USING GIS TECHNIQUES FOR ASSESSING WASTE LANDFILL PLACEMENT SUITABILITY. CASE STUDY: PRAHOVA COUNTY, ROMANIA

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ABSTRACT:
Prahova County is one the most urbanized and economically developed areas of Romania, and one of the main waste-generating counties. The present study aims to analyse, by using GIS techniques, waste landfill placement suitability, based on environmental and legal criteria. Firstly, the restrictive factors, established by law, were analysed, including distance from localities, forests, protected areas and water courses. Secondly, natural factors that influence the waste landfill siting suitability were also analysed, such as: slope, seismic risk, soil texture, and mean annual rainfall. The results, expressed by the suitability index for waste landfills (SIWL) in Prahova County, showed that 11% (516 km²) of the study area is favourable to waste landfill siting, but only 3.4% (160 km²) of the area is highly suitable.

Key-words: *GIS techniques, waste landfills suitability, Prahova County, Romania.*

1. INTRODUCTION

Waste management has become a global problem, due to accelerated process of urbanization and industrialization, population growth, standard of living improvement and fast economical development in the 20th century (Zamorano et al, 2009; Öcal, 2011). Nowadays, waste management strategies must consider public health and environmental protection (Marshall & Farahbakhsh, 2013). At European Union level, waste management is based on key principles, such as waste generation prevention, recycling and reuse, improving waste disposal methods and monitoring. Final waste disposal in landfills must be considered only after having applied preventive measures regarding waste generation and recovered useful materials and energetic power.

Studies on waste landfill placement suitability are particularly important, as they provide landfill design and construction models that take environmental protection needs into account. To this end, various international specialized studies were conducted in order to identify suitable areas for waste landfill location, several using GIS techniques (Siddiqui, 1996; Kontos, Komilis & Halvadakis, 2003; Leao, Bishop & Evans, 2004; Kontos, Komilis & Halvadakis, 2005; Zamorano et al, 2008). In Romania, several studies on waste landfill siting requirements were completed (Rojanski, Bran & Diaconu, 2002; Bold & Mărăcineanu, 2004; Antonescu et al, 2006; Apostol & Mărculescu, 2006), but waste management is still being inadequately implemented.

According to the latest Eurostat report (Eurostat, 2013), which includes data for 2011 on waste management, 99% of the collected municipal waste in Romania is disposed of in dumps and landfills, while 1% is recycled, thus Romania being ranked among the last in the European Union regarding municipal waste recycling. In the individual country report

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which refers to municipal solid waste management in Romania, published by the European Environment Agency (EEA, 2013) on March 19th 2013, the figures are similar to those presented by Eurostat, specifying that more than 95% of the collected municipal waste is stored, while only 1% is recycled. Therefore, the waste disposal management must take into account the restrictive environment variables, which are efficiently analysed and spatially modelled using Geographic Information System methods.

This study aims through its own methodology based on GIS techniques to identify suitable areas for waste landfills in Prahova County, the potential location being defined by specific environmental and legal criteria.

2. STUDY AREA

Prahova County is located in the south-central part of Romania and is included in the Southern Development Region. It overlaps all three major landforms: plains (Romanian Plain), Subcarpathian Hill and Carpathian Mountain areas (**Fig. 1**).

