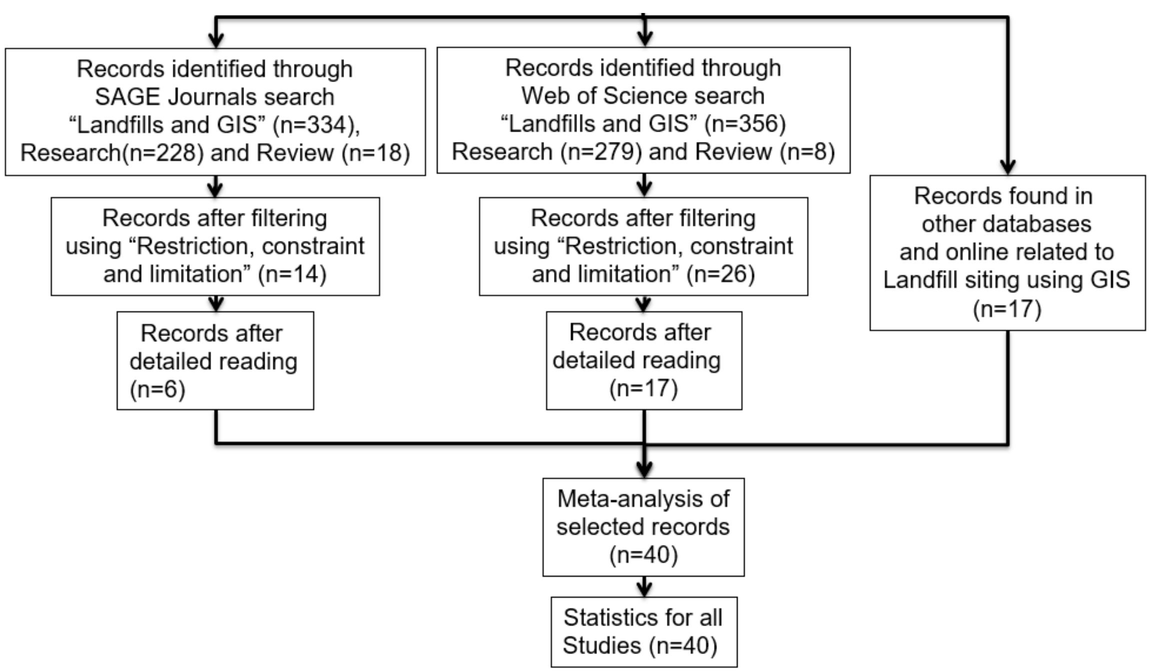

Figure 1 - Flowchart of the search methodology

3.3.2 Content meta-analysis

Table 1 – Meta-analysis review items

Items	Description
Publication name	Sources include only refereed journals
Authors names	Authors from the selected article
Journals	Journal from the selected article
Year of publication	Year of the publication
Study area location	Geographical location and coordinates of the study area
Study area size	Size of the study area in km^2
Software	Software used for imagery collection and processing
Image spatial resolution	The distance between two consecutive pixel centers measured on the ground

3.4 **Results and Discussion**

Figure 2 presents the number of articles selected and published between 1996 and 2018 about landfill restriction using GIS. From the literature, 40 published studies have been selected; these studies commonly focus on developing and improving the frameworks that can identify the most suitable location for landfill sites. It summarizes the progress of main published research concerning landfill GIS modeling documented in literature since 1996. Eighty percent (80%) of articles were released after 2012, which reflects the increasing interest in the last five years and also the awareness about the GIS benefits in this research scope as shown in (

Figure 2) and the increasing interest of Asian countries in this kind of research as demonstrated in (Figure 3)

