MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

CARACTERIZAÇÃO DOS RESÍDUOS SÓLIDOS URBANOS DOS MUNICÍPIOS PAULISTAS POR SETOR CENSITÁRIO

Anna Isabel Silva Loureiro

Relatório final de Iniciação Científica do programa PIBIC orientada pelo Dr. Pedro Ribeiro de Andrade Neto e coorientada pelo Dr. Victor Fernandez Nascimento. PROJETO: 800353/2018-8 / PROCESSO: 129379/2019-0

INPE
São José dos Campos
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RESUMO

O aumento da urbanização e populacional, a industrialização e o estilo da produção em massa e do descartável, são os grandes responsáveis pelo aumento da geração de resíduos sólidos urbanos (RSU). Aterros sanitários são uma opção segura para a destinação final desses RSU, por serem áreas especialmente preparadas com o objetivo de minimizar impactos ambientais, além de evitar danos à saúde pública. A identificação apropriada da localização dos aterros sanitários pode evitar efeitos indesejáveis a longo prazo. Porém, encontrar novas áreas para a implantação de aterros sanitários está se tornando cada vez mais difícil devido à crescente conscientização ambiental, legislações rigorosas e oposição política e social. Sabe-se que adotar fatores ambientais restritivos é importante para evitar a contaminação dos recursos naturais, assim como adotar fatores socioeconômicos é necessário para reduzir os custos financeiros e a oposição pública. Neste trabalho foram elaborados cenários de restrições para o estado de São Paulo considerando as legislações dos Estados Unidos (US), Europa (EU), Brasil (BR) e World Bank (WB). Observou-se, dentre as quatro legislações analisadas que as leis do BR, WB, EU e US estão ordenadas da maior para a de menor restrições, e se adotadas restringem aproximadamente 56%, 37%, 31% e 12% do território paulista. Se considerarmos a legislação brasileira, que é a mais restritiva em comparação com as outras restrições, o critério adotado mais restritivo é distância de aeroportos. Além disso, foram elaborados cenários para o estado do Rio Grande do Sul, considerando essas mesmas legislações, faltando apenas os dados espaciais "distância de áreas alagadas" e "declividade máxima" para ter uma análise completa também para esse estado. Este tipo de análise espacial permitiu comparar quais legislações internacionais ou nacionais são mais ou menos rigorosas para a implantação de aterros sanitários, bem como qual a porcentagem do território do estado de São Paulo onde a construção dos aterros é proibida. Estas informações serão de extrema importância para a próxima etapa do trabalho, que será mapear os aterros já existentes a fim de verificar se estão localizados em áreas permitidas para esse tipo de estabelecimento.

Palavras-chave: resíduos sólidos urbanos, aterros sanitários, áreas restritivas

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BR – Brasil

EU – Europa

GIS - Geographical Information System

IBGE – Instituto Brasileiro de Geografia e Estatística

INPE - Instituto Nacional de Pesquisas Espaciais

RSU - Resíduos Sólidos Urbanos

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

SIG - Sistema de Informações Geográficas

WB – World Bank

SW – Solid Waste

US - Estados Unidos

WB – World Bank

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 agosto de 2019 a julho de 2020.

Neste período do projeto foi dada continuidade as pesquisas das legislações dos Estados Unidos (US), Europa (EU), Brasil (BR) e World Bank (WB) que tratam das restrições para a construção de aterro sanitário, adicionando novas restrições encontradas. Com os resultados dessa pesquisa, oito restrições foram selecionadas, são elas distância de centros urbanos, distância de recursos hídricos, distância de unidades de conservação, distância de aeroportos, distância de rodovias, declividade máxima, áreas alagadas e distância de falhas geológicas. Foram escolhidos como área de estudo o estado de São Paulo para espacializar os dados restritivos encontrados nas legislações. Para isso realizou-se uma busca por bases de dados espaciais a fim de determinar a porcentagem do território do estado que é restrita e na qual se pode construir aterros sanitários.

Com os resultados obtidos a partir de uma nova revisão das legislações e busca por novos dados espaciais foram feitas alterações nas restrições, levando a uma nova porcentagem de área imprópria que foi apresentado no artigo científico escrito em inglês no qual encontra-se na íntegra nesse relatório no Capítulo 3. Também foram elaborados alguns mapas para o estado do Rio Grande do Sul, estes encontram-se no capítulo 4.

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 período da pesquisa e que documenta o trabalho realizado. O Capítulo 4 apresenta os mapas, elaborados até o presente momento, tendo como área de estudo o Rio Grande do Sul. Por último, o Capítulo 5 apresenta as considerações finais deste relatório seguido pelas referências utilizadas ao fim deste documento.

2. OBJETIVO

2.1 Objetivo geral

O objetivo principal desta pesquisa foi identificar as áreas impróprias para construção de aterros sanitários a nível estadual, utilizando os dados de legislações de quatro países diferentes, tendo como área de estudo o estado de São Paulo.

2.2 Objetivos específicos

1. Analisar nas bibliografias nacional e internacional as restrições de acordo com os aspectos ambientais, econômicos e sociais que podem impedir a construção de um aterro sanitário;

2. Espacializar os resultados das restrições a nível estadual;

3. Analisar qual legislação é mais restritiva

4. Analisar se os aterros sanitários já existentes estão dentro de áreas permitidas

3. ARTIGO

Spatial assessment of landfill sites restrictions using Brazilian, European, North American and World Bank law in São Paulo state, Brazil

Introduction

Defining areas for landfill sites is an important issue due to the urban population growing, the decreasing of land availability due to the growth of urban areas and social, economic and environmental restrictions, and the increase in waste generation. The world

generates about seven to ten billion tons of solid waste (household, commercial, industrial and civil construction waste) per year (UNEP ISWA 2015) From this amount, two billion tons per year corresponds to municipal waste and this rate increases in line with population growth. These information's can be a problem, considering that two billion people do not have regular access to solid waste collection (Fracalanza and Besen 2016).

Both collection and the final disposal are of extreme importance, for that, each country has its own laws and regulations for landfill sites to cope with their needs and geographical characteristics. This study analyses the legislation from United States (US), Europe (EU), World Bank (WB), those were the chosen legislation because EU and the US have similar climatic, environmental, social and economic characteristics, however different from the Brazilian, also in 2018, 79 million tons of solid waste were generated in Brazil, of which 92% (72.7 million) was collected (ABRELPE 2019).

In Brazil, proper disposal in landfills received almost 60% of all municipal solid waste collected. The remainder, 40% was dumped in inappropriate places by 3,001 cities more than half of all Brazilian municipalities. In other words, 29.5 million tons of MSW ended up going to dumps or uncontrolled landfills, which do not have a set of systems and measures necessary to protect the people's health and the environment against damage and degradation (ABRELPE 2019).

The WB is an international financial institution, one of the world's largest sources of funding and knowledge for developing countries, since Brazil is a developing country it can borrow from the WB if its restrictions are similar, that was the criterion of choice. With this study there is an intention to see if the laws adapt or look like each other.

The restrictions for landfill sites were applied for Sao Paulo state, in Brazil. This was the chosen state for this study because it is the most populous state in the country, with approximately 21.7% of the total, being the highest concentration of economic activities of the country (Dalmo et al. 2019), it represents almost one third of the Brazilian GDP (31.5%) (IBGE 2019).

To define which areas in the state are suitable or unsuitable for landfill sites were used Geographic Information System (GIS). Geoprocessing is an important tool to optimize the municipal performance due to the steps of data collection, problem diagnosis, decision

making, planning, design execution of actions and measurement of results. In general, knowing where problems occur and being able to visualize them spatially facilitates their understanding greatly and shows us the possible solution if not the only one (Cordovez 2002).

This paper is organized as following. This Introduction section is followed by a literature review, then the study area is defined and the study method is described in further detail. Results are then presented and discussed, followed by conclusions.

Review of Literature

Finding areas for landfills using GIS

One of the powerful methods for the selection of suitable landfill sites involves the use of GIS (Aksoy and San 2017). Applying GIS for landfill siting process includes selection of objective zone exclusion processes according to a set of provided screening criteria, zoning and buffering, handling and correlating large amounts of complex geographical data, and visualization of the results through mapping and graphical representation (Cheng and Thompson 2016). Soroudi et al. (2018) analyzed the restrictions for the construction of a landfill in the southeast of Tehran province, in Iran and concluded that 71% is unsuitable, Khan et al. (2018) analyzed the restrictions for the construction of a landfill in Alberta, Canada, and the constraint screened out 45% of the total study area. Yıldırım and Güler (2016) analyzed the restrictions for the construction of a landfill in Mersin province in Turkey and 84% of the study area was classified as unsuitable. Gbanie et al. (2013a) analyzed the restrictions for the construction of a landfill in Bo, Southern Sierra Leone, and 83% of the study area was considered unsuitable. Eskandari et al. (2012) analyzed the restrictions for the construction of a landfill in Marvdasht city, Iran and 87% of the study area was classified as unsuitable.

