ANALYSIS OF MINAS GERAIS COUNTIES AS TO THEIR LANDFILLS CONDITIONS

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Abstract

Since 2001, the environmental legislation in State of Minas Gerais, Brazil, foresees that every county or consortium of counties must present a Sanitary Landfill Project, contemplating the appropriate systems of pluvial drainage, liquid effluent collection and gas drainage. The licensing process requires the identification of all areas in the county that were, at some point, used for the disposition of wastes, as well as the description of the measures to be adopted for the recovery of the former landfill area, if the change of the disposal area is foreseen. The use of these measures, although necessary, has been neglected in most of the areas, generating environmental liabilities that are difficult to control and to quantify. Dispersion of the areas raises difficulties to the municipal managers, both to the inspection of the areas in operation and to the checking the efficiency of the required measures to recover the abandoned areas. Analyses of landfill areas processes, which had their activities closed, indicate a low index of implementation of these measures. The costs involved in the total recovery of any of these areas indicate the need of prioritization and systematization of actions. This paper aims at discussing the subject matter of the recovery of areas already degraded. Several techniques have been used as a contribution to the subject matter of recovery of degraded areas, among them, the geoprocessing techniques which, applied to the data available, allows the analysis and obtainment of several homogenous information plans for different areas.

Key-words: geoprocessing, landfill, multi-criteria analysis

Introduction

The inappropriate disposal of urban solid wastes is a considerable source of pollutants propagation. These pollutants may reach the surface or groundwater by direct throwing, precipitation, and flow through the ground surface or infiltration. Leachate, a waste generated in the process of urban solid wastes degradation in urban solid waste disposal areas (Santos, 2004) is a liquid that presents high levels of organic and inorganic contaminant characteristics and, therefore, represents a significant pollution source, whether in large or small urban agglomerations. It should be emphasized that surface and groundwater are, in most of the cases, interconnected. Therefore, a polluted surface fountainhead may cause the pollution of a subterraneous aquifer and vice-verse.

Besides, the USW disposition associates changes caused to ground or to air to water pollution. The waste dragged by the rain and the precipitation of air impurities are also mechanisms of water pollution. The areas occupied by the so-called “landfills” are evidenced by their potential of environmental, sanitary and social damages and require special attention from the society.

Concept

According to IPT/2000, Integrated Management Manual, a landfill is an inappropriate form of final disposal of municipal solid wastes, which is characterized by the simple disposal of wastes in certain areas, without environmental protection measures and protection to public health. It is located in areas with no prior preparation and has no liquid effluent treatment system. They percolate through the ground conducting toxic and contaminant substances to the water table. The absence of any mitigation or control system favors the proliferation of flies, necrophagous birds like vultures, harpies and some types of hawks, besides rats and other small animals that become vectors of pathogenic agents. The presence of trash scavengers, seeking for recyclable materials with economic use, is usually associated to the environmental damage of these areas. However, procedures to avoid negative social consequences, like the social isolation of the scavengers, are not taken. The landfills also present a great impact on the landscaping, and its simples presence causes discomfort and depreciate the adjacent areas. The consequences of the landfills operation remain for several years; Since these areas are usually located in the suburbs, the urban development increases the contamination risks of the populations and the accidents related to the geotechnical instability and emission of gases, even many years after the waste disposal activities at the area are terminated. In Minas Gerais, landfills represent the greatest typological proportion of disposal, both in absolute numbers and in relation to the population served by this form of disposal.

Objective

This paper aims at developing a methodological formatting and an analysis of available data, as a contribution to understanding Minas Gerais counties situation, concerning their landfills, classifying them in levels of risk status, which would enable the decision making to recover most critical areas.