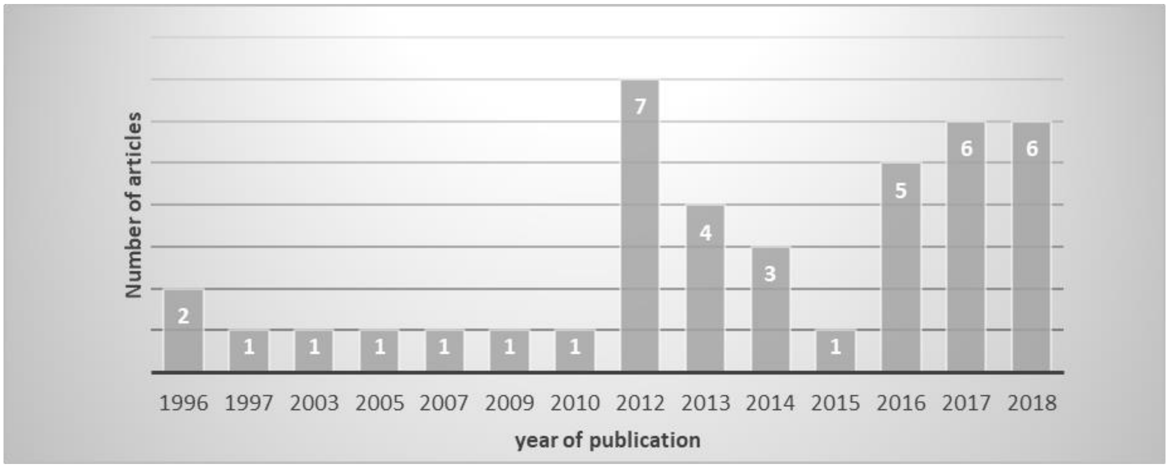

Figure 2 - Published articles from 1996 to 2018

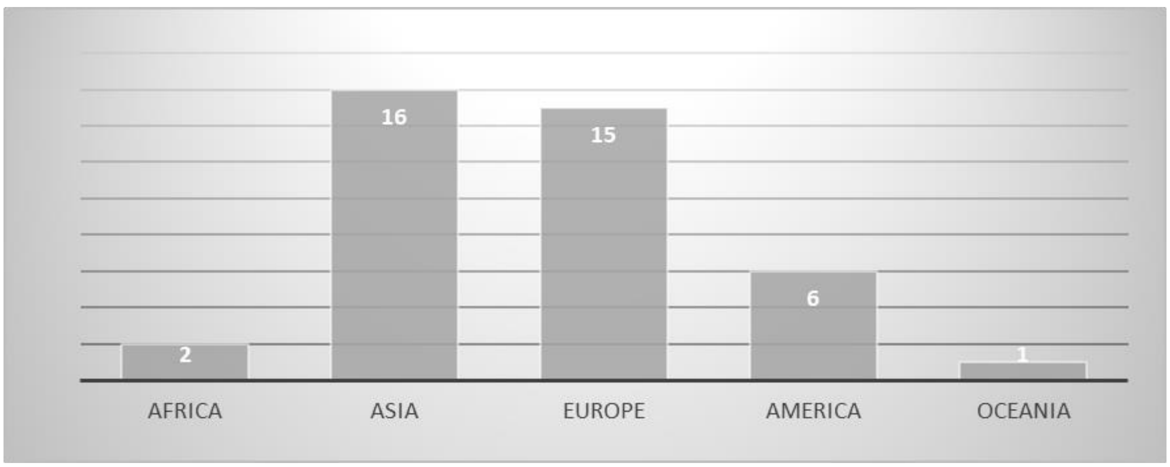

Figure 3 - Published article based on different location

The sub-criteria also statically accounted for the usage score (based on the 40 reviewed articles) to produce primary understanding regarding the used criteria and its usage frequency, which is presented in (Figure 4). The percentage for the frequency of sustainable criteria application is considerably high. The sub-criteria were grouped into three categories as per this percentage. (Figure 4) indicates that the environmental criteria account for 49% of the total criteria. This proportion shows the stress related to environmental issues during landfill modelling operation. The economical and social criteria accounted for 32% and 19%, respectively. These percentages emphasize that many articles emphasize environmental criteria in general also mentioning social and economical aspects, although not with the same emphasis.

