Methodology for estimating biowaste generation using municipal rurality indexes

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Abstract

The separate collection and management of biowaste (BW) must be implemented in next years in the European countries. In order to define a properly BW strategy, it is necessary to estimate the generation at a municipal level, since depending on the amount to be treated, the strategy may notably vary. The aim of this study is to develop a methodology to estimate the BW generation at municipal level, taking into account the characteristics of the region, the Municipal Solid Waste (MSW) management applied, and different socio-economic variables that define the level of rurality of a municipality.

A model to estimate the BW generation for each type of municipality has been developed using Multiple Linear Regression Analysis. As input data has been used, on the one hand, results from a Waste Compositional Analysis used for estimating the BW fraction of the mixed waste collected; and on the other hand, data of socioeconomic variables that have demonstrated to influence the generation of waste. Significant influence of socioeconomic variables on the level of BW generated is observed for the rural municipalities.

Statement Of Novelty

The novelty of this study lies in the development of a methodology to estimate the BW generation at municipal level, considering the characteristics of the region, the Municipal Solid Waste (MSW) management applied, and different socio-economic variables that define the level of rurality of a municipality. A model to estimate the BW generation for each type of municipality has been developed using Multiple Linear Regression Analysis.

1. Introduction

According to the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste [1], Biowaste (BW) is defined as *"biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, caterers and retail premises and comparable waste from food processing plants"*. Even though this Directive has been modified by the Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018, which amends the Directive 2008/98/EC on waste [2], the definition of BW has remained untouched. This waste flux is formed by (i) food waste (FW) formed by edible and inedible fractions of food, (ii) small vegetal fractions derived from gardening and pruning, and (iii) bigger pruning waste [3, 4]. While small vegetal fractions are generally generated in households, bigger pruning waste are generated in residential areas, gardens and parks. Furthermore, food waste can be generated during (i) food production, (ii) manufacturing, (iii) retail and (iv) consumption in the services sector and in households [5]. However, the food waste that is included in the BW definition established in the European Directives, excludes the waste generated during production.

The Directive 2018/851 [2] incorporates important modifications in relation to BW collection and management for all Member States:

- By 31 December 2023, BW must be collected separately, or separate and recycled at source, but never mixed with other types of waste.
- From 1 January 2027, BW entering aerobic or anaerobic treatment will be count as recycled, only if it has been separately collected or separated at source.
- As a consequence, home composting must be encouraged.

Due to these modifications, significative changes must be made to the Municipal Solid Waste (MSW) collection system. Given that till now, a high proportion of BW (food waste and small vegetal fractions) has been collected mixed with other types of MSW (paper, glass, metals, wood, cloths, etc...), the implementation of a new collecting bin, and the encouragement of home composting must be executed before 31 December 2023.

It is necessary to estimate the BW generated to stablish a proper new collection and management scheme. The main difficulty lies in the fact that small vegetal fractions and food waste are still collected in many regions mixed with other types of waste and establishing the estimation method is a critical step in the decision-making process.

The biowaste generation and therefore the management strategy that must be developed in next years will be closely related with the type of municipality, urban or rural, so first it is needed to define the typology of the municipalities. Depending on the characteristics of each region and municipality, the chosen collecting system for each of them will notably vary [6]. The rurality index is a helpful tool that can help the decision-makers to include this in the decision-making process.

1.2 Rurality Index

Currently, there is an open debate about what being "rural" means, so a definition of this concept is needed in order to optimize resource allocation and ease decision making [7]. Therefore, there is no standardized methodology that can be used to obtain a rurality index for a region, neither the variables associated to this concept. Population density has been traditionally used as an indicator to distinguish between (i) urban, (ii) intermediate and (iii) rural areas [8, 9]. This has been used by the OECD [10], who established in 1961 this criterion to consider as rural any area whose population density is lower than 100 inhabitants per Km².

At a national level, in Spain, The White Book of Agriculture and Rural Development [11] classifies the areas that form the regions into (i) mainly rural, (ii) rural, (iii) semi-rural and (iv) urban, depending on the population density and the intensity of agriculture and livestock. In addition, Prieto-Lara and Ocaña-Riola [7], López-Ratón and Santiago [12] and Ocaña-Riola and Sánchez-Cantalejo [13] executed studies in which a specific rurality index was developed for a specific region, considering demographic, economic and environmental variables.

These studies do not include in their definitions of rurality all the variables that are related to the generation of biowaste, so a new index of rurality, adapted to the characteristics sought, must be developed.

1.3 Biowaste estimation methods

For each type of municipality, it will be necessary to make an estimation of the amount of biowaste generated and for that, the most appropriate estimation method must be selected.

The variety of methods used to estimate biowaste generation is wide. Xue et al. [14], classify these methods into two categories: (i) direct methods based on first-hand data, and (ii) indirect methods derived from secondary data. Among them, three methods that are frequently used are (i) Waste Compositional Analysis (WCA), (ii) using existing data, and (iii) modelling.