Work methodology

The environmental evaluation tool based on the multi-criteria analyses, considered in literature the most adequate for this subject matter, was chosen, since the data, due to its own nature, try to express relations among values of different degrees. The environmental evaluation was used in this paper to generate a hierarchization map of counties related to the situation of their urban solid waste disposal sites. According to the methodology proposed by Xavier-da-Silva (2001), a Decision Tree was developed

and weights and grades were given to the information plans and each of their legends. To perform the maps algebra, according to the multi-criteria analysis model, all data were converted to *raster* information plans, data matrixes, as from the definition of a bounding rectangle, resolution unit and, consequently, number of matrix lines and columns. After modeling each subject matter unit of the maps, weights and grades were given to the variables, by using the "Delphi" technique, which consists in operating the debate among experts in order to establish a decision making process. The weights given to the variables were due to the risks to the neighboring populations and the environment, caused by the landfills.

Data Analysis of Landfills in operation in the State of Minas Gerais

Based on the information of landfills in operation, a tabular data base was developed, with characteristics relevant to the classification and normatization of the sites.
Figure 1 summarizes the results found, indicating the Counties with landfills localized and not localized through georeferencing.

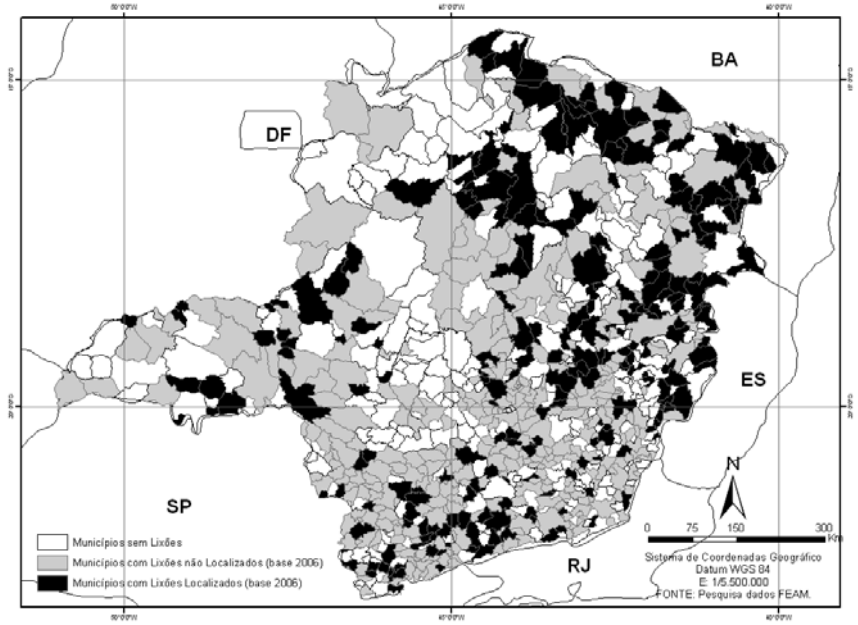


Figure 1. Counties with Landfills in the State of Minas Gerais

Methodology of the information plans definition

Minas Gerais has several data base, either Geominas site or other environmental entities, with potential information on the subject matter of the areas surrounding landfills and their application to municipal level. Other data were obtained through remote sensing, population surveys and compilation of pluviometric stations data. The purpose of this study is to analyze the natural factors and the ones resulting from the anthropic activity, systematically obtained in all the selected counties. Spatial variables

were combined for the territorial characterization or geographic space classification, based on surveys of environmental characteristics conjugation represented on the data base in order to classify the damage caused by the landfills. For this purpose, a numerical calculation to define the combined occurrence of environmental characteristics was made. It was aimed at the development of a logical analysis structure that would incorporate the accomplishment of maps algebra, according to the multi-criteria analysis method, leading to the characterization of USW disposal areas through the environmental evaluation process, supported by the development of a decision tree.

Definition of Natural Factors Definição de Fatores naturais

Natural factors for the analysis are the elements present at USW disposal sites that are perennial and independent from the anthropic actions; as the slope aspects of the sites, their distance from watercourses and the fragility of the subterraneous aquifers within the influence area. It also includes variables related to the hydrologic cycle and their interaction with the site, through water and percolation leached through the ground or its surface flow until receiving bodies.