Review of laws and regulations for landfill site selection

The laws and regulations for landfill site selection used in this study are shown in (Table 01).The US restrictions for landfill site selection were written in 1993, were found in (US EPA 1993) and contains all US criteria used in this study, the BR restrictions were found in three different laws (ABNT 1997; CONAMA 2010; BRASIL 2018), the first one was written in 1997 and presents three Brazilian criteria used in this study, the second law is about protected forest and was written in 2010 and last one was written in 2018 and involves airport restriction, the EU restrictions were taken from (Mutz and Oeltzschner 1994), it was written in 1994 and contains all European restriction used in this study. The WB restrictions are from (Cointreau 2004), it was written in 2004 and contains all WB's restriction criteria for landfill site selection. From now on, they will be called "regulations".

Table 1 - Regulations and laws for landfill site selection

Area	Title	Year
United States (US)	Solid Waste Disposal Facility Criteria: Technical Manual (Sub-B: Location Criteria Chapter 2 EPA/530-R-93-017.)	1993
Brazil (BR)	NBR13896/1997	1997
	Lei n° 9.985/2000 CONAMA 428/2010	2010
	Portaria COMAER n° 741/GC3/2018	2018
European Union (EU)	Guidelines for an Appropriate Management of Domestic Sanitary Landfill Sites	1994
World Bank (WB)	Sanitary Landfill Siting and design Guidance	1996 (Updated in 2004)

Methods and study area

Study area

São Paulo state, in Southeastern Brazil, is located between 19º and 25º South latitude and 53º West longitude. It borders the Minas Gerais state to the north, Rio de Janeiro state to the northeast, the Atlantic Ocean to the east, Paraná state to the south, and Mato Grosso do Sul state to the west. São Paulo is the most populous Brazilian state, with approximately 45.5 million inhabitants in 2018 living in 645 municipalities, with a total

area of 248.219,481 km^2 (IBGE, 2018). São Paulo is also the biggest producer of municipal solid waste in Brazil, generating approximately 40.7 thousand tons per day, which are disposed in 612 official municipal solid waste disposal sites (CETESB 2018).

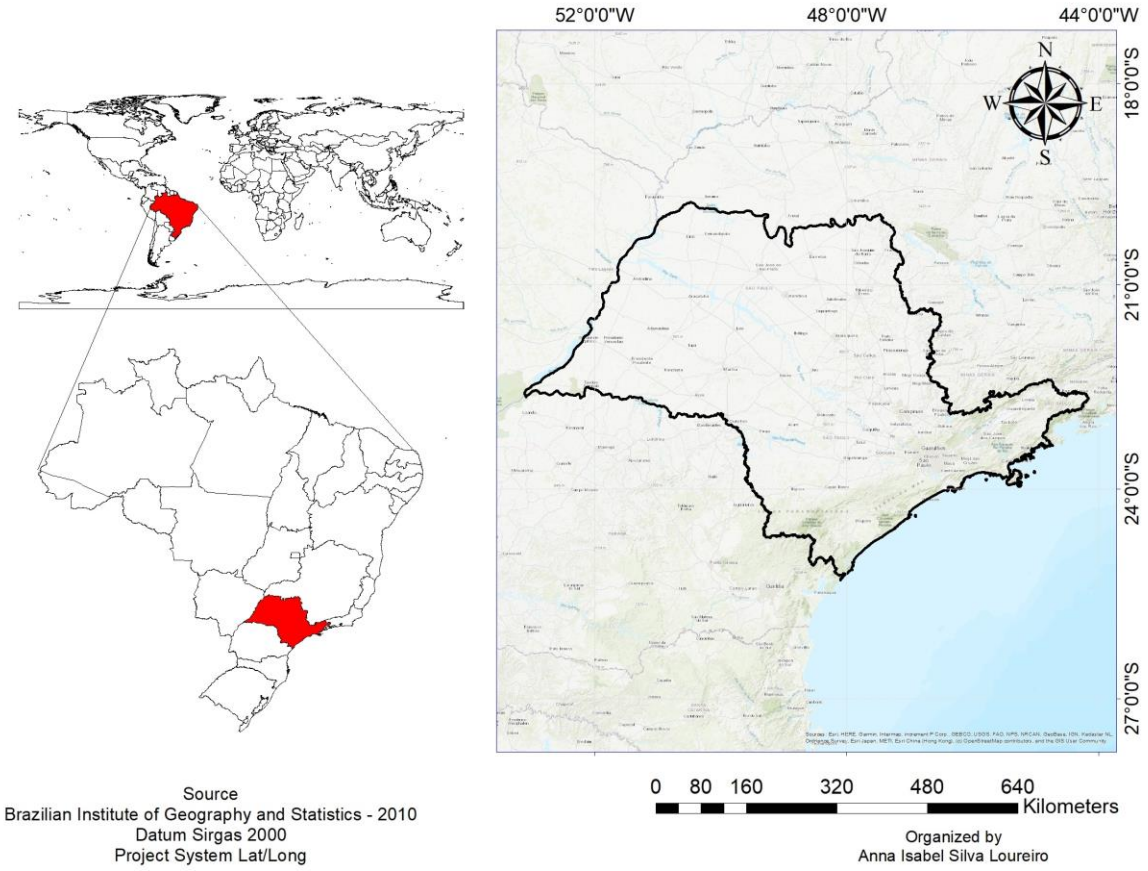

Figure 1 - Map of the state of São Paulo, Brazil

Methods

To spatial assess the landfill sites restrictions we considered four major steps: (1) selection of the most important regulations restrictions for landfill site selection in the world; (2) collection of spatial data and integration into a GIS database; (3) application of each restriction in the study area; and (4) Union of the restrictions according to each regulation (Figure 02). Each step is described as follows.

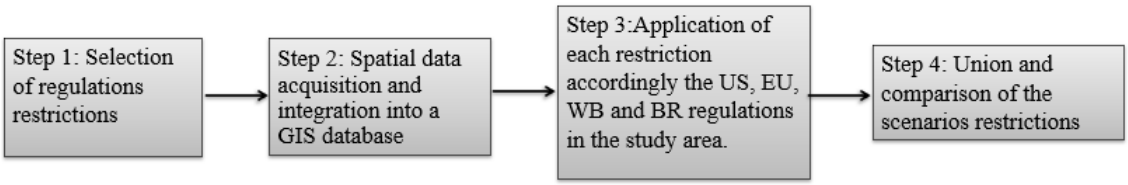

Figure 2- Flowchart of the methodology

Step 1: Selection of regulations restrictions

In this step, the most worldwide important restrictions were selected based on legislations, norms, and guidelines for Europe, United States, Brazil, and World Bank (**Table 02**). A total of eight restrictions were found.

Table 2 - Landfill siting restrictions

Parameter	**Area**			
	US	**BR**	**EU**	**WB**
Distance from residential areas (m)	-	<500	<200	<250
Distance from water bodies (m)	-	<200	-	<300
Distance from protected areas (m)	-	Within areas	Within areas	<500
Distance from airport location (km)	<3	<10	<5	<3
Distance from road line (m)	-	-	>5000	>10000
Maximum slope (%)	-	<1 and >30	-	-
Distance from fault line (m)	<60	-	-	<500
Floodplains	Within areas	Within areas	Within areas	Within areas

It must be said that in the US and in the WB legislations airport restriction says that should not exist siting within 3 km of a turbojet airport and 1.6 km of piston-type airport. Meanwhile, the BR legislation says that new landfills within 10km to 20km from airports

are autorized by CENIPA (Investigation and prevention center for aeronautical accidents) and under 10 km aren´t. In the same topic, EU legislation says that areas nearer than 2-5 km to airport should be excluded. Also, in the WB legislation, the distance from road line should be less than 10 km for large landfills serving metropolitan areas and less than 3 km for small landfills serving secondary cities. In this study the most restrictive values were used and are presented in table 2.

In addition to these restrictions mentioned in table 2, other restrictions are used to decide the landfill site, but those legislation's restrictions were not taken into consideration because there is no spatial data available. In the USA legislation wetlands, seismic impacts zones and unstable areas are also location restriction. In the BR legislation areas with less than 1,5 meters from groundwater line, a soil permeability bigger than 10-6 are also location restriction criteria. In the EU legislation less than 1 meter from groundwater line , karst and areas with soil conditions which allow a fast penetration and permeation of water or possible leachate to the next aquifer, unstable areas, areas with an extreme morphology, historical, religious or other important cultural sites or heritages are also areas considered unsuitable for landfill sites. In the WB legislation areas within the landfill boundaries that are part of the 10-year groundwater recharge area for existing or pending water supply development, wetlands, open areas of high winds, seismic impact zones, siting within 1 km of socio-politically sensitive sites where public acceptance might be unlikely are also areas considered unsuitable for landfill site.

