PERSPECTIVE OF SOLID WASTE GENERATION IN ALBANIA BASED ON A COMBINATION OF CORRELATION AND INTERPOLATION

MEDJON HYSENAJ[1,*] and SIDITË DURAJ[2]

[1] University of Shkodër, Department of Geography, Shkodër, Albania
[2] University of Shkodër, Department of Mathematics, Shkodër, Albania
* Corresponding author: medjon.hysenaj@unishk.edu.al

ABSTRACT

Waste management is a serious problem in developing countries. Solid waste (SW) statistics provide an indication of compliance with the targets of the Waste Framework Directives (WFD). This paper includes an analysis of specific variables that directly influence trends in the production of SW. Albania is divided into 12 first-level administrative units, counties. The objective of this paper is to concentrate on the geographical areas that provide the most striking results. The analyses use linear regression and Pearson correlation in which the dependent variable is waste generation and the independent variables, geographic, demographic and economic, are among those that are of greatest importance in the production of SW. The specific relationships are highly significant ($r > 0.98$) and are the input for the IDW interpolation maps. The disaggregated panorama is used to develop policy recommendations for waste management in the affected areas. Prediction of urban waste through a combination of mathematical equations and geographical tools is part of the results of this study.

Keywords: correlation; GIS; geographic dispersion; interpolate; spatial map

Introduction

Despite some advances in enhancing environmental protection, rapid urbanization and inequality in the developing world makes the collection of municipal solid waste (MSW) even more difficult (Vieira and Matheus 2018). Waste management is ranked among the basic challenges faced by developed countries worldwide, especially those municipalities that carry the burden of the largest share of the issue. SW is one of the main by-products of urban life (Pan et al. 2019). According to the European Environment Agency, Albania has very few recycling/reusing systems for waste and few engineered landfills for the disposal of waste. Understanding trends in waste production in terms of several variables is likely to improve waste management. Waste separation is almost non-existent and recycling is very low, also most waste continues to be disposed of unsafely, which is a serious cause for concern (European Commission 2014). The trend in the rural–urban process in Tirana is not unusual in the European Western Balkans (EWB). A famous quote from Peter Drucker says: "You can't manage what you can't measure". Hence, the goal of the current analyses is to identify the most important variables in waste generation followed by a spatial perspective of the affected areas. According to Smrekar et al. (2019), the increase in unfavourable residential conditions in some urban areas due to uncontrolled waste management can result in increased social degradation and differentiation and jeopardize the implementation of sustainable urban development. Production of solid waste is closely connected to population growth, general consumption and economic activity. Based on Rybova et al. (2018), we try to find the same significant correlations between socio-demographic aspects and SW in order to account for the much higher share of inter-municipal variability using geographically weighted regression, because this method is able to consider changing strength and even direction of the relationships in different spatial units.

Waste management must be strictly controlled, as it directly affects human health and the environment. The substances involved include volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), heavy metals, radioactive materials and pharmaceuticals (Pecci 2017). Waste management is closely related to geographical dispersion. To identify important variables and their spatial correlation it is crucial to develop an operational strategy. Through GIS technology, we manage environmental measures based on the combination and analysis of multiple layers. Statistical data based on mathematical formulas, such as linear regression or correlation are important for defining trends. The outcomes elaborated through geospatial tools improve the policy on waste disposal, which cannot be restrained, but controlled. This paper aims to benefit from GIS utilities overlapping multiple layers reflecting different themes to highlight specific issues (Hysenaj 2016). As is the case with maps in general, overlays are more helpful than indicators to accommodate reflexive scrutiny and plural perspectives (Rafols et al. 2010). To identify the most important variables that affect waste generation brings the goal of a prediction model much closer.

Evaluation Strategy

To develop relationships between variables and waste generation, many researchers use correlation and regres-

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sion analysis. To better understand the spatial extent of the issue and the symbiotic behaviour between applied variables, interpolation techniques are used to quantify the situation and define a future perspective. Overlay maps provide significant advantages in the readability and contextualization of disciplinary data and in the interpretation of cognitive diversity (Rafols et al. 2010). We combine multiple layers in order to produce heuristic interpretations of the internal dynamics of a research field. According to waste prediction models, many different variables are important, such as number of residents, income, household size, residency type, age groups, employment, consumer price index (CPI), gross domestic product (GDP), level of education, culture, geography and climate (Ordonez-Ponce et al. 2004). We analysed a subset of these variables for the area studied.