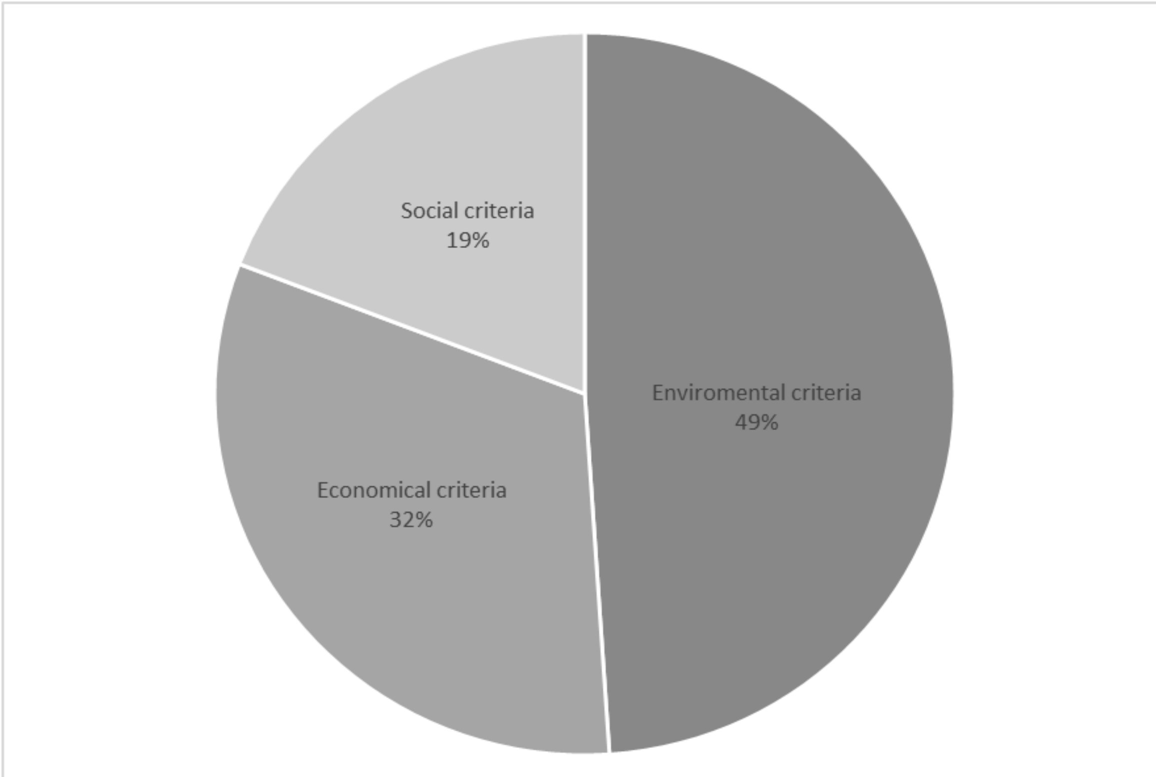

Figure 4 - Percentage of criteria frequency in landfill modeling

Geographical location and coordinates of study areas from the articles used in this research are shown in (Figure 5).

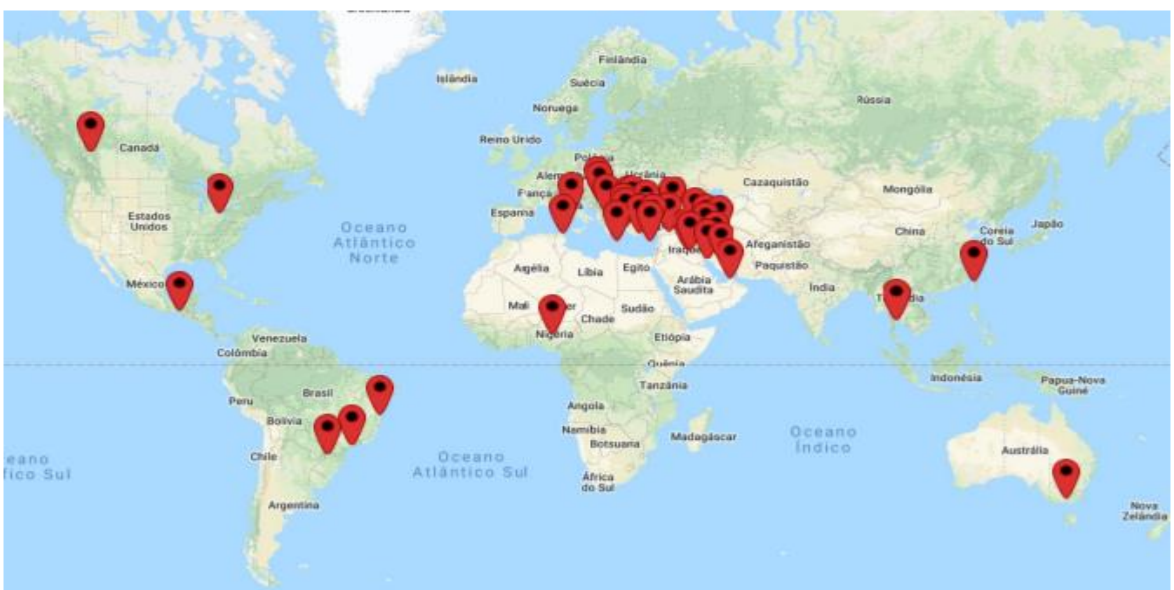

Figure 5 – Location of study areas of the articles used in this analysis

All articles and their numbers of restriction in the environmental, social, and economic factors are listed in Table 2.