Step 2: Spatial data acquisition and integration into a GIS database

By using GIS, it is possible to assess, store, retrieve and analyze a considerable amount of disaggregated data from various sources and to display the results on maps (Gbanie et al. 2013b; Kallel et al. 2016). Several studies have used GIS to identify areas for new landfills. For example,(Baban and Flannagan 1998) identified suitable areas in UK by using GIS and (Hatzichristos and Giaoutzi 2006) used GIS to find suitable areas in Egypt. Both studies also used a Boolean analysis, which is a form of algebra in which all values are reduced to either 1 or 0. This means that the land is arranged as suitable or unsuitable

for landfills sites (Cheng and Thompson 2016). This study also uses Boolean analysis, considering suitable for land sites all areas without legislation restriction and unsuitable all areas that have any restriction criteria.

The spatial database used in this study was created using a variety of data sources at different scales (**Table 03**). All data layers were stored, projected, manipulated, analyzed, and visualized using ArcGIS version 10.5. The data were georeferenced using the World Azimuthal Equidistant.

Table 3 Spatial data used to create the Boolean restriction for landfill sites in the state of São Paulo, Brazil

Parameter	Sources	Scale or Resolution	Date
Distance residential areas	(Embrapa 2015)	1:250.000	2015
Distance from water bodies	(IBGE 2017)	1:250.000	2017
Distance from protected areas	(MMA 2016)	1:250.000	2016
Distance from airport location	(ANAC 2013)	-	2013
Distance from road line	(Open Streetmap 2019)	-	2019
Maximum slope	(IGC 2010)	1:50.000	2010
Distance from fault line	(CPRM 2006)	1:1.000.000	2006
Distance from floodplains	(SÃO PAULO 2014)	1:50.000 and 1:75.000	2014

Step 3: Application of each restrictions in the study area

Each one of the parameters from all regulations used in this study for landfill site selection were grouped for the US, BR, EU, and WB regulations and intersected into a GIS presented in (Figures 03, 04, 05, and 06), respectively. The specific restrictions values used in this study were assigned considering the spatial data availability and the best spatial resolution for the state of São Paulo. For other Brazilian states or even another region in the world this can change according to the available data and resolution.

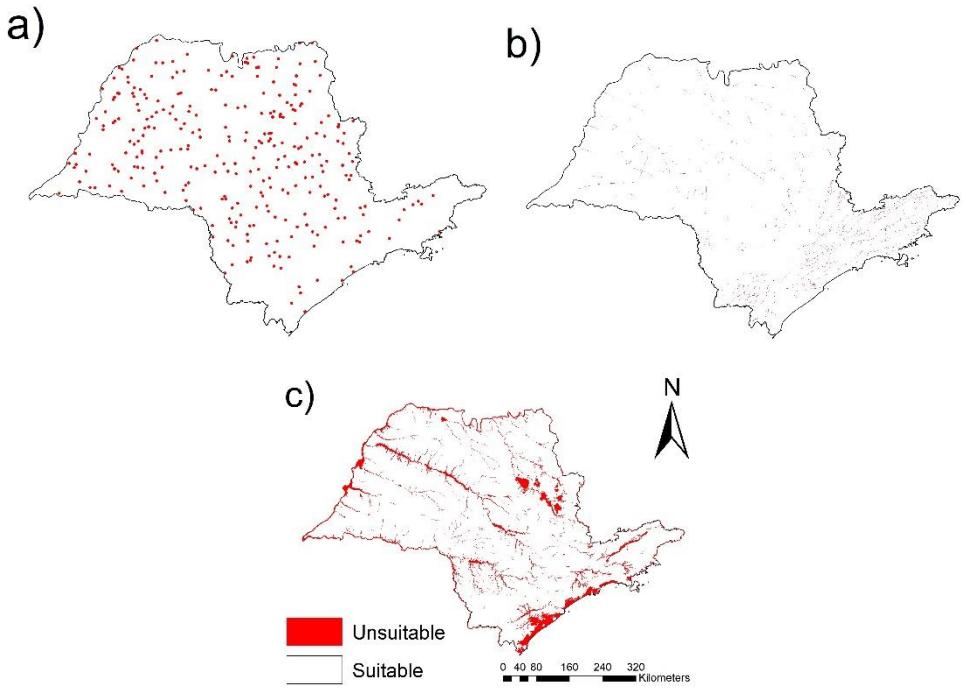

Figure 3 - Maps for each parameter considering the United States regulation for landfill site selection. a) distance from airports, b) distance from faultlines and c) floodplains

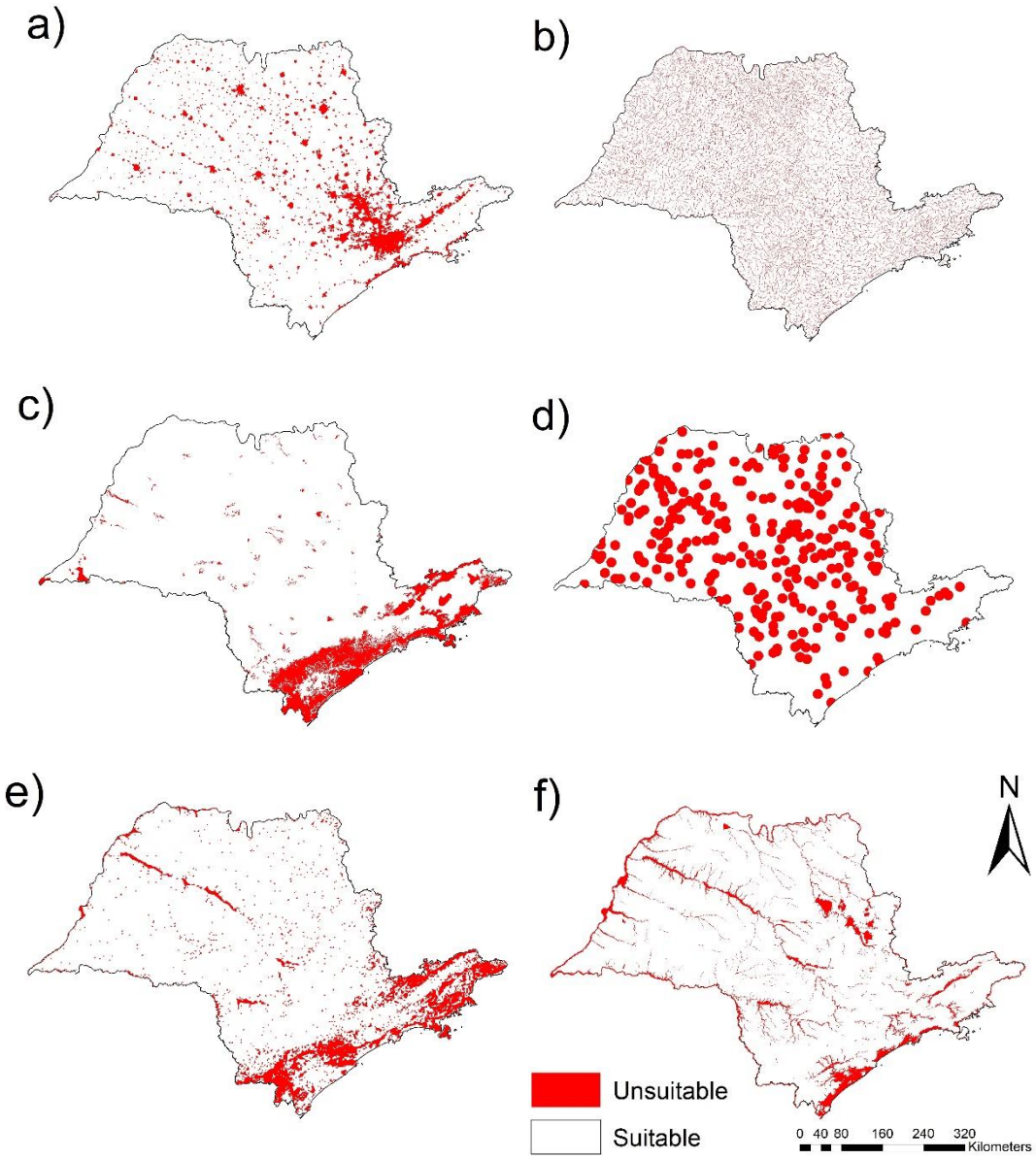

Figure 4 - Maps for each parameter considering the Brazilian regulation for landfill site selection. a) distance from residential areas, b) distance from water bodies, c) distance from protected areas d) distance from airports e) slope and f) distance from floodplains