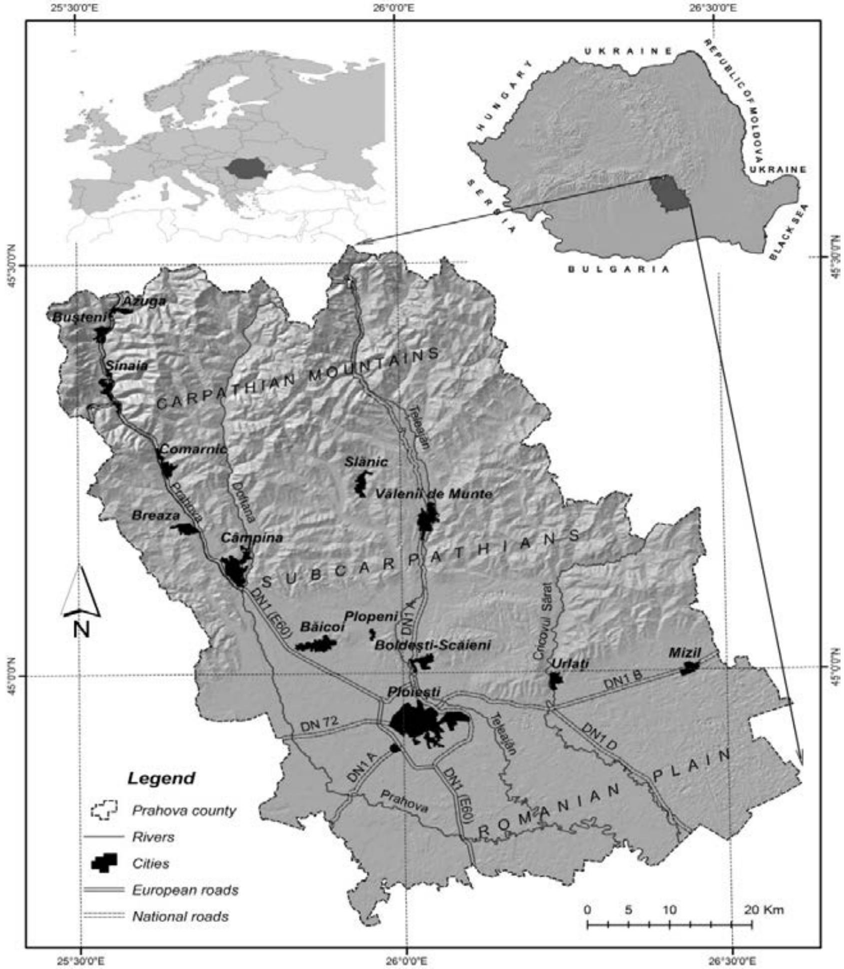

Fig. 1 Location of the Prahova County in Romania.

Prahova is one of the fastest growing counties in Romania in terms of economy, with a high degree of urbanization. According to the latest national census, conducted in 2012, Prahova totals 735.883 inhabitants and is the second most densely populated county after Bucharest. It ranks in the top six counties according to the evolution of GDP per capita from the beginning of the economic crisis (2008) to present time, being one of the most productive counties having overcome the economic crisis. It also ranks sixth in terms of economic value (surplus to the country's economy).

The current county municipal waste management plan is not being implemented appropriately, as old and nonconforming landfills are being used, resulting in a polluted city area and, through greenhouse gas emissions, contributing (nationally and globally) to the amplification of the greenhouse effect. The county generates approximately 300,000 tons of municipal waste annually. According to Environmental Protection Agency Prahova predictions, urban waste generation will have a continuous upward trend until 2038.

There is no ecological municipal waste landfill in Prahova County that meets the compliance requirements set out by EU Directives and the Romanian legislation. Currently, there are two licensed functional landfills for municipal waste: in Vălenii de Munte and Boldești-Scăieni.

3. DATA AND METHODS

In our study, we considered the waste landfill placement and design requirements listed in Annex 2 of the Government Decision no. 349/2005, subsequently modified and updated, in accordance with Annex I of Directive 1999/31/CEE.

The Suitability Index for Waste Landfills (SIWL) in Prahova County was computed and spatially modelled in GIS environment (in full compliance with the provisions of this normative act), going through a series of main steps (**Fig. 2**). For the spatial modelling of suitable landfill siting areas, the following location restriction factors were modelled in GIS: the necessary safety distance between human settlements and waste landfills, which must be of at least 1,000 m and that between landfills and forests, protected areas and watercourses, of at least 500 m.