Definition of anthropic factors

Anthropic factors are the ones that influence the analysis of the USW disposal sites, related to the anthropic activity, such as the daily generation of wastes, the establishment of population around the areas and the consumption, by these populations, of the ground water resources, as well as those determined by law aiming at the protection of natural resources, as the establishment of conservation units.

Preliminary results

After defining the information plans, called Declivity, Distance from Watercourses and Population Centers, Sites interference with the Conservation Units, Daily generation of wastes in the county, Permeability of grounds, Vulnerability of aquifers, Dependence of groundwater (divided in urban and non-urban usage) and intensive precipitation at the USW disposal sites, it was proceeded to the phase of data construction and homogenization to each information plan.

Declivity at the Landfills

In order to measure the declivity at the areas where the landfills are located, data obtained through SRTN orbital sensor, with spatial resolution of 90 m, was used. The declivity map was generated as from the altimetrical data. Declivity classes were determined in the following intervals: Smaller or equals to 30%; and Greater than 30%. Such intervals were chosen based on what is defined by the standardization for the USW disposal site. The data related to declivity of each USW disposal site was given to the county, within the intervals previously indicated. Thus, it was obtained a Table that

indicates which counties have their landfills in areas with declivity smaller than 30%, considered appropriate, and the others, considered inappropriate.

Distance from Watercourses

In order to identify the minimum distance from the landfills to the watercourses, it was used the hydrograph bases supplied by IBGE, which presents the water collection of the whole state of Minas Gerais. For these letters, a covering of 300 meters was generated through the Buffer tool. For the landfills selected in the previous phase, the "distance up to 300 meters from the water collection" information was entered and for the other landfills the "distance above 300 meters from the water collection" information was entered.

Aquifers Permeability and Typology

State of Minas Gerais has high groundwater potential areas in scenarios many times combined with surface water deficit. For the analysis of data related to permeability, SIG GEOMINAS database is used, which describes, at an exploratory level, the distribution of soil spots in the State of Minas Gerais. These typologies were arranged and reclassified according to sand and clay contents present in each one, even considering other characteristics, but always aiming at the permeability analysis of each one and its adequacy to the methodology proposed. As to the aquifers, database according the Groundwater Availabilities Publication in the State of Minas Gerais (COPASA/Hidrossistemas, 1995) was used, which sorts the aquifers in a territorial division of ten systems. The study aimed at analyzing the possibility of aquifer contamination to characterize the landfill areas, with a condition or percolation rate defined by the predominant nature related to recharge factors, redividing these typologies by their general characteristics in confined, semi-confined or free aquifers.

Critical Flows Due to Precipitations at the sites

Data from intense rain information were taken for the 230 counties of the present study analysis universe, for its evaluation per county of the study area. The precipitation zones found were rearranged to low, low to average, average, average to high and high precipitation.

Distance from Population Centers

To check the available distance data from population centers, MODIS sensor data was used, with 250 meters information unit (pixel). For this information, 100, 300 and 500 m buffer were created and the distance information between the urban center and each landfill was transferred to the respective county.

Conservation Units

Instituto Estadual de Florestas IEF 2000 Database, with the indication of 224 conservation units in the state of Minas Gerais was adopted for the interference checking. Then, a cross-checking with the landfills location basis was made, and the interferences identified.

Daily Generation of Wastes

Population data (IBGE, 2000) were used to determine waste generation in each county. Only urban population was considered, since rural population, in most of the cases, disposes its wastes in a disseminated and uncontrolled form.