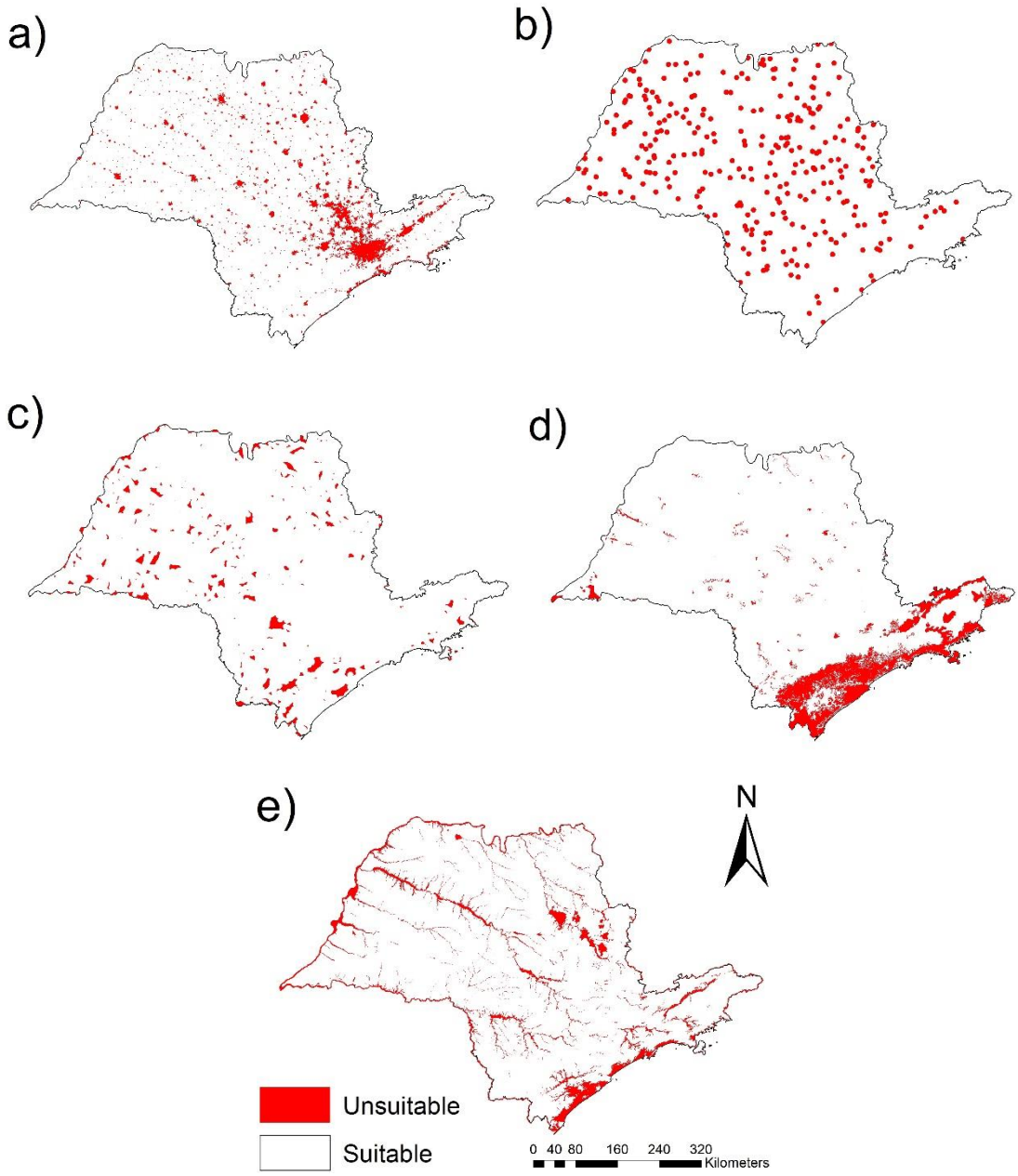

Figure 5 - Maps for each parameter considering the European Union regulation for landfill site selection. a) distance from residential areas, b) distance from airports, c) distance from road line, d) distance from protected areas and e) distance from floodplains

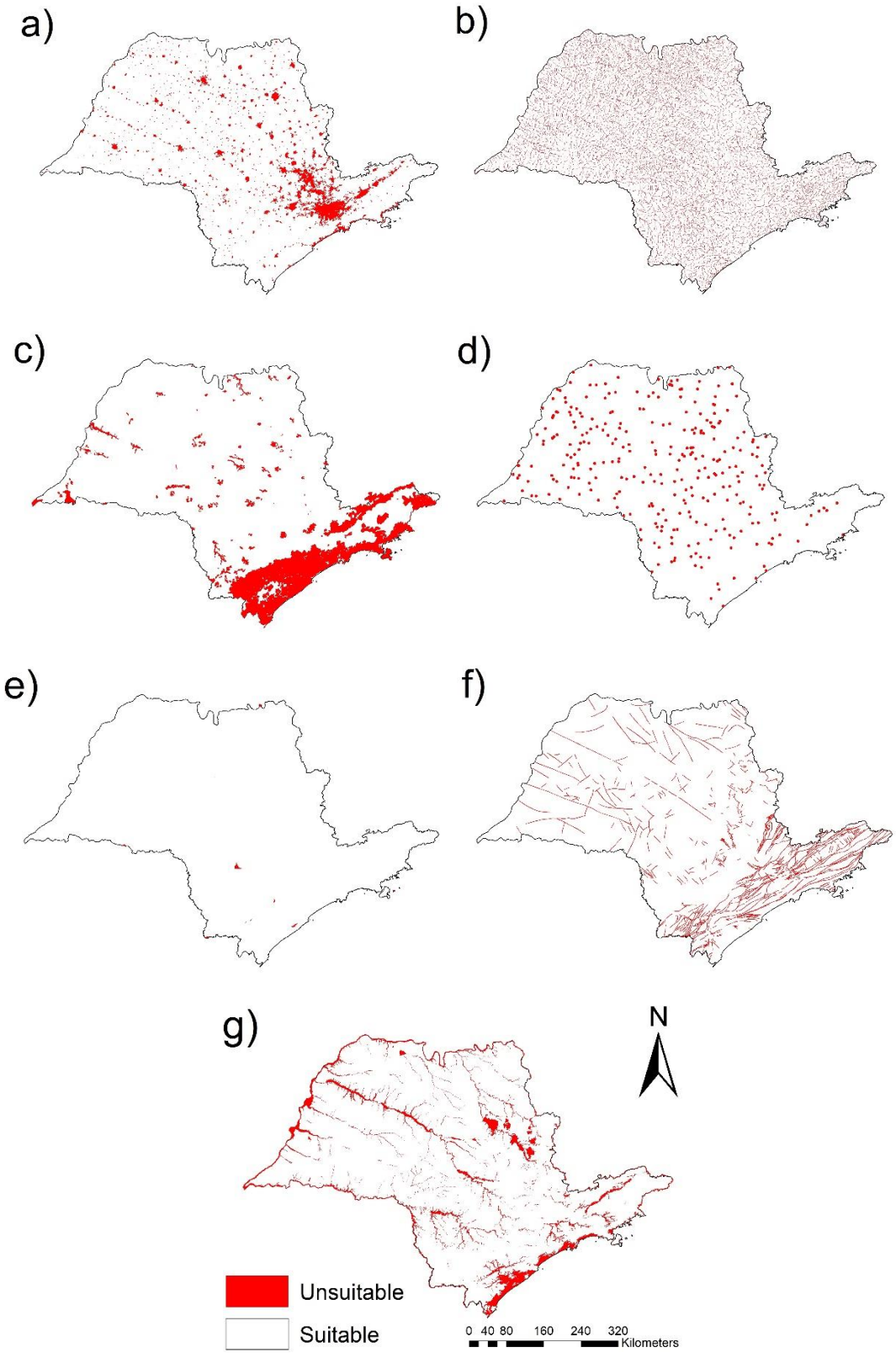
a)
b)
c)
d)
e)
f)
g)
N
Unsuitable
Suitable
0 40 80 160 240 320
Kilometers

Figure 06 - Maps for each parameter considering the World Bank regulation for landfill site selection. a) distance from residential areas, b) distance from water bodies, c) distance from protected areas, d) distance from airports, d) distance from airports, e) distance from road line, f) distance from faultlines and g) distance from floodplains

Step 4: Union and comparison of the restrictions

In order to conduct the spatial analysis for the landfills sites, all EU, US, BR and, WB restrictions regulation were merged, and the assessment were conducted for each one of the landfills. Spatial analysis was performed by overlaying the restrictions aspects with the landfill locations in the state of São Paulo. Considering the results analysis, for cases where just part of the landfill area was considered restrict the entire landfill was classified as restricted, this methodology was selected for a conservative analysis.

Results

Restrictions Analysis

United States regulation scenario

The results of the United States regulation restriction scenario for landfill sites in São Paulo state is presented in (**Figure 07**). The found area for each restriction is included in (Erro! Fonte de referência não encontrada.**)** and can be visualized in (**Figure 03**).