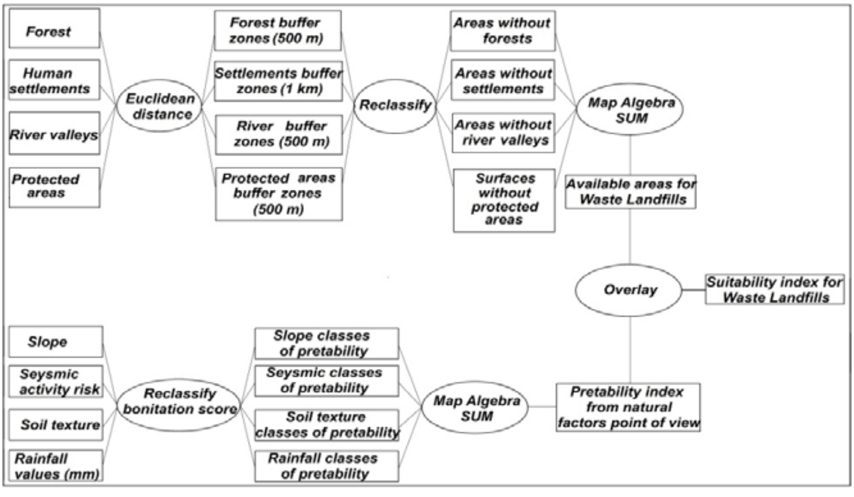

Fig. 2 The main steps followed in GIS environment in order to achieve.
The Suitability Index for Waste Landfills

In this respect, a vector database for Prahova County was used, comprising the areas to which safety distances are mandatory (**Fig. 3**). A buffer zone was created for each of the targeted factors, in accordance with the legislation in force.