Uses of Groundwater Resources

IGAM (2009) database, related to 7.839 approved grant processes for regular ground uses, are in cubic meters per hour per collection point. The data were georeferenced, with the creation of specific SIG and synthesized per county to be compared with population data. Besides, supplied data were grouped in urban usages, including public supply, human consumption, industrial consumption and cars washing and non-urban, comprising aquiculture, agro-industrial consumption and use for irrigation.
The information plans generated were unified in aspect Table, comprising the division of these aspects in classes, and framing the nominal scale variables present in ascending or descending order of association possibility with the risk presented by the USW disposal sites. Table 1 presents the classes obtained, as well the weights given to each aspect analyzed.

Table 1. Classification and assignment of weights and grades to aspects

Classification	Information	Source	Classes	Sub – Classes	Grades
Natural Factors	**Distance between Water Collections**	GEOMINAS	Up to 300 meters distant		0
			more 300 meters distant		10
	Declivity	SRTM	more than 30% of declivity		0
			Up to 30% of declivity		10
	Soils Permeability	GEOMINAS	High Permeability	Sandstone Quartz, Fluvic Neosol	0
			High and Average Permeability	Latosol , Litholic Neosol	2
			Average Permeability	Rock Outcrop, Cambisol	5
			Average and Low Permeability	Podzolic	8
			Low Permeability	Reddish Brunizen, Planosol, Humic Gley	10
	Pluviosity – Intense Rain	COPASA	220 - 1160 mm		0
			210 - 220 mm		2
			200 - 210 mm		4
			190 - 200 mm		6
			130 - 190 mm		10
	Types of Aquifers	COPASA	Confined	Sandstone, Carbonatic	1
			Semi-confined/ Covered	Gneissic - Granitic	5
			Free Aquifers	Alluvial, Basaltic, Dendritic Coverage, Pelitic, Carbonatic Pelitic, Dendritic Coverage, Schistose	10
Anthropic Factors	**Distance from Urban Centers**	UFMG	Landfill located in Urban Centers		0
			Landfill located up to 100 meters from urban centers		0
			Landfill located from 100 to 300 meters from urban centers		0
			Landfill located from 300 to 500 meters from urban centers		3
			Landfill located at mores than 500 meters from the urban centers		10
	Conservation Units	IEF	Landfill located in CU		0
			Landfill located outside CU		10
	Dependence of Urban Ground Water	IGAM	> 250 liters/ inhab. x day		0
			75 - 250 liters/ inhab. x day		2
			50 – 75 liters/ inhab. x day		4
			4 - 50 liters/ inhab. x day		6
			0 - 4 liters/ inhab. x day		8
	Dependence of Non-Urban Ground Water	IGAM	> 250 liters/ inhab. x day		0
			75 - 250 liters/ inhab. x day		2
			50 – 75 liters/ inhab. x day		4
			4 - 50 liters/ inhab. x day		6
			0 - 4 liters/ inhab. x day		8
	Wastes Generation	FEAM	Big > 100t/day		1
			Average 15 – 100 t/ day		5
			Small <15 t/ day		9

Source: Author compilation (2008).

As from the mapped information, a raster image was generated for each of the information plans. These Raster maps were used as input data to the Vista SAGA system (LAGEOP – UFRJ) in its Environmental Analysis module. The pixel value used in the generation of all these images was of 800 meters, considered enough, since general characteristics of the counties are transferred to the mapping in order to perform an integrated evaluation of the data, while preserving the accuracy of the information obtained; all of them with pixel values below 800 m.

Decision Tree

A decision tree was developed for the analysis formulation by applying Delphi Method to obtain the weights and grades of each variable. This method is based on the choice of a multidisciplinary specialists group, who know well the phenomenon and, even better, if they know well the spatial reality where it is located. These specialists are required to arrange or put the variables (or information plans) in importance order, concerning the manifestation or phenomenon occurrence studied. Thus, the decision tree was used as an analysis instrument of the relative importance of the parameters used in this construction. It was decided for grouping the information plans, according to their nature.

Natural factors were grouped as follows:

Hydrological Factors – include intense rain on the areas and the soil permeability, which relate to the quantity of water circulating through the massif of waste and generating leachate in the process. Weights of 60% were given for the soils permeability and 40% for intense rains.