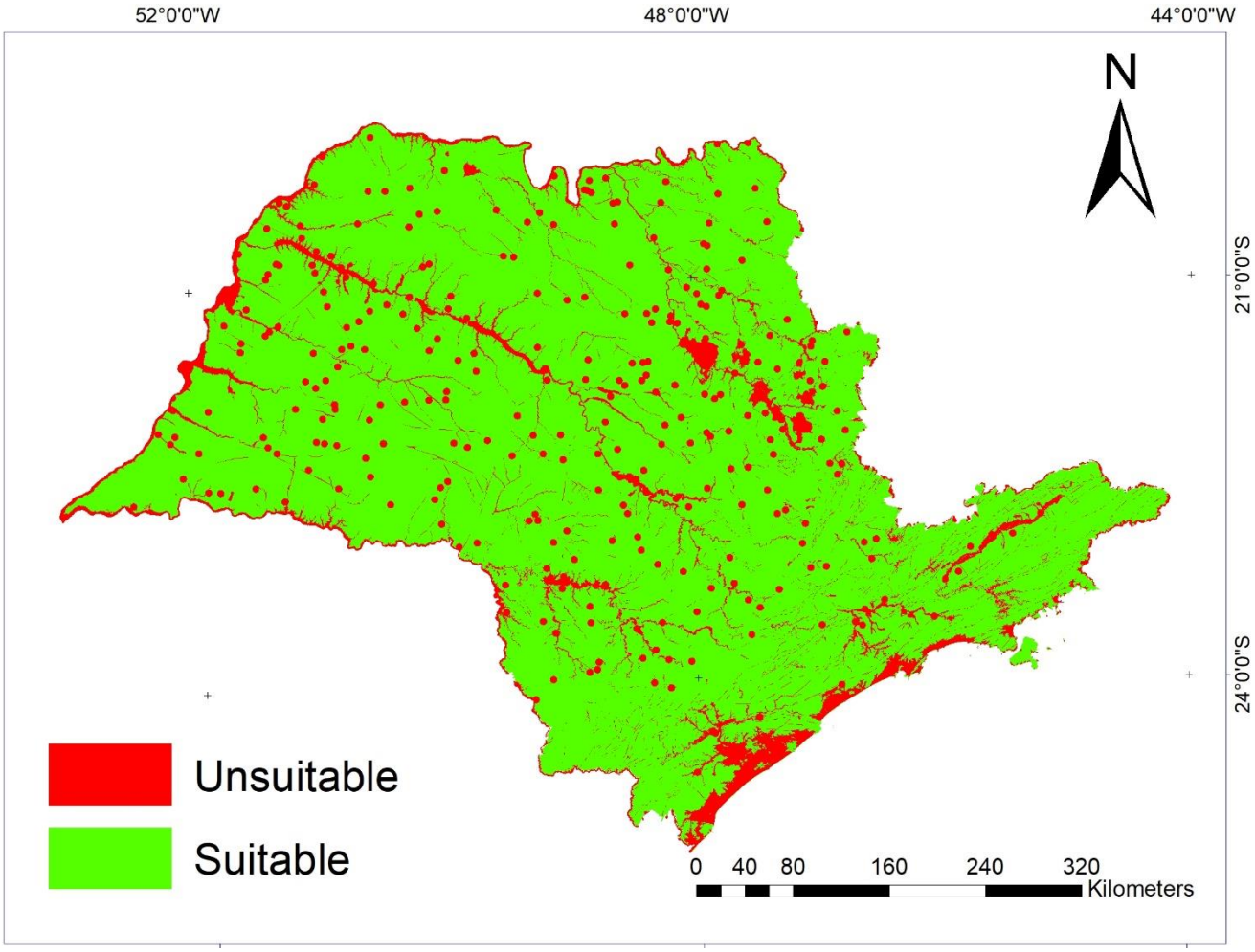

Figure 07 – United States landfill restrictions scenario applied to São Paulo State

Table 04 – Landfill restriction areas using United States regulation

Restriction	**Areas with restriction**		**Areas without restriction**	
	km²	**%**	**km²**	**%**
Distance from airport	8246,8	3,3	239972,6	96,7
Distance from fault line	1734,6	0,7	246484,8	99,3
Floodplains	20272,7	8,2	227946,7	91,8
Total	29524,4	11,9	218695,0	88,1

The red spots in Figure 07 refer to the unsuitable areas for landfill sites in São Paulo state according to the United States regulations. These areas were obtained by using only the three restrictions “distance from airport”, “distance from fault line” and “distance from floodplains”. It was observed that the restriction “distance from fault line” represents less than one percent of the unsuitable area. On the other hand, the unsuitable area for landfill siting related to the “distance from airport” and “distance from floodplain restriction covers more than 11% of the São Paulo state territory. Applying the United States regulations provides for São Paulo state approximately 12% of unsuitable area for landfill siting. It is important to say that the total is less than the sum of the areas because the same area can be part of different restrictions and it is necessary that it be added to the total area only once.

European regulation scenario

The results of the European regulation restriction scenario for landfills sites São Paulo state is presented in (**Figure 08**). The found area for each restriction is included in (**Table 05)** and can be visualized in (**Figure 05**).

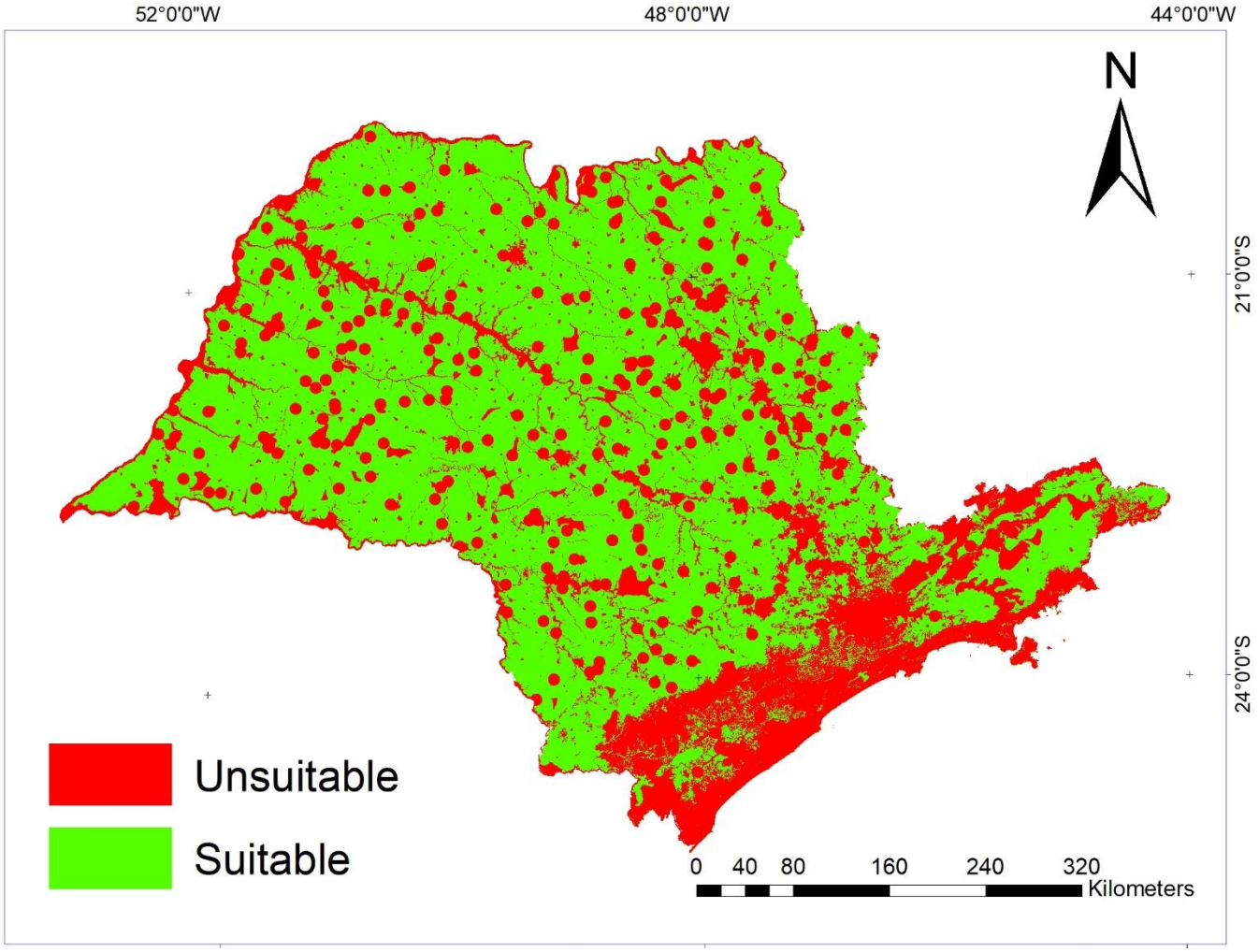

Figure 08 – European landfills restrictions scenario applied to São Paulo State

Table 5 – Landfill restriction areas using European regulation

Restriction	**Areas with restriction**		**Areas without restriction**	
	km²	**%**	**km²**	**%**
Distance from residential areas	14959,83	6,02	233259,651	93,98
Distance from airport location	22059,68	8,89	226159,801	91,11
Distance from road line	8398,266	3,38	239821,215	96,62
Distance from protected areas	25127,5045	10,12	223091,9765	89,88
Floodplains	20272,74	8,17	227946,741	91,83
Total	77077,4	31,05	171142,081	68,95

The red spots in Figure 09 refer to the unsuitable areas for landfill sites in São Paulo state according to European regulations. These areas were obtained by using five restrictions, it was observed that "distance from road line" contributed with 3%, "distance from residential" contributed with 6% of unsuitable area, "distance from floodplains" contributed with 8% "distance from airport location" contributed with 9% and "distance from protected area" contributed with 10%. According to European regulation, a total of 31% of the São Paulo state area is considered unsuitable for landfill siting. It is important to say that the total is less than the sum of the areas because the same area can be part of different restrictions and it is necessary that it be added to the total area only once.