Correlations between waste generation *per capita* and demographic and economic parameters

The data from each of the 12 administrative units in Albania was analysed using linear regression analyses in Microsoft Excel 2016 software and the Pearson correlation formula between waste generation per year (dependent variable) and the chosen list of demographic and economic factors (independent variables). Because of the recent great increase in population in Albania, this study mainly focused on demographic variables and their effect on urban waste management. The first set of scatter plots define the relationships between independent variables and urban waste per capita per year. Fig. 1 indicates a low degree correlation with population size. The R-value is positive. There are stronger relationships with population density and urban population (Figs 2 and 3). These scatter diagrams reveal that urbanization and population density have greater effects on waste per capita generation than population size.

Waste production per capita is also positively correlated with the independent variable *GDP per capita* (Fig. 4) and economic performance should also be considered.

Correlation between generation of waste per county and economic parameters

The second set of scatter plots reveal the relationships between generation of urban waste per county per year and independent variables (Figs 5–8). All four cases show strong positive increases (R > 0.70). The correlation coefficients and their significance (Table 1) indicate that the predictions at the county level are likely to be accurate. As reported previously (Troschinetz 2005; Senzige et al. 2014; Challcharoenwattana and Pharion 2018), the re-

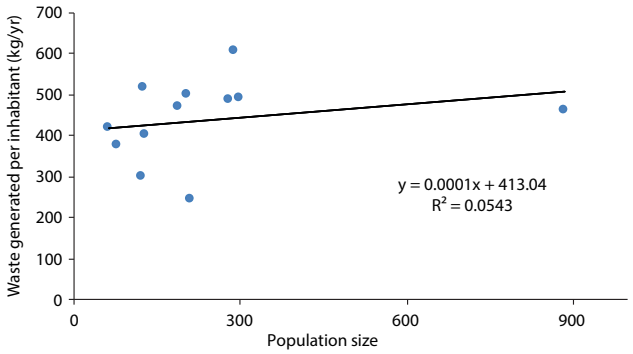

Fig. 1 Waste generated per inhabitant (kg/yr) against population size.

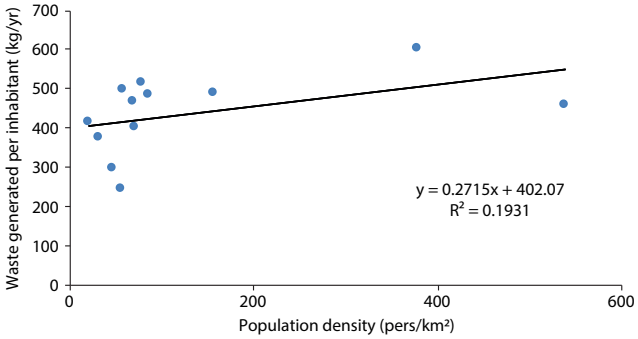

Fig. 2 Waste generated per inhabitant (kg/yr) against population density (pers/km²).

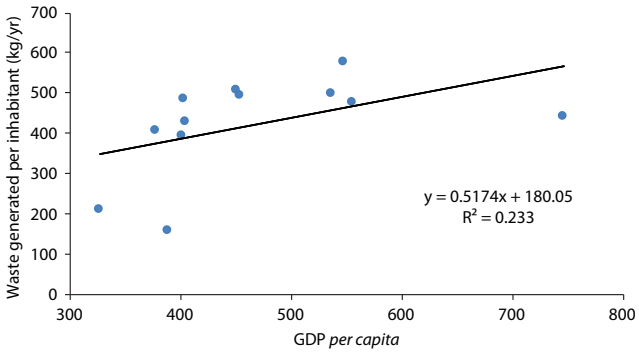

Fig. 3 Waste generated per inhabitant (kg/yr) against GDP *per capita*.

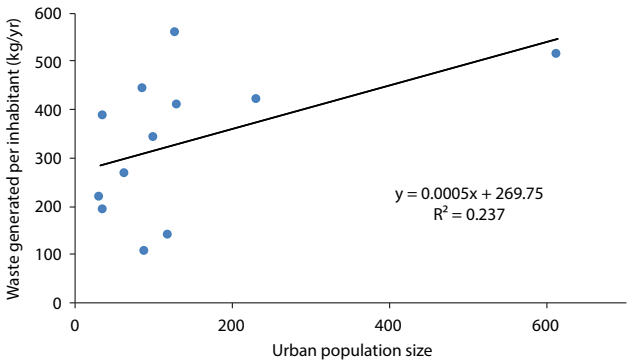

Fig. 4 Waste generated per inhabitant (kg/yr) against urban population size.