Topographic and Geological Factors – gather the data relative to aquifer typology, declivity and distance from water courses, related to the geomorphology of the sites. For these factors, cross-checking was adopted; weights of 50% were given for the distance from water courses, considered preponderant on the others, to which weights of 25% were given.

For *anthropic factors*, the following groupings were adopted:

Location factors – Those related to the landfills location in each county, their interference to Conservation Units and to the distance from population centers. Weights of 70% were given to the distance from population centers and 30% to interference with Conservation Units.

Dynamic or Load Factors – Include the waste daily generation, the urban and non-urban usage of groundwater, grouped for being directly connected to population data and also related to the population activities. Weights of 60 % were given to waste daily

generation, 30 % to urban usage of groundwater and 10 % to non-urban usages. The results are found in Figure 2.

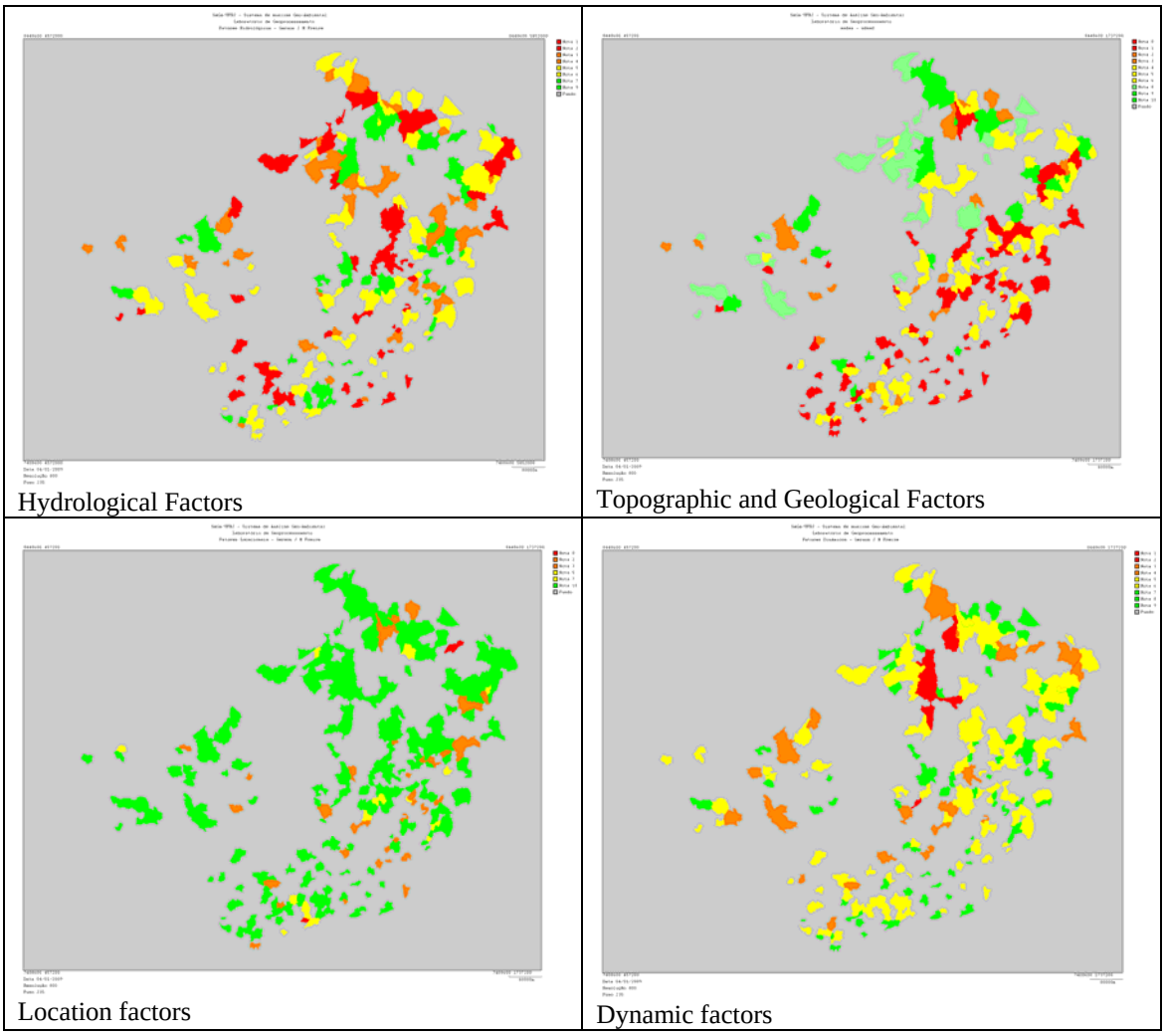
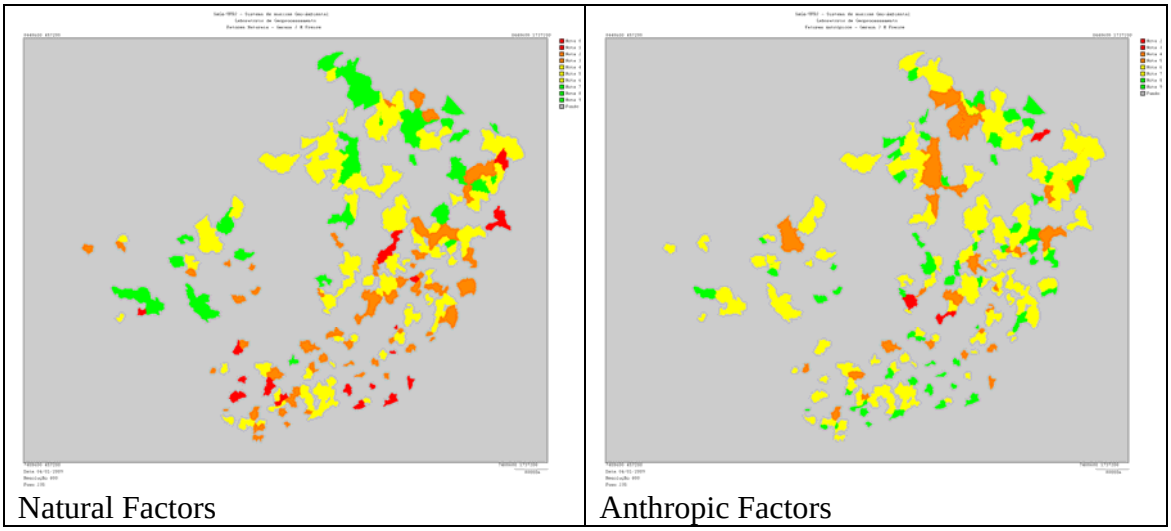


