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Use of a geographic information system to find areas for locating of municipal solid waste management facilities

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ABSTRACT

Municipal solid waste (MSW) management is a pressing concern for Goiás State, Brazil. Of the state's 246 municipalities, only 16 send their waste to licensed landfills. This means that 93% of the cities in Goiás dispose of their MSW inappropriately, in dumps or unlicensed landfills. This practice poses a danger to both the environment and to public health. On this basis, the goal of this study was to survey potential landfill sites in Goiás. A geographic information system tool was used to first identify Goiás landfills and dumps and then examine them, to check whether they are located in legally restricted areas. This tool cross-references morphology, land use and occupancy, conservation of the environment, public health and population projections for 2040. It then outputs restriction-free areas that are suitable for landfill construction. The results indicate that, by 2040, Goiás will have 59,500 km² available for landfills, i.e., 17% of the state's total area. Conversely, 60% of the state's geographical area will be off limits for landfill construction. The most urgent need is in the Goiânia Metropolitan area, which will be producing about 40%, of 6,850 t·day⁻¹, of the MSW generated in the state by 2040. This metropolitan area will have the smallest restriction-free area for landfill construction (832 km²). A total of 235 MSW final disposal facilities were identified in Goiás: 15 licensed landfills, 23 unlicensed landfills and 197 dumps. Of these, 15 are in permitted areas, 38 are in areas subject to approval and 182 are in restricted areas. These numbers highlight the need for Goiás municipalities to terminate and/or readjust landfills and unlicensed dumps and to set up new MSW management facilities that conform to the legal and environmental requirements and the expected population growth.

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1. Introduction

Ever since the National Policy on Solid Waste (PNRS) was instituted by Law No. 12,305/2010, there has been significant debate in Brazil on how to properly manage municipal solid waste (MSW). Regardless of the availability of MSW treatment facilities, the problems faced by Brazilian municipalities are exacerbated by a lack of infrastructures, particularly landfills, for the approved and environmentally appropriate final disposal of waste, (Gbanie et al., 2013).

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Moreover, the uptake of an increasingly urban lifestyle in Brazil in recent years has led to a rise in MSW production and, consequently, severe environmental damage (Hannan et al., 2015; Lavee and Nardiya, 2013). In 2014 alone, approximately 78.6 million tons of MSW were produced in Brazil, a 3% increase compared to 2013. Despite advances in recycling, reuse and reduction and in the use of composting and incineration technologies, the country still uses landfills as the main alternative for MSW disposal. This is true of both landfills that comply with legal and engineering requirements (destination of 58% of the MSW produced in Brazil) and dumps (ABNT, 1992; ABRELPE, 2015; Abreu et al., 2016; Brasil, 2010).

According to Mannarino et al. (2016), the way to curb increased production of MSW in Brazil is to get people and industry (in particular packaging producers) to accept responsibility. Furthermore, integrated MSW management should be delegated to Brazilian

municipalities, since they are responsible for solid waste management services. However, producers, importers, traders and the public in general should share responsibility for product life cycles (Brasil, 2010; Goiás, 2002).

Goiás has a poor MSW management record. According to the Goiás Environmental, Water Resources, Infrastructure, Cities and Metropolitan Affairs Office (SECIMA/GO), of the 246 municipalities in the state only 15 have licensed landfills, which reflects their environmentally poor management of MSW (SECIMA/GO, 2015). These landfills receive MSW from 16 municipalities in Goiás, since Cidade Ocidental shares its waste disposal facility with neighboring Valparaíso de Goiás (Colvero et al., 2015a). The remaining municipalities send their MSW to unlicensed landfills and dumps.

The implementation of technical, economic and legal MSW management strategies would radically change the state of affairs in Goiás, and ensure the prevention of risks to human health and the environment (Feo and Malvano, 2009; Guerrero et al., 2013; Soltani et al., 2015). As integrated MSW management facilities require a process for the final disposal of waste resulting from intermediate treatment facilities, there is a need to identify appropriate sites for landfills (Cherubini et al., 2009).

Therefore, the dual goal of this study was to identify restriction-free areas for setting up landfills in Goiás municipalities and to locate existing landfills and dumps (whether or not licensed by SECIMA/GO), to see if they are suitably sited. This mapping of the location of MSW final disposal facilities is necessary, particularly in the case of unlicensed landfills and dumps, as these can contaminate soil and water resources and endanger human health (Barros et al., 2015; Malakahmad et al., 2017).