World Bank regulation scenario

The results of the World Bank regulation restriction scenario for landfill sites in São Paulo state is presented in (**Figure 9**). The found area for each restriction is included in (**Table 06**) and can be visualized in (**Figure 06**).

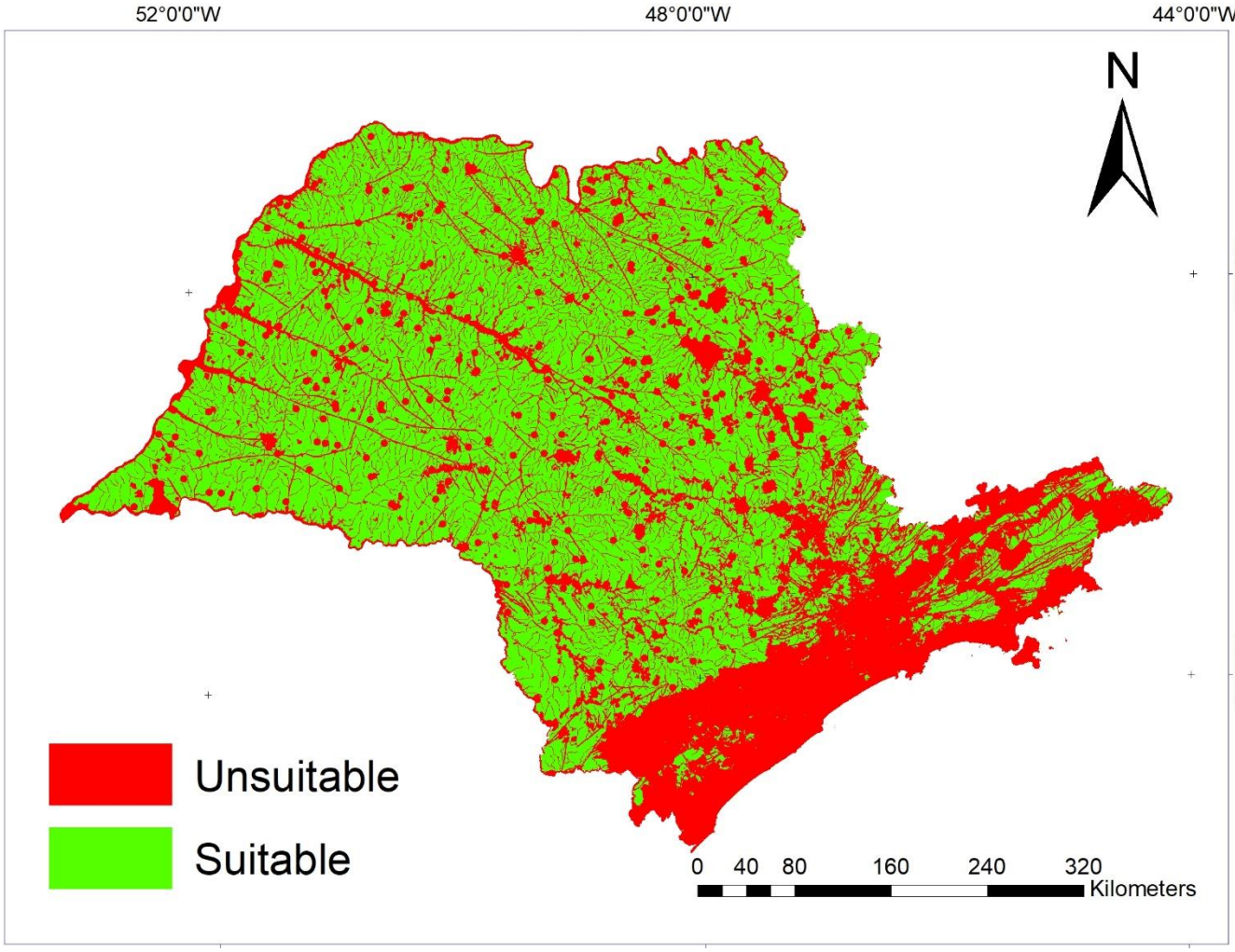

Figure 9 – World Bank landfills restrictions regulation applied to São Paulo State

Table 6 – Landfill restriction areas using World Bank regulation

Restriction	**Areas with restriction**		**Areas without restriction**	
	km²	**%**	**km²**	**%**
Distance residential areas	15906,5	6,41	232312,981	93,59
Distance from water bodies	22651,4	9,13	225568,081	90,87
Distance from airport location	8246,85	3,32	239972,631	96,68
Distance from protected areas	35895	14,46	212324,481	85,54
Distance from road line	240,016	0,10	247979,465	99,90
Distance from fault line	14480,3	5,83	233739,181	94,17
Floodplains	20272,74	8,17	227946,741	91,83
Total	92177,68	37,14	156041,801	62,86

The unsuitable areas for landfill siting in (**Figure 10**) comprise approximately 37% of the total São Paulo state area. For the World Bank regulations, the most relevant restrictions were “distance from water bodies”, “distance from protected areas”, “residential areas” and “distance from floodplains” together contributing to approximately all of the unsuitable areas. The other three restrictions corresponded to about less than 6% each of the unsuitable areas.

Brazilian regulation scenario

The results of the Brazilian regulation restrictions in São Paulo state is presented in (**Figure 10**). The found area for each restriction is included in (**Table 07)** and can be visualized in (**Figure 04**).

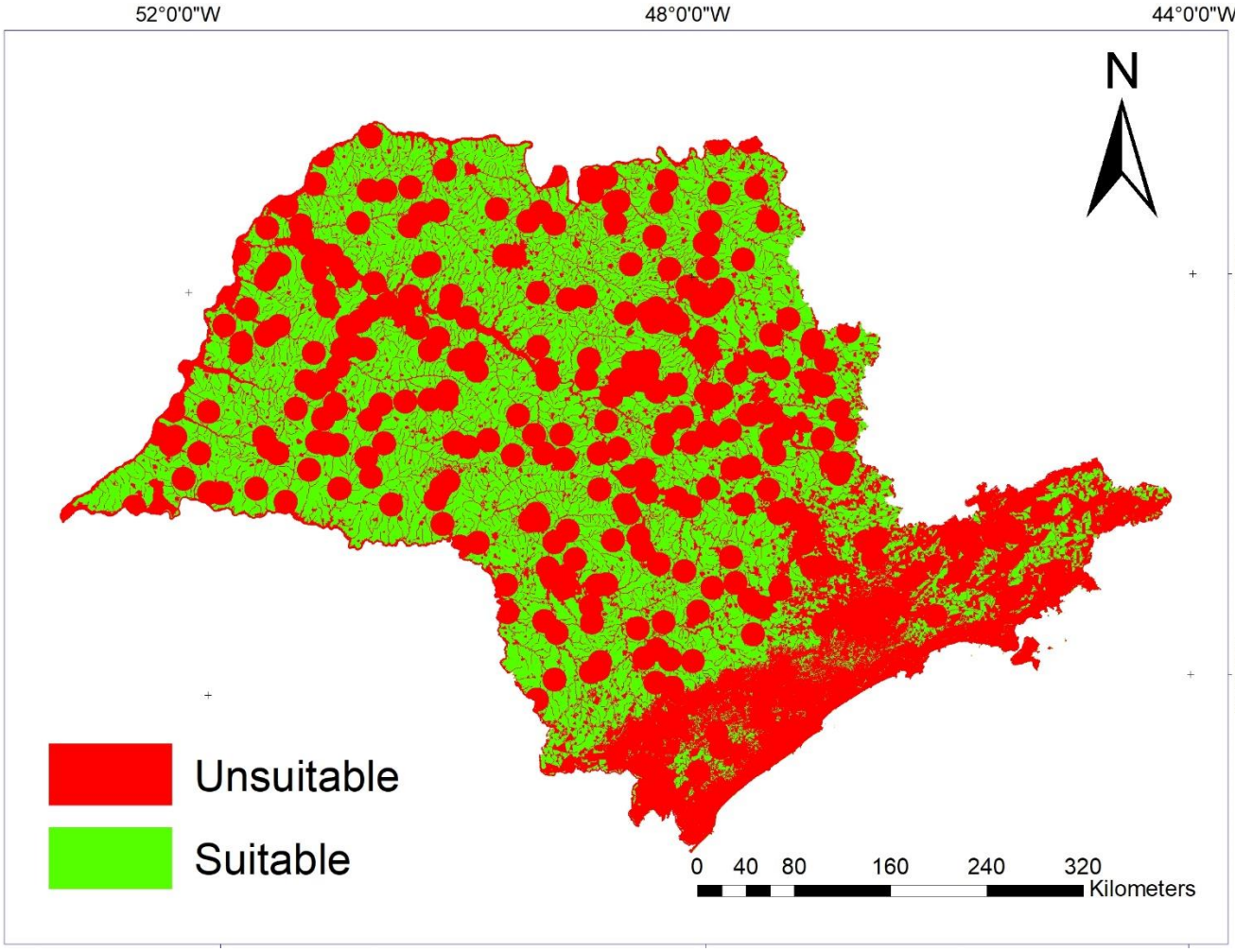

Figure 10- Brazilian landfills restrictions scenario applied to São Paulo State

Table 07 - Landfill restriction areas using Brazilian regulation

Restriction	Areas with restriction		Areas without restriction	
	km²	**%**	**km²**	**%**
Distance residential areas	20629,61	8,31	227589,871	91,69
Distance from water bodies	22651,4	9,13	225568,081	90,87
Distance from protected areas	25127,5045	10,12	223091,9765	89,88
Distance from airport location	75659,87	30,48	172559,611	69,52
Maximum slope	26767,4	10,78	221452,081	89,22
Floodplains	20272,74	8,17	227946,741	91,83
Total	138807	55,92	109412,481	44,08