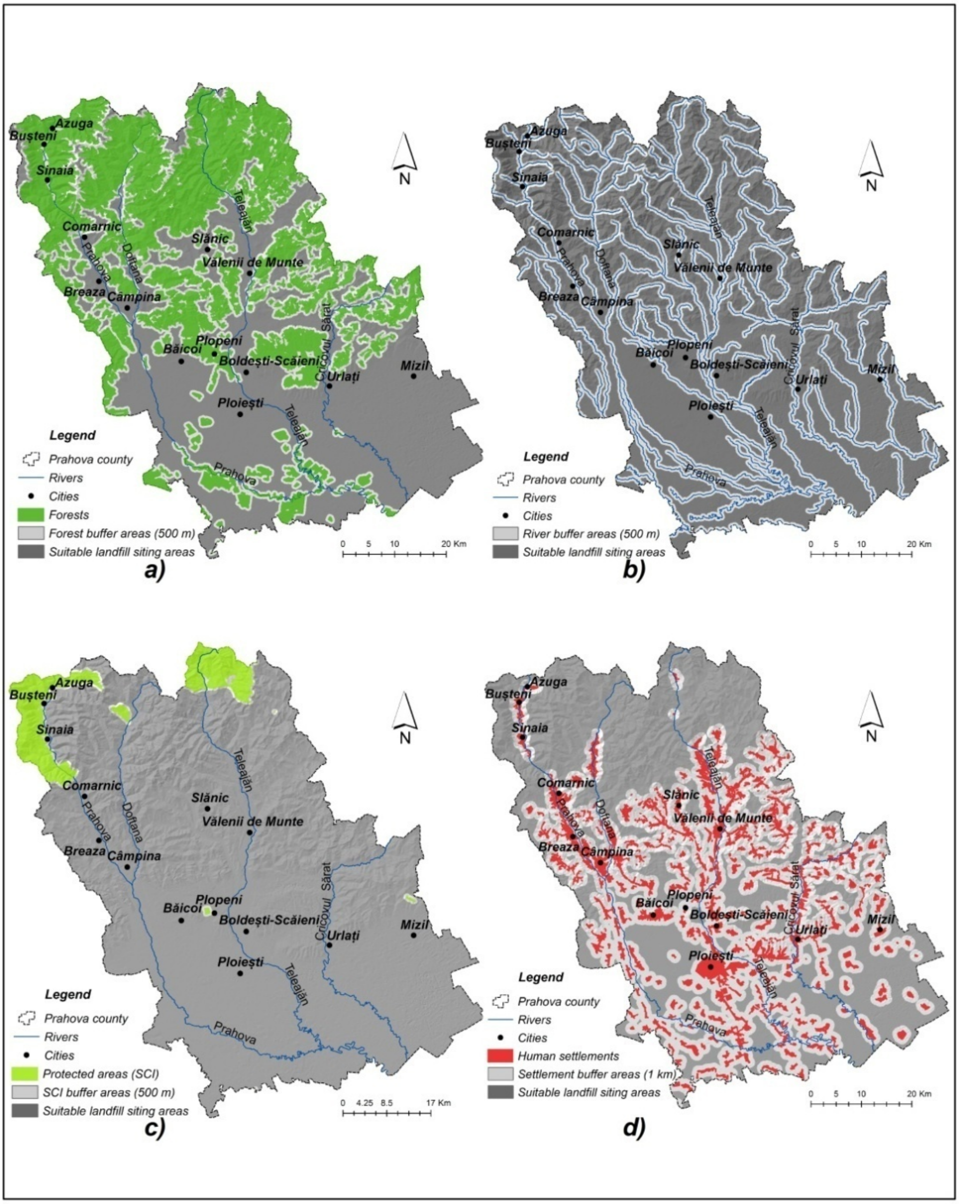

Fig. 3 Buffer areas for: forests (a), water courses (b), protected areas (SCI) (c) and human settlements (d).

Thus, in order to eliminate buffer zones and restrictive factors, the Euclidean Distance tool in the Spatial Analyst extension of ArcGIS 10.1 was used. The modelling phase resulted in four raster layers with cell value of 0 and cell size of 30 m. The final raster, depicting suitable landfill siting areas, was obtained by summing up the four rasters through Map algebra tool.

In the second phase of the study, four natural factors influencing waste landfill placement suitability were considered: landform slope, seismic degree, soil texture and average annual rainfall throughout the county (**Fig. 4**).