WCA is a direct method, commonly used to determine the composition of waste streams collected by local authorities [15]. An example of this method is the characterisation of the food waste generated by households, taking data from the collecting bins by those who will execute the quantification [16].

An indirect method widely applied is using existing data, as ratios. This is the easiest, cheapest and quickest among all methods. These ratios are obtained from another case studies, databases or statistics. However, its accuracy depends on the reliability of the source of data [14]. This is related to its main drawback, which is that the data used to execute the estimations might be very different, depending on how it was initially obtained.

Mathematical, statistical or computational models are indirect methods that calculate biowaste generation quite efficiently. Their main advantage is that they allow the inclusion of climatic phenomena, agricultural statistics or other variables with influence, for example, on the different Food Supply Chain Stages [17], as well as the characteristics of the region or municipality in which the study is being executed.

Different models have been used to estimate and predict MSW generation, such as Multiple Linear Regression Analysis (MLRA), Artificial Neural Networks (ANN) or Autoregressive Integrated Moving Average (ARIMA) [18]. A combination of ANN and MLRA has been used by Azadi and Karimi-Jashni [19] to predict MSW generation, and the obtained results showed that ANN is more precise to make this prediction than the MLRA.

Regression analyses have been used by Grazhdani [20] and it was considered adequate to study the different socio-economic variables that affect the generation of this waste flux. On the other hand, the ARIMA model, has been used by Owusu-Sekyere et al. [21] and Mwenda et al. [22] for the same purpose, and the conclusion extracted from the results is that this model is the most appropriate model to forecast MSW generation. One of the main characteristics of this method, is that to be used, the evolution of the temporal series must be similar to the one had in the past [23].

Although the use of ANN is considered the most accurate and feasible when it comes to estimate and predict waste generation, it requires a high amount of data that are not always available, especially if these data correspond to variables at a local level. In addition, to use ANN a deep knowledge of the tool is needed due to its complexity. MLRA is a quite simple statistical method that allows estimating BW, but not requiring that amount of data, and considers paramount socio-economic variables of each municipality.

The aim of this study is to develop a methodology to estimate the BW generation at municipal level, taking into account the characteristics of the region, the Municipal Solid Waste (MSW) management applied, and different socio-economic variables that define the level of rurality of a municipality. A model to estimate the BW generation for each type of municipality has been developed using Multiple Linear Regression Analysis based on the results of a Waste Compositional Analysis executed over 38 municipalities.

2. Methodology

In the Fig. 1 the methodology developed to estimate the BW generation is shown. The different aspects covered by the methodology are explained in detail in the corresponding sections of the methodology.

Figure 1 Methodology developed to estimate the BW generation at a Municipal level

2.1 Characteristics of the Region

Cantabria is a small region of 5.300 Km² located in the north of Spain, and it is formed by 102 municipalities that are distributed in three major areas: the coast, the centre and the south. According to the regional statistics office, 582.206 people lived in this region during 2016 [24], although a high proportion of its population is concentrated in the coastal area, where the two main urban areas (Santander and Torrelavega) are located [25]. In addition, during summer, these coastal areas receive people from other Spanish regions who have a second house in Cantabria, so, population in these municipalities significantly grows. This means that population in Cantabria is not homogeneously distributed: while the municipalities located in the coastal areas have a high population density, those in the centre and south have a notably lower population density.

In coastal areas, the most developed activities are related to the services sector, representing the 70% of the regional production, and industry, which represents the 22% of the regional production. On the other hand, in the centre and south of Cantabria, population are dedicated to agriculture and livestock, which represents the 1%-2% of the regional production [25]. This entails that younger people and immigrants tend to live in municipalities located in the coastal areas, where job opportunities are more numerous and related to industry and services.

As it has been mentioned, the municipalities, due to the area in which they are located, have very different socio-demographic and economic characteristics that define them, such as (i) population density, (ii) ageing rate, (iii) youth rate, (iv) immigration index, (v) people working in primary (vi) industry and (vii) services sector.

2.1.1 MSW management

According to the Spanish law 22/2011, of wastes and contaminated soils [26], local entities must provide the collecting, transport and management of the MSW generated in households and stores.

In Cantabria, MSW is collected using 4 kerbside bins: (i) a grey bin for mixed MSW, (ii) a yellow bin for plastic and metal packaging, (iii) a blue bin for cardboard packaging and paper, and (iv) a green bin for glass packaging. Vegetal oils and clothing are also collected in different kerbside bins that are located, in a lower proportion, in specific areas of the municipalities. In addition, there is also a network of green points where specific wastes can be left to ease their selective collection (e.g., furniture, bulky waste, electronic devices or electrical household appliances).

Currently, the biodegradable fraction of the MSW (excluding bigger pruning waste), which is formed by food waste and small vegetal fractions, is collected in the grey bin mixed with other waste materials that were not deposited in a selective collection bins by citizens. These mixed MSW are transported and managed in a central MSW facility (Meruelo) where the biowaste is separated from the other MSW materials using a trommel, and then composted. The rejections produced after the composting process are incinerated to produce energy [27]. However, according to the Directive 2018/851 of the European Parliament [2], this collection and management will no longer be adequate and must be defined a new strategy that collect and manage biowaste separately.