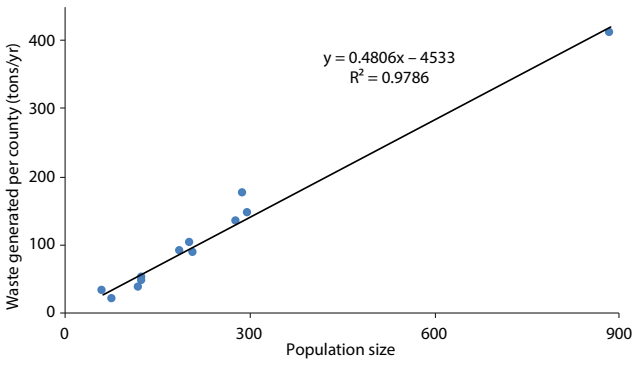

Fig. 5 Waste generated per county (tons/yr) against population size.

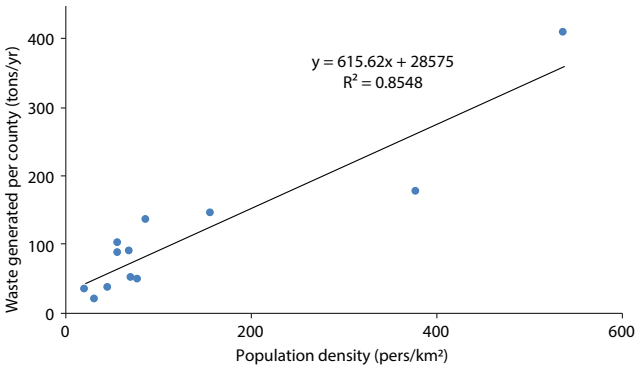

Fig. 6 Waste generated per county (tons/yr) against population density (pers/km^2).

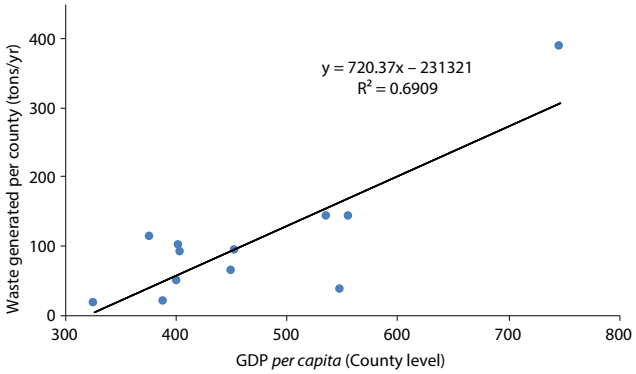

Fig. 7 Waste generated per county (tons/yr) against GDP *per capita* (county level).

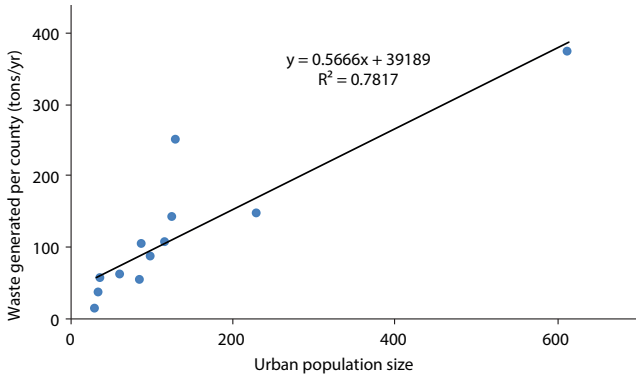

Fig. 8 Waste generated per county (tons/yr) against urban population size.

sults are not unexpected. This information can be used by policy makers to improve urban waste management, especially in areas where there is a high rate of urbanization.

Reflecting correlation results through interpolation map methods

The independent demographic and economic variables are for counties, so it is important to investigate their dynamics at the county level. As in any optimization process, the collection and analysis of data is of great importance because the accuracy of the optimization or simulation is only as good as the accuracy of the data (Monzambe et al. 2019). The analyses presented are based on data for the period between 2003 and 2018, for which there is sixteen sets of data for each of the counties. For two of them (Tirana, Durrës) there is a strong positive increase (Table 2) because they also show a positive correlation between (year – population) variables. In these two counties, there has been a steady and continuous increase in population growth. The correlations for the other ten counties are negative. This means that the dynamics at the county level differ from those at the country level. Generation of urban waste continues to increase in all the other counties despite the fact that their population growth has decreased. Based on Table 2, we conclude this is mainly due to the effect their urban population, population density and GDP *per capita*. In addition, we should consider the role of the national policy on waste management.