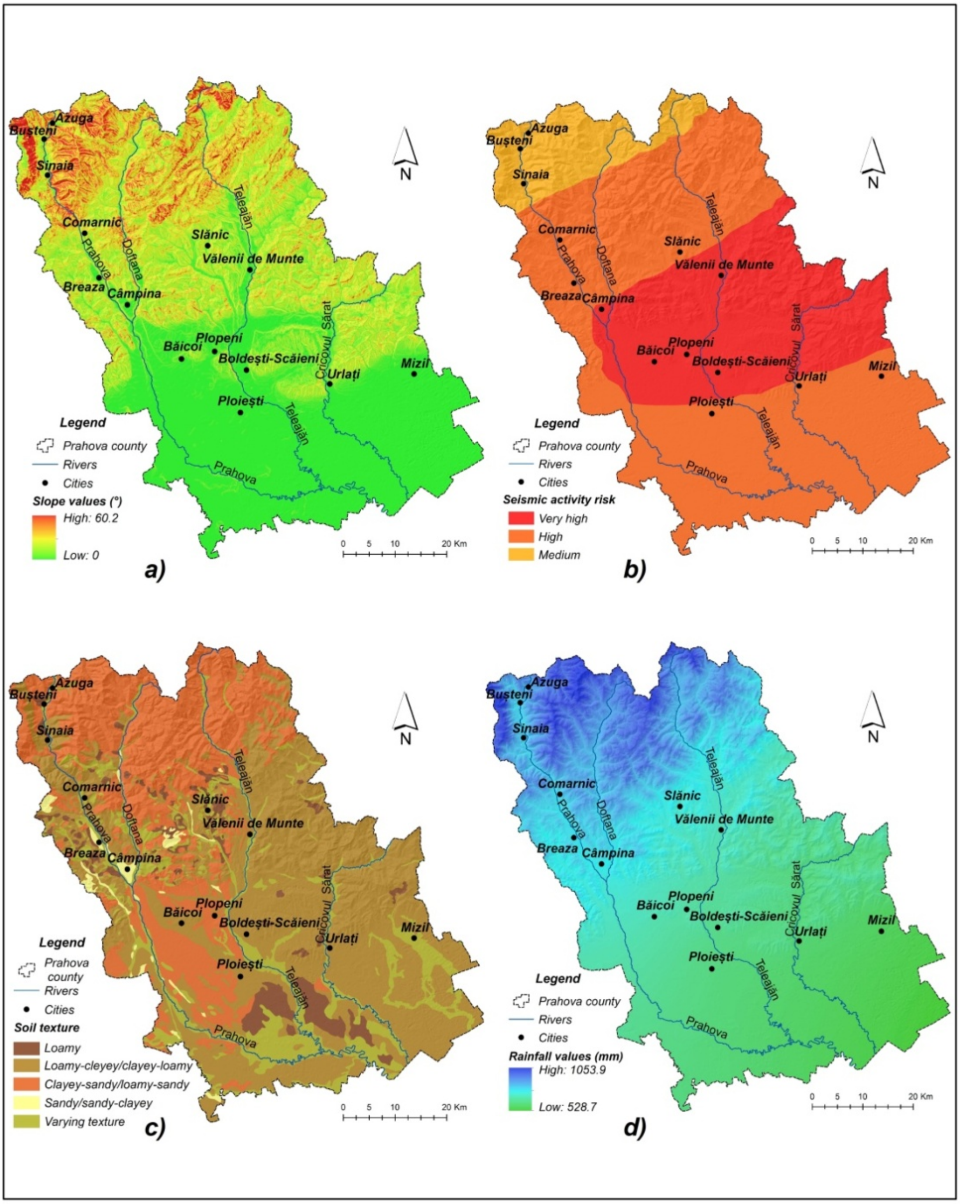

Fig. 4 Natural factors included in the suitable landfill siting areas analysis: slope (a), seismic activity risk (b), soil texture (c) and average annual rainfall (d).

The declivity was obtained at a cell size of 30 m, from the digital terrain model resulting from level curve vectoring on a 1:50000 topographic map. Its values were grouped into 5 classes, depending on the suitability degree for landfill siting (**Table 1**).

Seismic risk values in Prahova county were obtained in polygon vector format by digitizing the isolines on the Seismic Map of Romania (URBAN-INCERC, 1991, 1994). These values were divided into three classes and the resulting polygon was subsequently transformed into raster format, with cell values ranging from 3 to 5, based on earthquake exposure risk (**Table 1**).

The Soil Map of Romania 1:200000 in polygon-shaped was used for soil texture spatial modelling. Each type of texture was given a suitability score in the attribute table. Bonitation score 1 was given to predominantly sandy textures (favourable to water and leakage infiltration) and bonitation score 5 to clay textures, due to their impermeability to water (Teodor & Mătreață, 2011; Zaharia et al, 2012) and also to pollutants (**Table 1**). The resulting layer was converted to 30 m cell sized raster format.

Average annual rainfall was spatially modelled by processing values recorded at weather stations in the county and the surrounding area, as well as the numerical land model. Thus, depending on the amount of rainfall recorded at each station and its altitude, the regression line between the two rows of values was generated, with altitude as the independent variable. Rainfall spatial modelling in 30 m cell sized raster format was executed through mapping algebra, by introducing the DEM in the linear regression equation ($y = 0.1881*x + 608.69$). The values were grouped into five classes, with levels ranging from 1 (more than 870.5 mm/year) to 5 (less than 609.4 mm/year), depending on rainfall impact on suitability index for waste landfills (SIWL) (**Table 1**).

In the third and final stage of the study, the resulting raster layers from the previous phases were superposed, thus determining the suitability degree for landfill siting throughout the county.

Table 1. Scores given to natural factors that influence waste landfill placement suitability

Parameters	*Types/Values*				
Slope (º)	> 25	15 - 25	7 - 15	3 - 7	< 3
Rainfall (mm)	1053 - 870	870 - 777	777 - 689	689 - 609	609 - 528
Soil texture	Sandy; loamy-sandy; sandy-loamy; from sandy-loamy to loamy-sandy;	From loamy-sandy to loamy; from loamy-sandy to loamy-clay;	Mixed texture; from loamy to loamy-clay; from loamy to clay; loamy	From loamy-clay to clay; loamy-clay;	Clay
Seismic risk			Very high	High	Moderate
Score	1	2	3	4	5
SIWL	5 - 7	7 - 9.9	10 – 13	13.1 - 15	15.1 - 17

4. RESULTS AND DISCUSSIONS

Following the aforementioned methodology, *The Suitability Index for Waste Landfills (SIWL)* in Prahova County was obtained (**Fig. 5**), this index showing the suitable areas for waste landfill placement in this county. The index values, ranging from 5 to 17, were grouped into 5 classes through the Natural Breaks.