The analysis is justified because few Goiás municipalities have licensed MSW landfills, a fact that underscores the need to find potential landfill sites. Furthermore, the identification of non-restricted areas for such landfills in Goiás resulted in a macroscopic overview of the current situation. This study is the first of what will be a series of assessments proposing future MSW management facilities for Goiás municipalities. These will serve as support tools for Goiás decision makers as they draw up guidelines for changing MSW management in the state. In the future, Goiás will likely be served by MSW management facilities that use a range of treatment technologies for material, organic and energy recovery.

The identification of the existing final disposal facilities in Goiás shows that this study aims to go beyond the mere identification of non-restricted sites suitable for the construction of municipal landfills. There is a consonance here with municipal urban environmental planning, which must seek appropriate alternatives to the municipality's urban reality and also enact prevention of environmental liabilities, whether incurred through unauthorized MSW disposal or the future installation of facilities that are not legally compliant and harm the environment (Colvero et al., 2015b). According to Grazia et al. (2001), decision makers need to have a vision of social and environmental sustainability, i.e. the municipalities must develop in a way that does not cause a collapse of natural resources or the exclusion of part of the population.

2. Material and methods

This study identified potential areas in Goiás for the construction of MSW final disposal facilities, namely landfills, that are available, subject to approval or restricted. The definition of the parameters for potential landfill construction areas drew on an analysis of the relevant legislation. These laws and codes determine the minimum distances between such facilities and areas where the land has a certain use or occupation, e.g. specific communities, environmentally protected areas, watercourses and

aerodromes, among others, and also the increasing amounts of waste produced by municipalities (Gorsevski et al., 2012).

The available areas are those where there is no legal impediment to the construction of MSW management facilities. The areas subject to approval are those which depend on Brazilian Environmental Control Agency – ECA authorization for the waste management technologies to be installed. Restricted areas are those where there are legal barriers to the construction of landfills or any other MSW management facility. Landfills or any other MSW management facilities only can be constructed after authorization has been obtained from the ECA. That is, building facilities in any of the areas identified in this study still requires a license from the competent agency. Moreover, authorization for a landfill in a specific location involves assessment of other types of constraints, such as land use, underground hydrology, geology, the road network and socio-economic activities, and requires a lot of site specific investigations.

2.1. Study area

Goiás State is located in Brazil's Midwest region. It has an area of around 340,000 km², or 4% of the country's landmass, making it the seventh largest state. It is bordered by Tocantins to the north; Bahia and Minas Gerais to the east; Mato Grosso to the west and Minas Gerais and Mato Grosso do Sul to the south (IBGE, 2016; IMB, 2014).

In 2015, Goiás had an estimated population of 6,610,681, distributed across 246 municipalities (IBGE, 2016), which equates to a population density of 19.4 inhabitants·km⁻². It is divided into ten administrative regions (Fig. 1), a strategic arrangement that allows the state government to prioritize investment as a function of the socio-economic needs of each region (IMB, 2014).

2.2. Identification of available and restricted areas for the construction of landfills in Goiás

Five laws and regulations were analyzed to determine the geographical and environmental restrictive aspects that must be taken into account when making a preliminary selection of areas in Goiás that are available or off limits for landfill construction. The legal documents used here to identify restrictions (which are subject to the consent of the competent environmental agency) on the construction of landfills are summarized in Table 1.

CEMAm Resolution No. 05/2014 addresses the technical aspects of constructing MSW landfills in Goiás State (SEMARH/GO, 2014). In addition to listing a number of restrictions, this document references other standards and laws with respect to the definition of specific location parameters for MSW landfills. This is the case of landfill-to-CU distances, for which the resolution refer the definition given in CONAMA Resolution No. 428/2010. This document states that landfills and CU should be 3 km apart (CONAMA, 2010). A CU is an area, including its environmental resources, which is under special protective administration because of its particular characteristics. This administration preserves and safeguards the defined boundaries (Brasil, 2000). The CEMAm Resolution also specifies that landfill-to-aerodrome distances must be those defined in Law No. 12,725/2012. This law (Brasil, 2012) states that there must be a minimum distance of 20 km between the aerodrome and any activity that attracts wildlife, e.g. MSW dumps or may attract wildlife, e.g. landfills.

Quilombola and indigenous lands (occupied by remnant communities) are also restricted zones, which rules out the building of landfills across a considerable area (Tavares and Carissimi, 2012). Any environmental licensing of an activity that is potentially polluting and could negatively affect the environment

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