Maps were produced using ArcGIS package and ArcMap 10.2.2 software. Source of data is the Albanian Institute of Statistics. We included a set of vector-based areas derived from GADM (Global Administrative Areas). The geographic coordinate system is GCS_WGS_1984 and datum D_WGS_1984. The scale of the maps is 1 : 2,000,000. Figs 9 and 10 present the quantity of urban waste produced in the different counties and dispersion of the population, respectively. Using inverse distance weighting (IDW) to overlap these two remaps (Fig. 11) provides an overview of the relationship.

Table 1 Correlation between the generation of SW and demographic and economic factors (the correlation is at county level).

Factor	Correlation (r)	Significance
Population	0.989	< .001
Urban population	0.884	< .001
Population density	0.924	< .001
GDP	0.831	< .001

Table 2 Correlations between the generation of SW per county and their urban population, population density and GDP *per capita*.

County	Correlation (R)	Urban Pop[1]	Pop. density[2]	GDP *per capita*[3]
Berat	–0.90	63395	70.9	451
Diber	–0.67	36375	46.8	389
Durrës	**0.94**	**230938**	**378.1**	**536**
Elbasan	–0.88	119006	87.1	377
Fier	–0.85	130659	157.7	556
Gjirokastër	–0.70	37216	21.8	548
Korçë	–0.44	89262	56.6	405
Kukës	–0.52	30612	32.6	327
Lezhë	–0.86	86005	78.3	401
Shkodër	–0.90	100128	57.6	403
Tiranë	**0.91**	**613518**	**538.0**	**747**
Vlorë	–0.74	127034	69.9	454

[1] Data for column belong to 2015. [2] Data for column belong to 2017. [3] (pers / km^2), data for column belong to 2018.
Source: INSTAT

Based on the values in Table 2 column *correlation* the geographical dispersion (Fig. 12), the relationships between the correlations between *urban waste* and *population* were produced. There is a strong positive correlation in the area around the capital and a negative correlation in the rest of Albania.

Discussion

The reason for analysing SW data using ArcGIS mapping software is to provide forecasts supported by geospatial technology. Poor solid waste management leads to serious environmental issues. According to (Ardian-

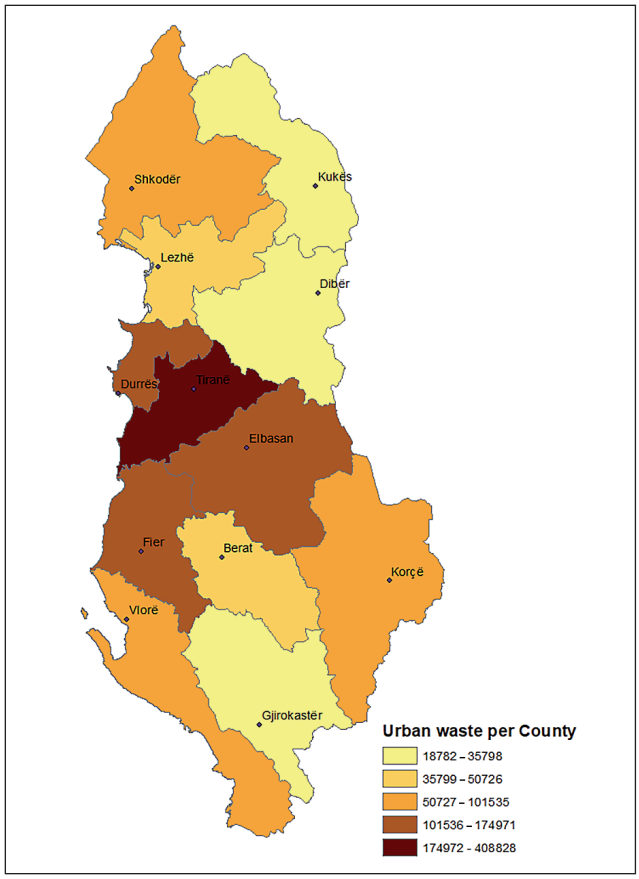

Fig. 9 Waste generation per county (tons/year).