Most suitable areas for waste landfill placement were found in plains; a compact area of approximately 108 km^2, covering 2.29% of the county, was outlined to the west and northwest of Ploiesti City. Another suitable area is located to the east and southeast of the city, in the vicinity of county boundaries with Buzău, Ialomița and Ilfov. There are 7 compact suitable areas totalling 292.86 km^2, accounting for 6.21% of the county's surface area. Overall, from the legislative point of view, about 10.9% of Prahova County's surface is suitable for landfill siting. Other suitable territories, in terms of legal restraints, can be found in hilly and mountainous areas, but such cases are less relevant, as they are highly dispersed and of reduced extent.

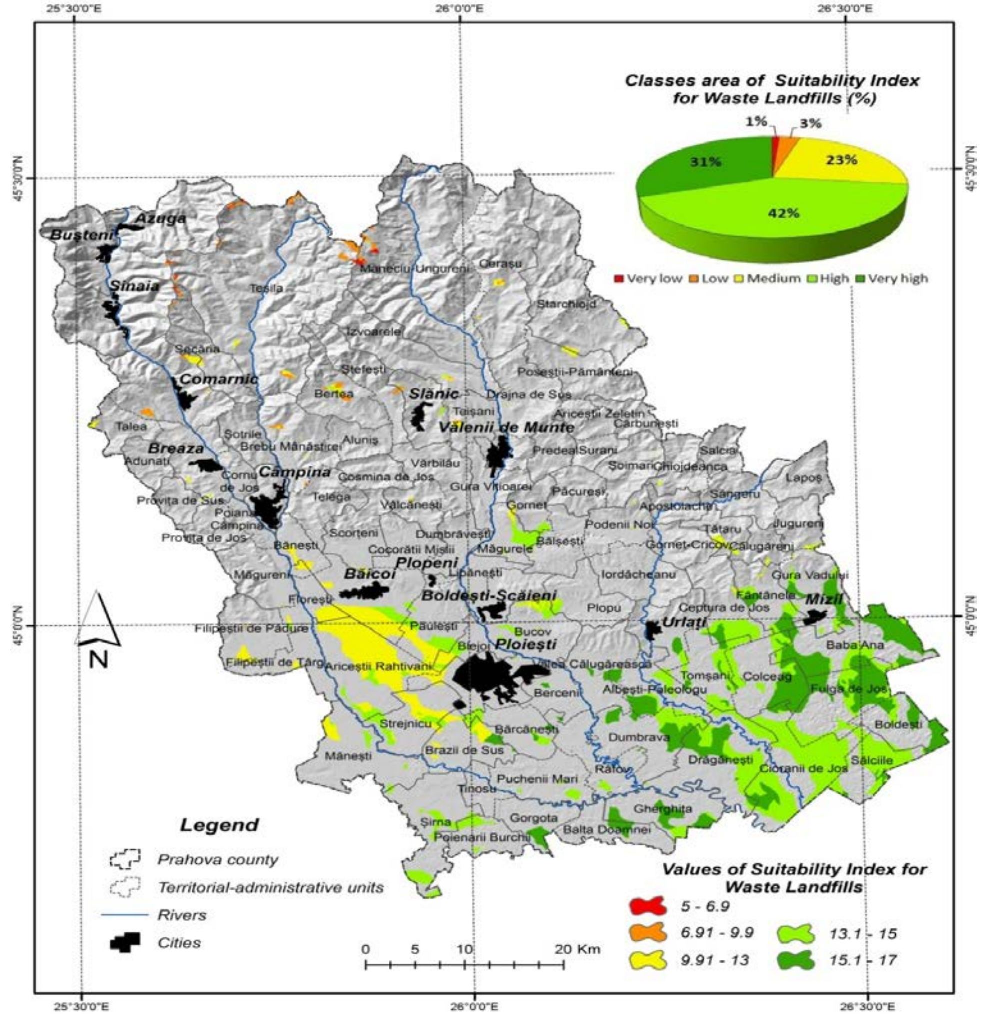

Fig. 5 The spatial representation of Suitability Index for Waste Landfills values within Prahova county.