Table 2 – Numbers and characterization of restrictions for each article

Article	Environmental restrictions	Social restrictions	Economical restrictions	Total
(Afzali et al. 2014)	3	-	-	3
(Al-Ruzouq et al. 2018)	4	1	3	8
(Luz et al. 2017)	3	1	-	4
(Chabuk et al. 2016a)	1	4	5	10
(Zelenović Vasiljević et al. 2012)	4	3	1	8
(Saatsaz et al. 2018)	5	3	2	10
(Araiza Aguilar et al. 2018)	3	-	-	3
(YAZDANI, M. – MONAVARI, S. M. – OMRANI, G. A. – SHARIAT, M. – HOSSEINI 2017)	4	1	-	5
(Cheng and Thompson 2016)	4	3	4	11
(Gomes et al. 2017)	5	1	-	6
(Aksoy and San 2017)	5	1	3	9
(Gorsevski et al. 2012)	4	1	-	5
(Kara and Doratli 2012)	5	3	2	10
(Ersoy and Bulut 2009a)	5	3	1	9
(Alavi et al. 2012)	3	3	1	7
(Kontos et al. 2003)	8	6	2	16
(Baiocchi et al. 2014)	6	3	4	13
(Chabuk et al. 2017)	1	4	5	10
(Bahrani et al. 2016)	4	3	3	10
(Yıldırım and Güler 2016)	4	1	1	6
(Güler and Yomralıoğlu 2017)	3	2	1	6
(Demir et al. 2016)	1	1	1	3
(Yesilnacar et al. 2012)	3	3	5	11
(Simsek et al. 2014)	3	2	4	9
(Khan et al. 2018)	5	2	5	12
(Kao and Lin 1996)	3	-	-	3
(Eskandari et al. 2012)	5	2	2	9
(Sener et al. 2005)	3	2	3	8
(Nas et al. 2010)	3	3	1	7
(Ghobadi et al. 2013)	1	2	1	4
(Eskandari et al. 2015)	3	1	2	6
(Donevska et al. 2012)	4	3	-	7
(Aydi et al. 2013)	5	1	-	6
(Arkoc 2013)	-	-	4	4
(Milosevic and Naunovic 2013)	6	1	-	7
(Charnpratheep et al. 1997)	2	4	-	6
(Despotakis and Economopoulos 2007)	5	-	-	5
(Siddiqui et al. 1996)	3	2	1	6
(Aderoju et al. 2018)	4	2	2	8
(Spigolon et al. 2018)	5	2	1	8

This environmental section referred to 23 criteria founded in the literature. (Figure 6). Frequency of criterion usage for environment criteria has clearly shown the criterion importance, where the seven most significant environment criteria are distance from source water resources, which referred to 31 articles in the literature, while slope (21 articles), distance from groundwater fount (15 articles), distance from fault line (14 articles), protected areas (9 articles), lithology/geology (8 articles) and hydrogeology (7 articles). Seventy-one percent (71%) of articles referred to the above criteria. In these studies, 7 out of 23 criteria were applied only once, including soil productivity, infiltration, environmental degradation, bedrock material, irrigational canals, seismicity and water flowing body. The small score does not mean the criterion is negligible.

According to the literature reviewed, the environmental factors are listed as follow:

- Distance from surface water resources may vary from 100 to 2000 meters. (Aksoy and San 2017) mentions 100 meters for rivers and 2000 meters for lakes;
- The depth of groundwater is proposed as 5 meters (Eskandari et al. 2012) and as 39 meters by (Araiza Aguilar et al. 2018);
- Distance from groundwater fount may vary from 50 to 1000 meters;
- Distance from fault line may vary from 60 to 1000 meters;
- About Lithology/Geology, 6 articles consider Granite unsuitable for a landfill site, (Gomes et al. 2017) sandstone, (Aksoy and San 2017) and (Bahrani et al. 2016) considers unsuitable highly permeable areas, (Ersoy and Bulut 2009b) considers unsuitable Unconsolidated lithology, (Nas et al. 2010) sand and gravel, (Ghobadi et al. 2013) considers unsuitable Limestones, sandstones, dolomite and evaporite, alluviums and terraces, 39 considers quartzite unsuitable;
- Distance from regional resources for water supply may vary from 200 to 2000 meters.
- Distance from Protected areas may vary from 500 to 1000 meters. (Aksoy and San 2017) mentions that Historical, touristic, natural, and wildlife areas which are protected by laws or acts are unsuitable and (Baiocchi et al. 2014) mentions that Parks: national, regional and provincial; Natural reserves; Protected natural areas,

Sites of Interest for European Union and areas with Special Protection Status are unsuitable for landfill sites;