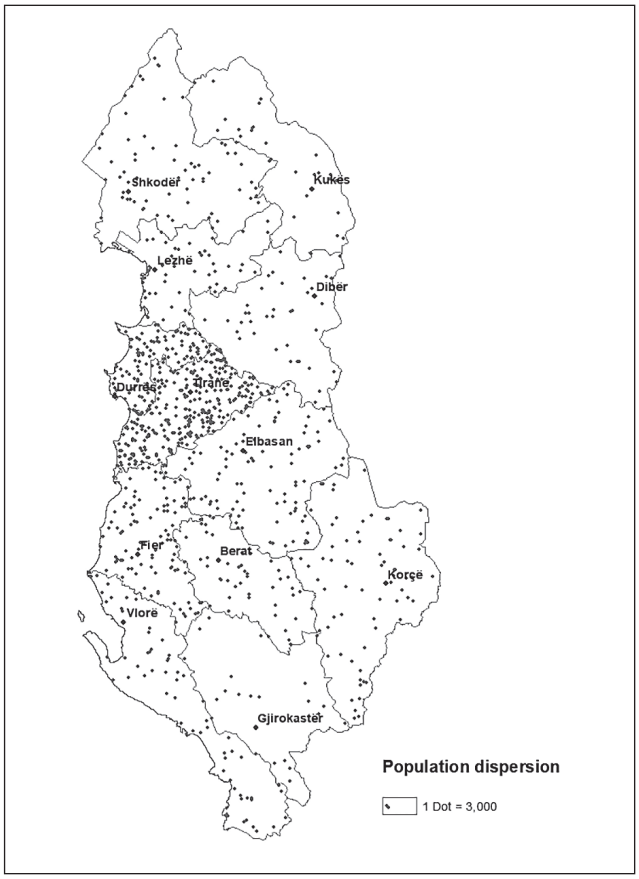

Fig. 10 Population dispersion per county.

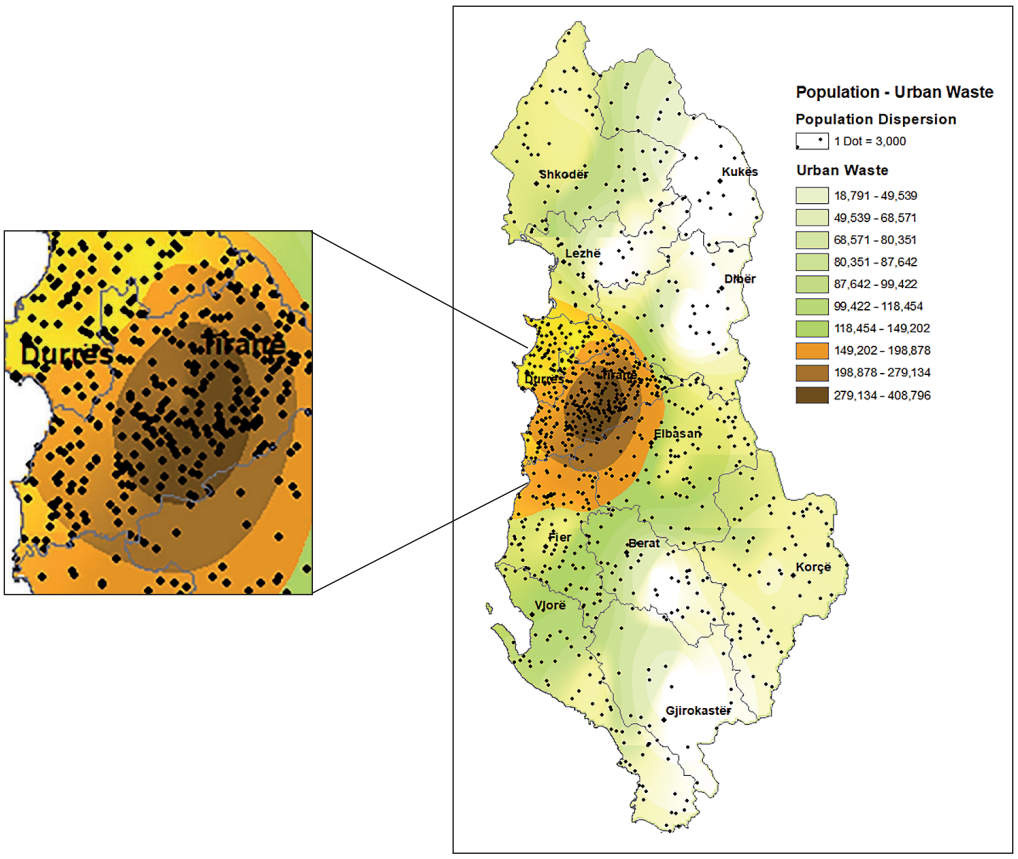

Fig. 11 Population dispersion – waste generation per county (tons/year), IDW interpolation.