The SILW values in the first two classes (5 - 9.9) indicate areas with low and very low waste landfill placement suitability. These represent approximately 4% out of the entirety of suitable areas, covering the highest peaks of the Bucegi, Baiului and Ciucaş Mountains, and steep side slopes. Mean SIWL values resulted on 23% of the total suitable area. These correspond to compact areas in the western and north-western part of Ploieşti City. Landfill siting in these areas is to some extent limited by factors such as high rainfall values (about 700 mm/year) and earthquake risk, but also by soil texture prone to maintaining stagnant surface water.

The most suitable areas for waste landfill siting are found in the south and south-east, with SIWL values ranging from 13.1 to 17. These areas cover about 73% of the total suitable area for landfill placement, totalling 377.3 km^2. The high suitability degree for waste landfill siting in these areas is due to mild side slopes (< 1°), low rainfall (<550 mm/year) and soil texture preventing water infiltration. Moreover, this area of Prahova County is traversed by major transport routes, such as DN 1, DN 1A, DN 1B, DN 1D and by the recently completed A3 highway. Areas with high and very high SIWL values cover about 8% of the territory.

In this study we also tried to overlay the Suitability Index for Waste Landfills values at the level of territorial-administrative units. A number of 78 administrative units (almost 80% from the all 99 which are situated in Prahova County) intersected the five classes of the suitability index. Taking into account that the classes with medium, high and very high suitability values represent 96% from the total suitable area and that these classes are the most representative from this point of view, a graphical analysis at the level of administrative units was made. We selected 65 territorial-administrative units (out of all 78 that intersected Suitability Index for Waste Landfills values) in which the cumulated areas of the above-mentioned three classes cover at least 5 ha, this threshold being chosen for an optimal graphical view.

The results reveal that the administrative units in which the cumulated suitable area have the biggest values are Cioranii de Jos (5977 ha), Ariceștii Rahtivani (4407 ha), Baba Ana (3922 ha), Fulga de Jos (3654 ha) and Drăgănești (3210 ha), while the smallest values are in Brebu Mânăstirei (5,5 ha), Măgureni (6,2 ha), Cerașu (6,9 ha), Scorțeni (7,3 ha) and Lipănești (10,8 ha) administrative units (**Fig. 6**).

The individual analysis of the three classes reveals that the maximal values are in the following administrative units: Ariceștii Rahtivani (4119 ha), Băicoi (1623 ha) and Păulești (1272 ha) for the medium suitability class; Cioranii de Jos (5298 ha), Salciile (2027 ha), Drăgănești (1935 ha), Fulga de Jos (1375 ha) and Tomșani (1246 ha) for the high suitability class; Baba Ana (3178 ha), Fulga de Jos (2280 ha), Colceag (1607 ha), Drăgănești (1275 ha) and Boldești (1033 ha) for the very high suitability class (**Fig. 6**).

It should be mentioned that all these suitable areas for waste landfill siting (especially areas with high and very high SIWL values) can be very useful for landfill developers (local public administration authorities and local councils), that have the responsibility of finding the optimal location for siting a waste infrastructure. The principal aims of the overall site selection process from an environmental perspective are to find a landfill site, which will safeguard public health, have minimal impact on the environment, and provide for safe disposal of waste. Taking these considerations into account, the Suitability Index for Waste Landfills (mainly high and very high values) could be a real solution to achieve those objectives.

