Analysis of the Illegal Landfills Ocurrence in La Palma Island, Spain

Lorenzo Carlos Quesada-Ruiz
Universidad de Las Palmas de Gran Canarias
quesada.lorenzo@gmail.com

Keywords: Illegal landfill, factor analysis, discriminant analysis.

1. INTRODUCTION

The European Parliament Directive on waste (Directive 2008/98/CE, 2008) defines a landfill as a waste disposal site for the deposit of the waste onto or into land. Despite the above directive not providing a definition for an illegal landfill (IL), the directive on environmental liability with regard to the prevention and remedying of environmental damage (Directive 2004/35/CE, 2004) establishes that unmanaged waste must be managed, including its collection, transport, recovery and disposal. Furthermore, it requires measures to prevent and evaluate environmental damage to plan for its remedy. On the other hand, the autonomous regions of Spain (NUTS 2) consider illegal landfills as those areas that are affected by deposits of waste, without any type of management or control, which exceed 2,000 m^2 for more than two years. Thus, this paper focuses exclusively on IL with these features.

The problem of the emergence of illegal landfills has been addressed principally in mainland territories such as: Italy (Silvestri et Omri, 2008; Biotto et al. 2009), Slovenia (Matos et Kranjc, 2012), Greece (Alexakis et Sarris, 2013), and Spain (Jordá-Borrell et al., 2014), neglecting island areas. La Palma, with its 81,486 inhabitants (INE[1]:2016), is the fourth populous island of the outermost region of the Canary Islands. Unlike other islands like Gran Canaria and Tenerife, La Palma has preserved its environment and led the insular economy to ecotourism. During the year 2016, it has received 167,838 foreign visitors (http://estadisticas.tourspain.es), consolidating in this way as one of the most important nationally and internationally tourist destinations.

This research focuses on the characterisation of factors that have an influence on locating IL on the island of La Palma, and in the prediction of potential areas on the island. It will therefore be possible to improve the enforcement of prevention and recovery policies for damage by environmental agents.

[1] Instituto Nacional de Estadística, Gobierno de España.

Revista de Estudios Andaluces, vol. 34, núm. 1 (2017) pp.380-398. e-ISSN: 2340-2776
http://dx.doi.org/10.12795/rea.2017.i34.13

2. METHODOLOGY

The process of locating IL was carried out in three stages: i) Identification of potential IL through photointerpretation of orthoimages at a spatial resolution of 0.5 m from 2012 and 2015; ii) Field inspection of 215 potential sites; and iii) Sorting IL from deposits that have existed for less than 3 years, thereby obtaining 153 IL sites. Information referring to the waste type, degree of accessibility, fencing, access control and the presence of deterrent measures was incorporated for each IL site.

The sample is supplemented by the inclusion of unaffected sites where no IL were present, following the methodology described by Carranza et al. (2008). To this end, a random sampling that met the following conditions was applied: i) distance of greater than 1594 m from IL sites, ii) equal number of unaffected and affected areas. Affected and unaffected areas were coded with a value of 1 or 0, respectively, which resulted in a total of 306 cases.

a. Feature extraction

Similar to other works (Tasaki et al., 2006, Silvestri and Omri, 2008, Biotto et al., 2009, Alexakis and Sarris, 2013), this study began with a series of different types of spatial features: socioeconomic features such as per-capita income, population, indicators of tourism activity, industry and economic activity; management features such as waste type, degree of access, accessibility, security and control; and finally terrain features, such as elevation and concavity. Based on this initial set of features, a subset of derived features was obtained through the application of different GIS analysis procedures. Criteria that were taken into account include: the Euclidean distance (ED) between the IL site and the features of interest (Tasaki et al., 2006, Biotto et al., 2009, Jordá-Borrell et al., 2014), and densities within three search radio (250 m, 500 m, and 1500 m) (Table 1). The densities were obtained by applying the kernel functions and other search functions based on the distance to a particular radius. Finally, in order to extract the features related to land use, both the density calculation and distance to a specific land use were considered.

Each feature was standardised, rasterised and resampled at a spatial resolution of 10 m. The values for all previously mentioned features were extracted for the affected and unaffected IL sites.

b. Exploratory and multivariate analysis

An exploratory analysis of the data was performed and IL sample outliers were filtered. The multivariate analysis techniques, factor analysis (FA) and discriminant analysis (DA) were applied in a SPSS 24.0 software environment. The FA was applied with the

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objective of determining the relationship between the different features, and the DA to predict the potentiality of IL occurrence.

Principal component analysis (PCA) was selected as the FA method. The PCA was only applied to values of 1. Features were grouped into factors considering eigenvalues greater than 1. The multivariate normality of the features and their interrelation were tested using the Kaiser-Meyer-Olkin test for sampling adequacy (KMO: 0.715) and Bartlett's sphericity test, respectively. The ratio chosen for the PCA of 10 cases per feature was respected. The factors were rotated using the quartimax method. It was ensured that a minimum of 2 features were present per factor, and that each feature had correlations equal to or greater than 0.40.

In the DA, just as many 0s were used as 1s, and the features that condition the appearance of 1s instead of 0s were identified. The number of independent features required to achieve a greater discrimination between affected and unaffected areas was determined using the forward selection inclusion method. The standardised coefficients, along with the centroids of the discriminant function (0s:1.634; 1s:-1.634) were used to determine the sign and magnitude of the relationships between the features and IL occurrence. The canonical discriminant analysis was constructed as a linear combination of the independent features selected to distinguish both groups:

$$D= c + b1*x1 + b2*x2 +\dots bn*xn$$

Where *D* is the Z-score, *c* is a constant, *b* is the canonical discriminant function coefficient and x is the feature.

The suitability of the DA was evaluated based on the eigenvalue (2.694) and the canonical correlation (0.854). On the other hand, both the significance (0.00) and the Wilks' lambda distribution (0.271) were analysed.

The discriminant function was applied to each of the selected features in a GIS environment in order to obtain the mapping for the potentiality of IL occurrence.

3. RESULTS AND CONCLUSIONS

Both the FA and DA show how the location of illegal landfills on the island territory of La Palma is not random. The PCA was a first approach in identifying factors and features that are best to include in the DA. This work applies methodologies used in mining studies through the inclusion of cases of unaffected areas (0s) to the IL case study. Therefore, the DA can be applied to map the potentiality of IL occurrence.

The first three PCA factors, which correspond to the features of distance to elements of interest and socio-economic features, explained 53.22% of data variance. The remaining

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factors, which were of less explanatory significance, corresponded to the distance from rural settlement, the distance from the coastline and the density of cover transition between 1990 and 2012.

The DA reduced the feature space from 22 to 9, amongst which the influence of road density, transitions between land use, proximity to urban centres, population density and distance to forest areas. The socio-economic features used may not be adequate due to their level of aggregation and low spatial variability, demonstrating the need to incorporate additional information. Map 2 shows the mapping of IL occurrence potentiality obtained after applying the discriminant function.

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