- Distance from environmentally sensitive areas may vary from 200 to 1600 meters;
- Landslides may vary from 500 to 200 meters.
- Elevation may vary from 200 to 650 meters;
- Distance from water generation source vary from 200 to 300 meters;
- (YAZDANI, M. – MONAVARI, S. M. – OMRANI, G. A. – SHARIAT, M. – HOSSEINI 2017) considers Permeable flood basin floor as an unsuitable bedrock material, also areas with high infiltration;
- Coastline criterion may vary from 100 to 200 meters, except for (Aydi et al. 2013) that considers 3000 meters;
- (Milosevic and Naunovic 2013) considers areas with seismicity 9 MSC unsuitable;
- (Despotakis and Economopoulos 2007) considers distance lower than 100 meters between forests and landfill site unsuitable, and (Aderoju et al. 2018) considers distance lower than 500 meters unsuitable;
- Minimal pollution impact from other activities ("clean" sites) are unsuitable and a minimum distance of 100 meters from water flowing body and a landfill site is proposed (Kontos et al. 2003);
- Landfill sites should not be located on prime agricultural land such as first and second classes, and areas degraded by quarry activities or disused quarries should be considered as preferential within evaluation process (Kara and Doratli 2012);
- Landfill must not be located within 100 m of irrigational canals(Nas et al. 2010);
- (Al-Ruzouq et al. 2018),(Gomes et al. 2017),(Kara and Doratli 2012), (Ersoy and Bulut 2009b),(Simsek et al. 2014), (Spigolon et al. 2018) studies accepts a maximum slope of 20%, while (Yesilnacar et al. 2012)(Simsek et al. 2014)(Kao and Lin 1996)(Sener et al. 2005)(Ghobadi et al. 2013) studies accept up to 15%. (Aydi et al. 2013) the study is the one that accepts the smallest maximum inclination of 5% whereas (Alavi et al. 2012) study is the most tolerant and accepts a maximum inclination of 45%.