According to the Brazilian regulation, almost 56% of the São Paulo state is considered unsuitable for landfill siting due to the restrictions “distance from residential areas”, ‘distance from water bodies”, “distance from protected areas”, “distance from airport location” and “maximum slope” and “floodplains”. It was observed that the restriction “distance from airport location” contributes more than 30% of the restricted area. The other five restrictions contributed between 11 to 8% each. It is important to say that the total is less than the sum of the areas because the same area can be part of different restrictions and it is necessary that it be added to the total area only once.

Discussion

BR, EU and US present the restriction “distance from residential areas” but with different values, BR has the most restricted value (500m) and EU the less restricted value (200m).

Only BR and WB presented the restriction “distance from water bodies” and WB has the most restricted value (300m).

The criterion “distance from protected areas” was found in BR, EU and WB legislation, which BR and EU have the same value (within areas) and WB has the most restricted value (500m).

The criterion “distance from airports” were found in all four regulations, the US and WB regulations have the same and the less restricted value (3km), BR presents the most restricted value (10km).

“Distance from road line” restriction was found in EU and WB regulation, and the most restricted is EU (more than 5km from roadlines are considered unsuitable).

The only regulation that presented “maximum slope” as a landfill siting restriction is the BR, that considers unsuitable areas with slope less than 1% and more than 30%.

The criterion “distance from faultlines” was found in the US and WB regulations but with different values, the most restricted is the WB (500m).

The only criterion that all four regulations have and that presents equal values is “floodplains” considering within the areas unsuitable for landfill siting.

Despite the similarities (climatic, environmental, social and economic characteristics), US and EU do not have equal restrictions besides floodplains, and the EU regulation presented 19% more unsuitable areas than the US. Despite the WB having seven restrictive criteria and BR six, BR was more restrictive since it presented 19% more unsuitable areas than WB.

This study presents the importance of spatial data analysis for the restriction scenarios for landfill siting. This type of spatial analysis can help decision makers to promote the mitigation of environmental impacts and assists in the process of identifying areas for new landfills.

Conclusions

In this article we presented the suitable and unsuitable landfill siting areas in Sao Paulo State. The novelty of our study is first to do this spatial analysis for a big region, such as the São Paulo state, and second, to consider different scenarios accordingly different regulations in the same study to compare them. Our findings showed that the United |States

regulations are the less restrictive when compared to the other ones. In increasing order we have United States regulation which presented a restriction with approximately 12% from São Paulo territory, followed by the European (31%), Word Bank (37%) and Brazilian (56%).

4. MAPAS DAS RESTRIÇÕES ESPACIALIZADAS NO ESTADO DO RIO GRANDE DO SUL

A metodologia realizada para o estado de São Paulo, foi replicada para o estado do Rio Grande do Sul, um dos maiores geradores de RSU dos estados da região Sul do Brasil. Nossa intenção é de verificar se os resultados do estado de São Paulo também são validos para outros estados brasileiros. Algumas restrições preliminares já foram espacializadas e se encontram nas Figuras 11, 12, 13 e 14. Por exemplo, a Figura 11 apresenta as restrições "distância de aeroportos" e "distância de falhas geológicas" da legislação dos Estados unidos. Para esta legislação ainda falta encontrar os dados de "áreas alagadas" para obter a porcentagem total do estado do Rio Grande do Sul que é considerado impróprio para a construção de um aterro sanitário.

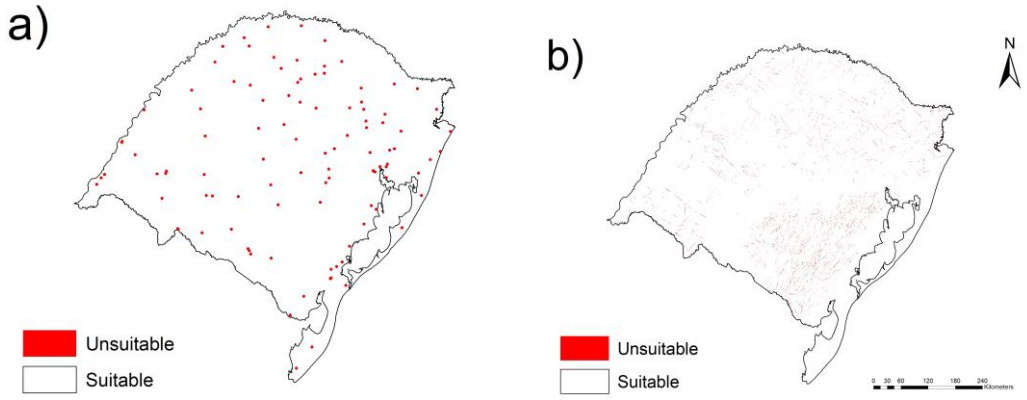

Figure 11 - Maps for each parameter considering the United States regulation for landfill site selection. a) distance from airports, b) distance from faultlines

A figura 12 apresenta as restrições "distância de áreas residenciais", "distância de corpos d'água", "distância de áreas protegidas", "distância de aeroportos" referentes à legislação brasileira. Para obter a porcentagem total da área imprópria do estado do Rio Grande do Sul, para essa legislação, falta encontrar os dados para a restrição "declividade máxima" e "áreas alagadas".

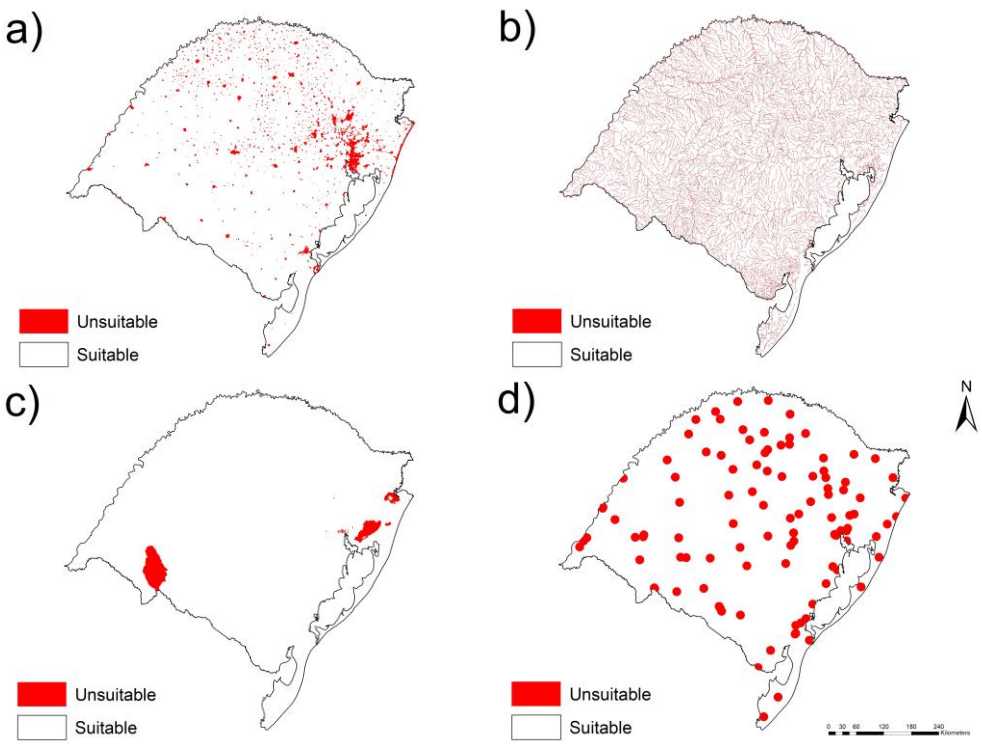

Figure 12 - Maps for each parameter considering the Brazilian regulation for landfill site selection. a) distance from residential areas, b) distance from water bodies, c) distance from protected areas and d) distance from airports

A figura 13 apresenta as restrições encontradas, até o presente momento, da legislação da Europa. São elas “distância de áreas residenciais”, “distância de áreas protegida”, “distância de rodovias” e “distância de aeroportos”. Para essa legislação falta encontrar os dados de “distância de áreas alagadas” para obter a porcentagem total do território imprópria para para a construção de aterros sanitários no Rio Grande do Sul.