Figure 2. Mapping of factors

After the factors described above were calculated, they were regrouped in natural Factors, including Topographic /Geologic and hydrologic Factors, and Anthropic Factors, comprising Location Factors and Dynamic/Load Factors. For the natural factors, weights of 60% were adopted for the Topographic / Geological Factors and 40% to Hydrologic Factors. For Anthropic Factors, weights of 30% were given to Location Factors and 70% to Dynamic Factors.



Natural Factors Anthropic Factors

Figure 3. Partial synthesis of factors

Results

The information plan synthesis was obtained by gathering results obtained for the Natural and Anthropic Factors, with weights of 40% given to Natural Factors and 60% to Anthropic Factors. The results obtained can be seen in Figure 4

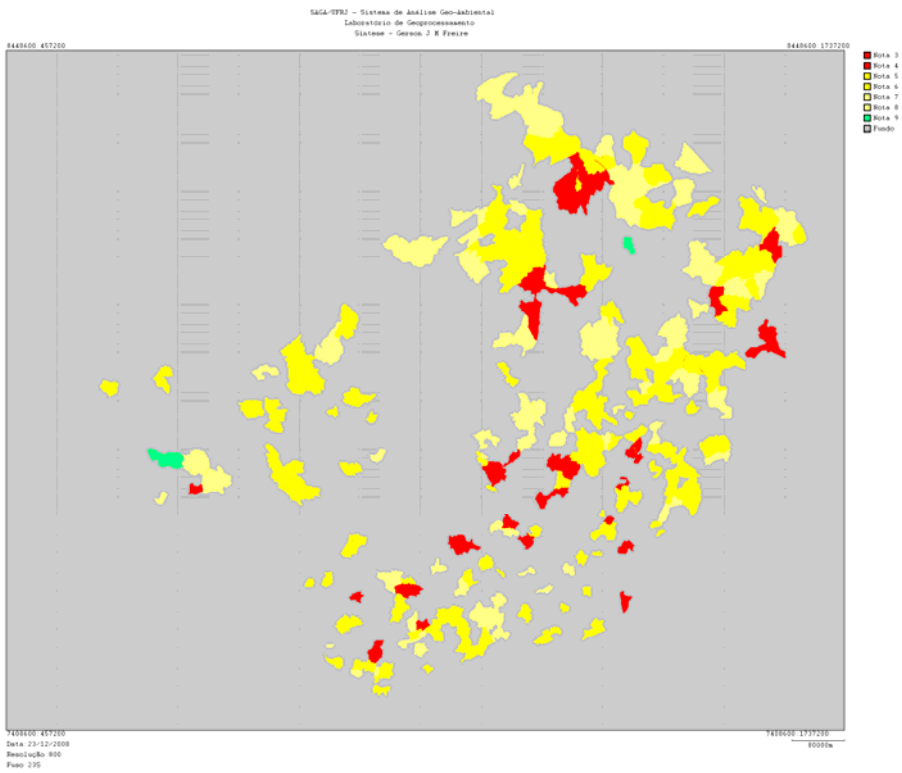


Figure 4. Final results

Discussion of the results obtained and categorization of the counties according to their landfills condition

The counties of the State of Minas Gerais that received the ten worst grades in the characterization are presented in Table 2, with the respective grades obtained.

Table 2. Worst grades in the classification obtained

County	Topographic and Geological factors	Hydrological Factors	Location Factors	Dynamic or load factors	Natural Factors	Anthropic Factors	Synthesis
Santa Bárbara	2,5	1,2	3,7	3,0	2,0	3,2	**2,7**
Conselheiro Lafaiete	1,3	4,6	3,0	3,8	2,6	3,6	**3,2**
Cambuquira	1,3	1,2	3,0	5,4	1,2	4,7	**3,3**
Três Pontas	3,8	2,0	3,7	3,8	3,1	3,8	**3,5**
Palma	1,3	1,2	3,0	6,2	1,2	5,2	**3,6**
Esmeraldas	3,8	5,6	3,0	3,2	4,5	3,1	**3,7**
Nanuque	1,3	2,0	10,0	3,2	1,6	5,2	**3,8**
Sapucaí-Mirim	0,0	5,2	2,1	6,2	2,1	5,0	**3,8**
Itabira	1,3	4,6	10,0	2,4	2,6	4,7	**3,8**
Oliveira	1,3	2,8	10,0	3,2	1,9	5,2	**3,9**

Source: Author Compilation (2008).

Conclusion

The results obtained in the present study allowed to check the adequacy of the multi-criteria analysis to the subject matter of the landfills and may be an indicator to actions searching for alternatives to recover inappropriate wastes disposal sites. The method also allows the establishment of hierarchies through an evaluation process, in analogy to the one performed through conventional logic. This study does not intend to drain the possibilities of the Maps Algebra usage on the proposed subject matter, since other characteristics involved are mappable, as long as the information is available, specially the ones related to the landfill operation, the existence or not of burn processes, etc. which can be contemplated in future studies on the subject matter.

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