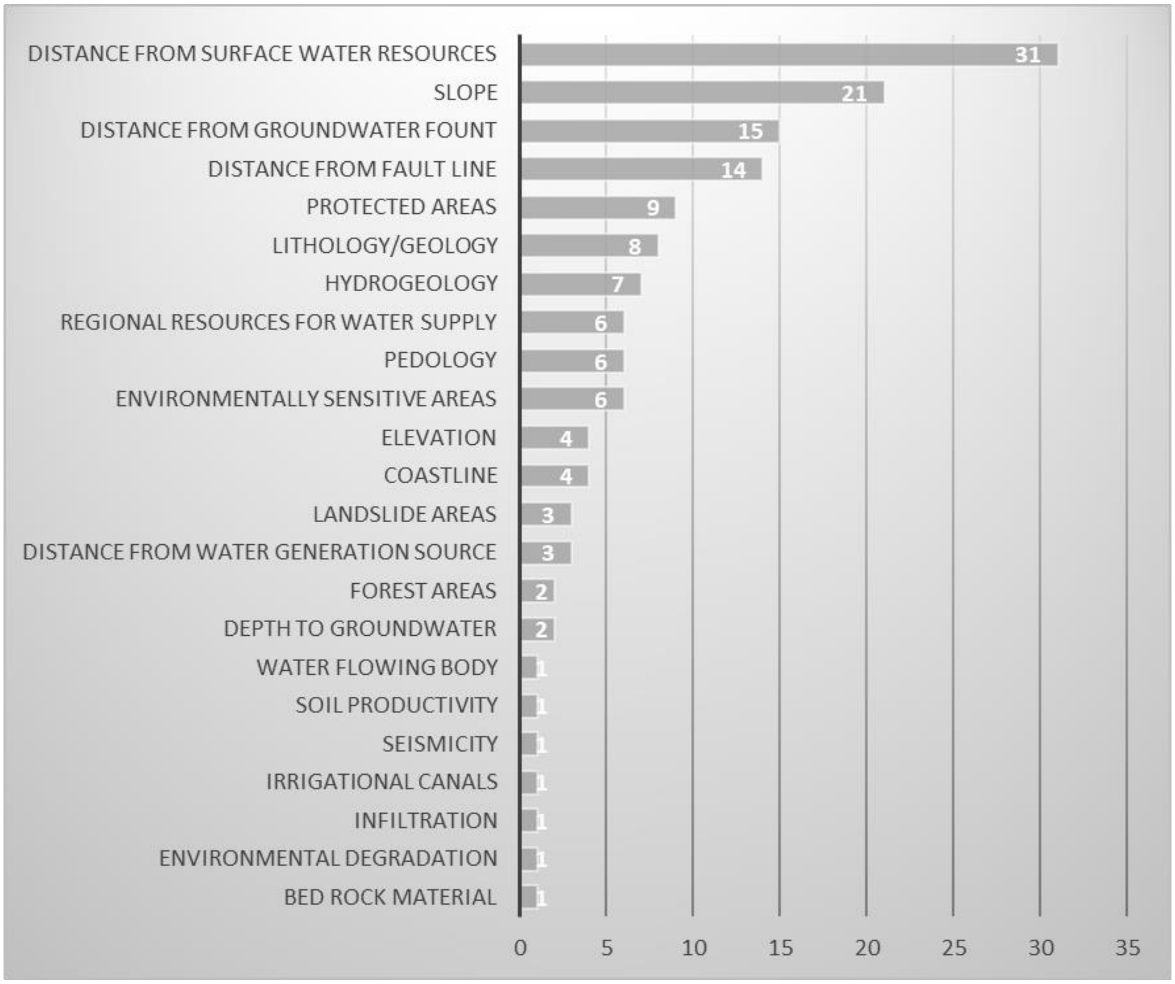

Figure 6 - Environmental criteria

This economical section referred to 15 criteria in the literature. (Figure 7). The frequency of criterion usage score for economical criteria has clearly shown the criterion importance score of usage, where the three most significant economical criteria are roads, airports and power lines, accounting for 21, 15 and 6 articles, respectively, which is imposed from the national/international guidelines. Sixty-six percent (66%) of articles referred to the above criteria. In these studies, 7 out of 15 criteria were applied only once or twice, including oil pipelines (2 articles), size, roads accessibility, the presence of public utilities, power plants, and substations, ownership, average landfill depth. The small score does not mean the criterion is negligible.

According to the literature reviewed, the economic factors are listed as follow:

- Distance from state borders, city boundaries may vary from 1000 to 3000 meters;
- The lower distance from roads may vary from 100 to 200 meters and the highest distance from roads may vary from 2000 to 5000 meters;
- Distance less than 500 meters from railways are unsuitable, except (Baiocchi et al. 2014) which less than 30 meters is considered unsuitable;
- (Baiocchi et al. 2014) describes detailed restrictions for each type of road, for example, landfill sites within 60 m from highways; 40 m from trunk roads; 30 m from intermediate roads; 20 m from local roads; 30 m from railways; 300 m from airports; 200 m from cemeteries;
- Power lines distance vary from 30 to 100 meters. In (Bahrani et al. 2016) study, a distance of less than 500 meters and distance higher than 10000 are considered unsuitable;
- Distance from gas pipelines may vary from 100 to 300 meters;
- Distance from oil pipelines may vary from 75 to 100 meters;
- Distance from highways may vary from 60 to 1000 meters;
- Distance from roads accessibility is specified in (Cheng and Thompson 2016) wich specified 500 meters;
- The ownership and the size of the landfill site are proposed in (Cheng and Thompson 2016), it stats that public land has priority and the size must be equal to or higher than 2 hectares;
- According to (Kontos et al. 2003), the absence of public utilities turns a site unsuitable and average landfill depth lower than 2.5 m3 of waste per m2;

  Distance from industries may vary from 500 meters to 1000 meters;
- Power plants and substations cannot be located 100 meters from landfill site according to (Khan et al. 2018).
- There are works such as (Baiocchi et al. 2014) that describe detailed restrictions for each type of road, for example: landfill sites within 60 m from highways; 40 m from trunk roads; 30 m from intermediate roads; 20 m from local roads; 30 m from railways; 300 m from airports; 200 m from cemeteries.

- Distance from airports varied much in the reviewed articles due to national and international regulations and laws. The smallest required distance is 300 m (Baiocchi et al. 2014), which refers to a landfill site in Italy. The largest distance is mentioned in (Spigolon et al. 2018), which studies a landfill in Brazil and requires a minimum distance of 9000m.