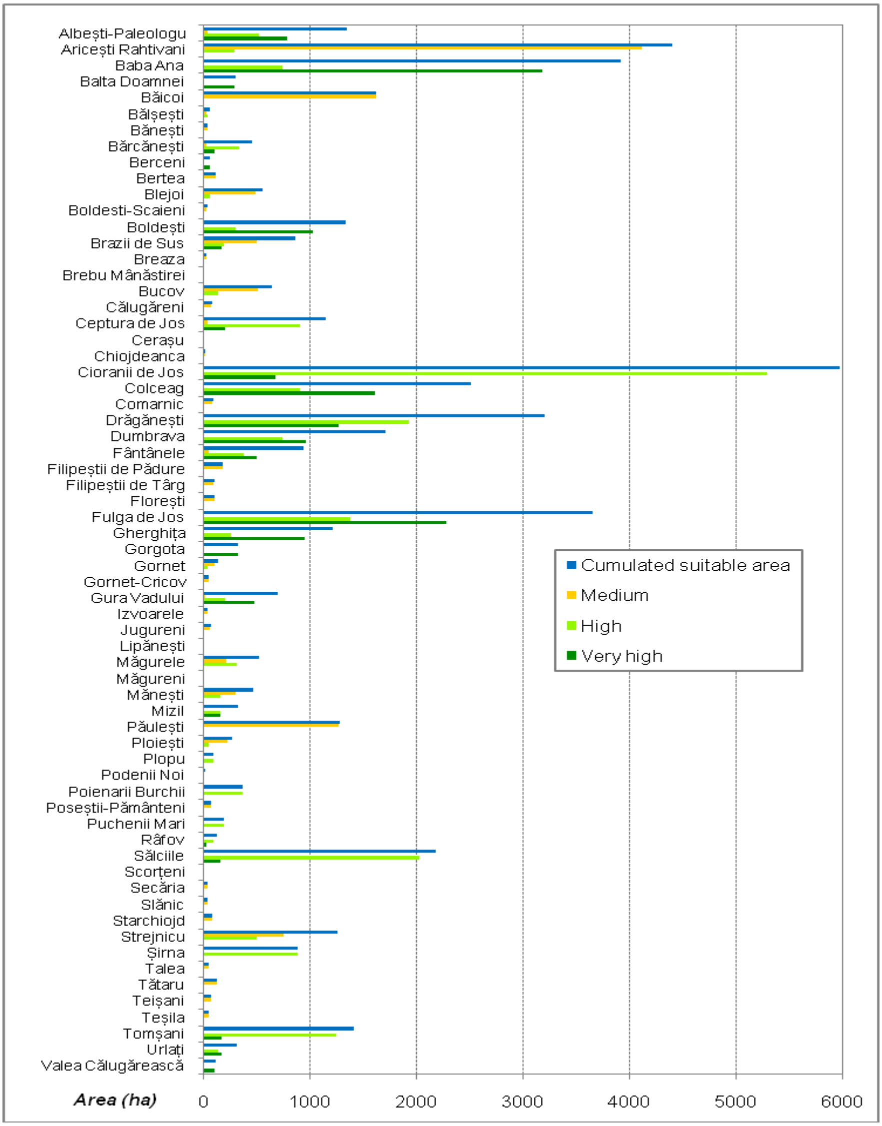

Fig. 6 The distribution of medium, high and very high SIWL values surfaces (ha) at the level of the territorial-administrative units.

5. CONCLUSIONS

We believe that the methodology is innovative in two main respects:

(1) The use of GIS mapping algebra in order to eliminate unsuitable areas in terms of legislation for waste landfills placement;

(2) The use of GIS mapping algebra in order to identify different suitability degrees for landfills siting.

The methodology was applied to Prahova, which is one of the most economically developed and urbanized counties in Romania, where such spatial planning projects should represent a priority. Our study revealed several areas with high SIWL values (13.1 - 17), mainly in the lowlands and the south-eastern part of the area.

The study, due to spatial modelling approach, is important for a more efficient management of waste landfills, which requires information about the restrictive geographical factors. We consider that the present work can be of real help mainly for Prahova Public Authorities, landfill contractors and operators, in choosing the best location for siting a new ecological municipal landfill in the county.

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