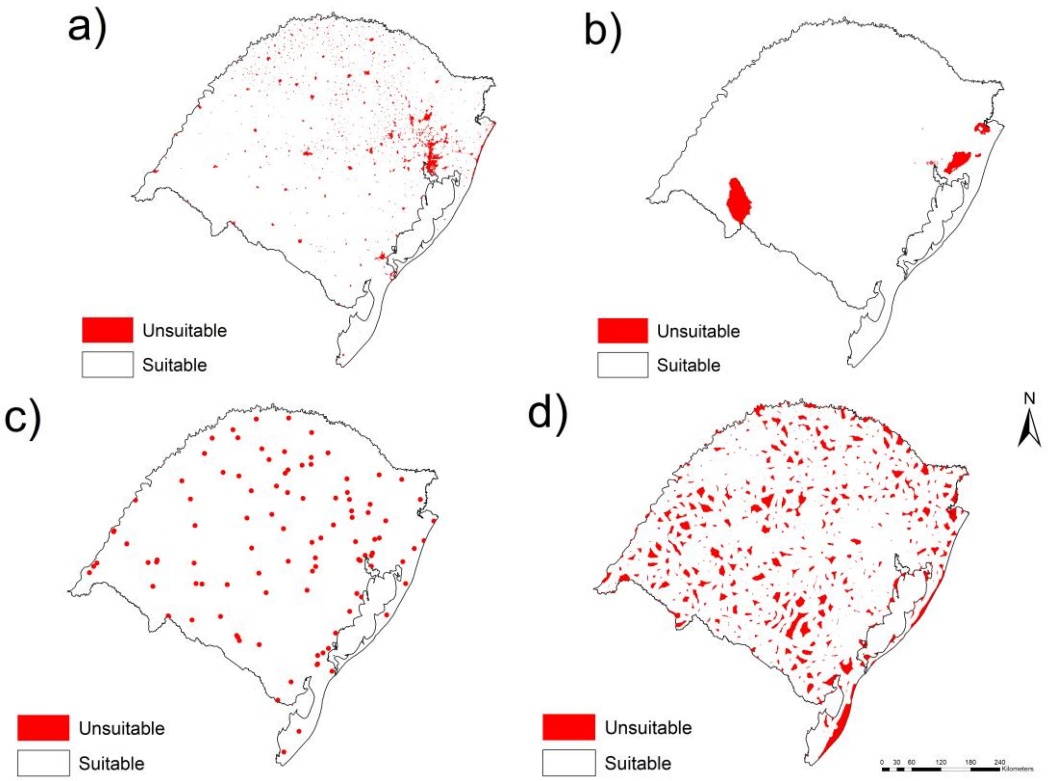

Figure 13 - Maps for each parameter considering the European Union regulation for landfill site selection. a) distance from residential areas, b) distance from protected areas, c) distance from airports, d) distance from road line

A figura 14 apresenta as restrições “distância de areas residenciais”, “distância de corpos d’água”, “distância de aeroportos”, “distância de áreas protegidas”, “distância de rodovias” e “distância de falhas geológicas”, restrições segundo a legislação do World Bank. Para calcular a área total do estado do Rio Grande do Sul para essa legislação falta encontrar os dados da restrição “distância de áreas alagadas”.

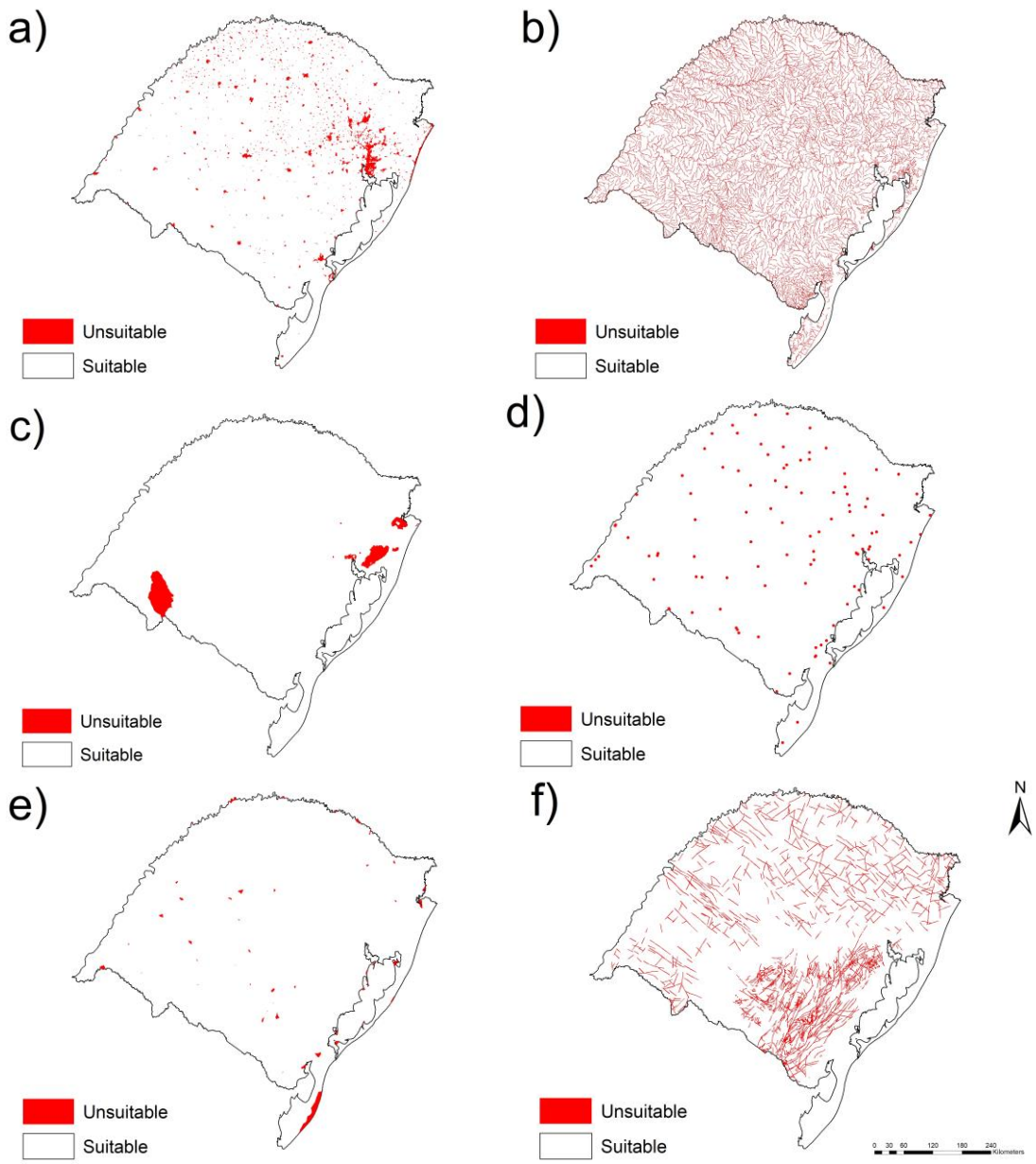

Figure 14 - Maps for each parameter considering the World Bank regulation for landfill site selection. a) distance from residential areas, b) distance from water bodies, c) distance from protected areas, d) distance from airports, e) distance from road line, f) distance from faultlines

5. CONCLUSÃO

Este relatório apresentou o progresso do projeto de iniciação científica intitulado "Caracterização dos resíduos sólidos urbanos (RSU) dos municípios paulistas por setor censitário", neste período foram analisadas as legislações dos Estados Unidos (US), Europa (EU), Brasil (BR) e World Bank (WB) que citam as restrições para a construção de um aterro sanitário. Essas restrições foram aplicadas à área geográfica do estado de São Paulo utilizando SIG. Dependendo da regulamentação escolhida, diferentes porcentagens do território do estado foi considerada inapropriada e apropriada para construção de aterros sanitários. A regulamentação que se mostrou mais restritiva foi a brasileira em que aproximadamente 56% da área de estudo foi considerada inapropriada. A menos restritiva mostrou-se ser a legislação americana, com aproximadamente 12% da área de estudo considerada inapropriada.

Considera-se o método utilizado efetivo para prover uma ferramenta de planejamento urbano. A obtenção, análise e disponibilização de dados espaciais das restrições devem ser objetivos constantes desse processo, bem como o aprimoramento da qualidade dos dados.

Com os resultados obtidos foi elaborado um artigo científico, que foi apresentado no Capítulo 3 e encontra-se em aperfeiçoamento antes de ser submetido. Pretende-se ainda fazer uma análise dos aterros já existentes a fim de verificar se eles estão dentro das áreas consideradas apropriadas para a construção de um aterro sanitário. No Capítulo 4 encontra-se os mapas prévios das restrições espacializadas no estado do Rio Grande do Sul, até o momento. A partir da finalização desses mapas será possível avaliar qual legislação é mais restritiva para esse estado e será elaborado um artigo científico a fim de mostrar a metodologia, o desenvolvimento e os resultados obtidos com essa pesquisa.

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