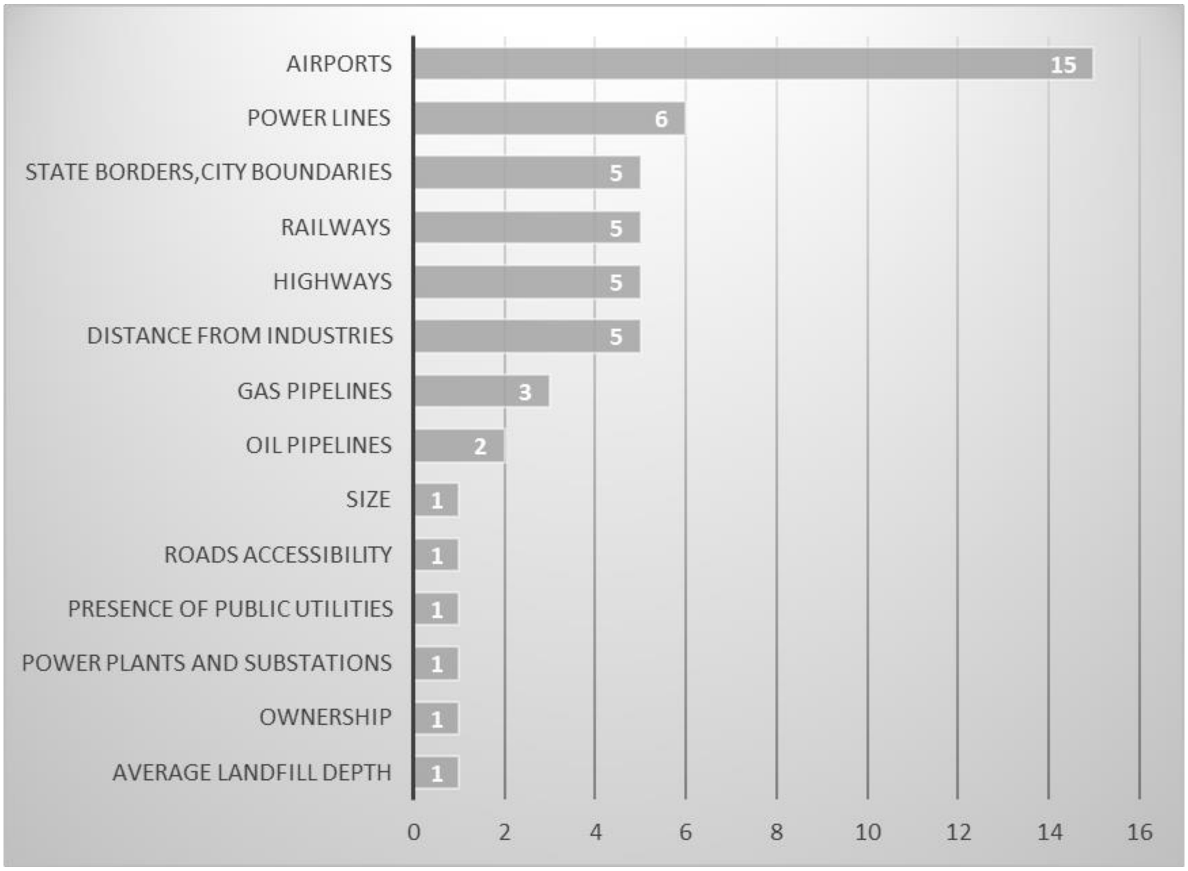

Figure 7 - Economical criteria

This social section referred to nine criteria in the literature as shown in (Figure 8). The four most significant landfill modeling criteria are land use and land cover, which referred to 21 articles, followed by the distance from urban areas (18 articles), cultural heritage or archeological areas (11 articles) and settlements (8 articles). In these studies, five of the total nine criteria were applied only twice to six times, distance from villages, agricultural areas, residential areas, distance from waste generation sources, natural monuments, parks, and recreation areas.

According to the literature reviewed, the social factors are listed as follow:

- The “land use” criterion changes from one article to the other because of each address different regions with a different climate, soil, and, mainly, legislation which allows and prohibits different uses of soil. According to (Chabuk et al. 2016b), (Chabuk et al. 2017), (Aydi et al. 2013) studies, Industrial Area, Urban Centers, Villages, University, Rivers, Archaeological, Agricultural Lands are unsuitable for land use. Other articles include also wetlands, forest, protected areas and settlements as unsuitable for land use;
- Distance from urban areas may vary from 300 to 3000 meters;
- Distance from villages may vary from 200 to 2000 meters;
- Distance from cultural heritage or archaeological areas vary from 500 to 7100 meters;
- Distance from settlements vary from 300 to 1500 meters;
- Distance from residential areas vary from 250 to 1000 meters;
- Natural monuments, parks and recreation areas must have more than 500 meters from the landfill.