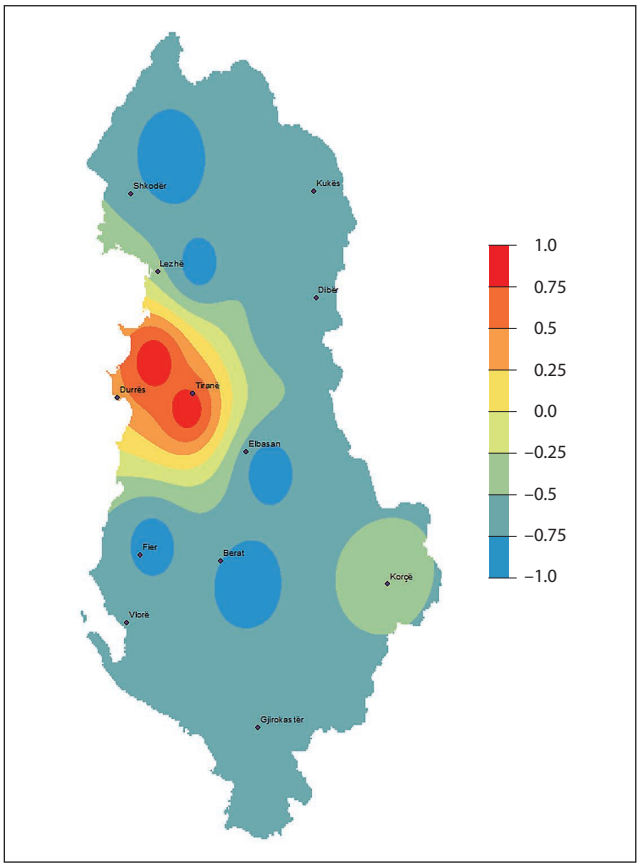

Fig. 12 Correlation between population dispersion and waste generation per county. IDW interpolation (time span 2003–2018).

syah and Maryono 2018), to be able to identify influential factors and the spatial distribution pattern of waste, it is necessary to use a statistical and spatial approach. The results presented, similar to those of Mushtaq et al. (2020), show that SW management varies from region to region, due to factors, such as demographic, socio-economic and accepted policy. Several studies (Kukula 2016; Ghosh and Ng 2021) indicate that waste management strategies depend on the approach of each administrative unit to the most decisive factors. We found a significant correlation in most of the administrative units, which can be used to implement decision-making strategies in each of them. The results indicate that correlation for waste generation *per capita* is stronger (R = 0.989) than for waste generation per county (R = 0.233). Although the correlation coefficients are both positive, they reveal that SW depends on geographical dispersion. In other words, SW is spatially dependent. The highlighted counties in Table 2 have the highest population densities and positive correlation coefficients for SW. The other administrative units had negative correlation coefficients due to lower population numbers. This study lacks data on sub administrative units, which would help us to better understand the detailed dynamics of waste management and the effect of socio-economic factors. Based on the data presented, policies can be implemented for counties, which may not be appropriate for sub administrative units. In the future, it would be of interest to expand the study to smaller ad-

ministrative units and then determine whether the correlation formula follows the same trend as the presented data or if it behaves differently.

Conclusion

This paper presents the results of a study on the characteristics and trends in the generation of solid waste in Albania. Geographic and mathematical methods were used to classify the first-level administrative division, the counties. The areas of interest are counties with positive correlation between year and population size. This study reveals the most important variables affecting the amount of waste generated and presents a predictive scenario for a spatiotemporal interpretation. At a comparative level, we focused this investigation on economic and demographic variables determining waste per capita and per county. There is a steady trend between waste generated and economy (moderate – strong), which indicates it is an important factor. The importance of demographic variables are divided into (low – strong) for the population variable and (moderate – strong) for urban and density variables. Although the dependent variable, waste per county, is strongly correlated with population density, the waste per capita is not associated with population growth.

The data analysed indicates the specific dynamics at the country level and also in each county. During the last fifteen years, there was a general increase the amount of SW generated in all counties, which is not reflected in population density. The population growth in the counties Tirana and Durrës was positive whereas in other counties it decreased. The linear correlations for the relationships are either strongly positive or negative. We conclude that both the demographic factor (pop. density) and economic factor (GDP per capita) play an important role in determining this relationship. In addition, the role of internal policy regarding waste management needs to be considered. The results of this study can be used to predict urban waste generated at the county level.

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