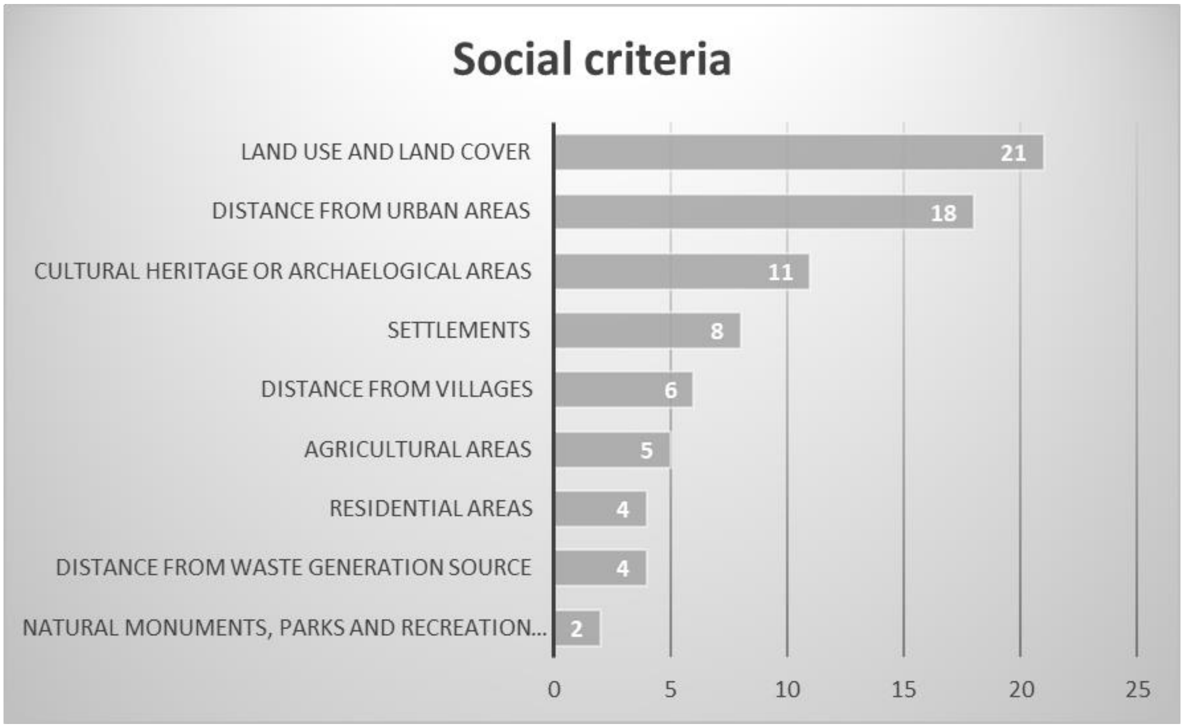

Figure 8 - Social criteria

3.5 Conclusions

A comprehensively surveys literature conduct related to the developments of 40 landfill models and their procedures in the past 22 years (from 1996 to 2018) reflects the growing awareness of this research scope. 47 criteria were found in previous works to evaluate land for landfill modeling given different importance levels. In addition, the different criteria list derived from previous models are justified by data availability, which is related to the application area and is suitable for landfill policies.

The varied frequency in the input criteria of previous models reflects an imbalance in the determination of criteria in landfill modeling and limitation. This imbalance causes miscalculations and other issues. In addition, this result means that differences in the input criteria increase the cost of search procedures for new landfill sites.

Environmental, economic and social criteria were identified in the literature. The most mentioned criteria were summarized here. The most (75 % of the total) mentioned environmental criteria are the distance from source water resources, slope, distance from groundwater fount, distance from the fault line, protected areas, lithology/geology, and hydrogeology. The most (66 % of the total) mentioned economic criteria are roads, airports and power lines. The most (73% of the total) mentioned social criteria are land use and land cover, distance from urban areas, cultural heritage or archeological areas and settlements.

4. CONSIDERAÇÕES FINAIS

Este relatório apresentou o progresso do projeto de iniciação científica intitulado “Caracterização dos resíduos sólidos urbanos (RSU) dos municípios paulistas por setor censitário”, desenvolvido pela bolsista Anna Isabel Silva Loureiro, no período de março a julho de 2018.

No início de 2018 identificou-se a necessidade de se analisar os critérios restritivos que interferem na localização e construção de áreas para aterros sanitários no Brasil e no mundo. Para isso foi realizada uma revisão bibliográfica sistemática das restrições e suas classificações dentro de três vertentes: ambiental, social e econômico. Essa revisão permitiu avaliar os fatores de restrições mais comuns utilizados no mundo e principalmente identificar os valores de restrições para cada um dos critérios, resultando na elaboração do artigo cientifico aqui apresentado.

Estas informações serão de extrema importância para a próxima etapa do trabalho que será mapear as áreas restritivas para localizações de aterros sanitário em duas escalas diferentes uma regional, tendo como área de estudo o estado de São Paulo e outra mais abrangente tendo como área de estudo o Brasil.

Para que a bolsista possa concluir as últimas etapas da elaboração do artigo aqui apresentado e dar continuidade nos demais objetivos propostos, solicita-se a renovação do período desta bolsa de iniciação cientifica por mais um ano.

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