2.2. Rurality Index

Due to the different characteristics of the municipalities of Cantabria, that greatly condition the future biowaste management strategy, for this study, to classify the 102 municipalities 5 categories have been set depending on their rurality degree: (i) Urban, (ii) Semi-Urban, (iii) Semi-Rural, (iv) Rural and (v) Rural*.

To do the classification a rurality index has been developed, taking into account the independent socio-economic variables that reflect the level of rurality of a municipality. Variables related to the three dimensions of sustainability should be considered, to obtain an index as complete as possible.

In this study, some of the variables suggested by Prieto-Lara and Ocaña-Riola [7], López-Ratón and Santiago [12], Quintá and Arce [28] and Lasarte-López et al. [29], have been considered, taking into account the data availability for Cantabria: (i) Population Density (PD, hab/Km²); (ii) Senior Index (SN, %); (iii) Junior Index (JN, %); (iv) Primary Sector Working Index (S1, %); (v) Industry Working Index (S2, %); (vi) Immigration Index (IM, %); (vii) Economic Dependency Index (ED, %); and (viii) Retirement Index (RI, %). The necessary data to calculate these variables for each municipality have been obtained from the regional statistics office [24].

Before the analysis execution, it is necessary to ensure that (i) the variables are continuous, (ii) the sample size is large enough, and (iii) the variables follow a normal distribution [30]. The statistical method applied was the Factorial Analysis [7, 12], that delivers a linear function as a result, that relates the independent variables, weighting the influence of each one. To obtain these weights, the Principal Component method was used, whose objective is to gather the information of a specific number of variables into a lower number of components or factors, orthogonal among each other [12]. Once these factors are extracted, the rotation of their values is executed, using the *Varimax* rotation and the *Kaiser* normalization. Then, the final weights, and the linear function that provide the rurality index is obtained.

The results obtained were standardised, using the Eq. 1, so their values will vary between 0 and 1:

$$RI_{standard} = \frac{(RI_i - RI_{min})}{(RI_{max} - RI_{min})} \text{ (Eq. 1)}$$

To classify the 102 rurality indexes into the 5 categories that have been established, a *Conglomerate Analysis* is executed and using the *Ward* method.

All statistical analysis has been executed using SPSS (IBM) Software.

2.3 Biowaste estimation

The collection companies provide data related to MSW collection (grey bin) in each of the 102 municipalities of Cantabria. It is necessary to define the ratio of biowaste composition in MSW for each municipality and its evolution over time.

Periodically, the regional Ministry of Environment develops and updates the Waste Plan of Cantabria, in which the current outlook of waste in the region is presented. In that section, a global characterisation of the MSW generated in the region is provided. The percentage of BW collected in the grey bin provided by the Waste Plan [27] has been used to estimate BW in the region for years. However, this ratio has been obtained from a single compositional analysis of municipal waste from the whole region, so its use to estimate biowaste at the municipal level entails a significant error.

In this study, a new methodology is proposed to estimate the BW generation at municipal level, modelling different socio-economic variables that in different studies have shown an impact on the generation of biowaste and that can be obtained at the municipal level. Two aspects of the methodology must be highlighted: (i) In order to apply the modelling to the socio-economic variables, it is necessary to have a complete characterization of the waste generated in the different municipalities; (ii) Once the modelling has been carried out, it can be used to estimate the BW of each municipality, using the socioeconomic variables of each year, without the need to carry out further characterizations or wait for the collection data from the companies involved.

In Table 1 the characteristics of the estimation methods considered, existing data, previously applied, Waste compositional analysis to characterize at municipal level the MSW composition and the modelling developed in this study, are collected.

Table 1 Summary of the characteristics of the potential BW estimation methods

Method	Input Data	Source	Estimation Level	Calculation	Results
Existing data	BWF	Regional Waste Plan (2010)	Region	$BW_i = BWF \times MSW_i$	Estimation of BW at municipal level with a regional ratio
	MSWi	Collection Companies (2012-2017)			
Waste Compositional Analysis	BWF (38 of 102 municipalities): BWFj	Waste Compositional Analysis (2016), Rural Index	Rurality/ Municipality	$BW_{ij} = BWF_j \times MSW_{ij}$	Estimation of BW at municipal level with a rural index based ratio
	MSWi	Collection Companies (2012-2017)			
Modelling	BWi,j PDi,j, SNi,j, JNi,j, Rii,j, S1i,j, S2i,j, S3i,j	Waste Compositional Analysis (2016), Rural Index Regional Statistics office	Rurality/ Municipality	$BW_{ij,m} = f(PD_{ij,m}, SN_{ij,m}, JN_{ij,m}, Rii,j,m, S1_{ij,m}, S2_{ij,m}, S3_{ij,m})$	Estimation of BW at municipal level with a modelled function based on socio-demographic variables

BWF: Biowaste Fraction; MSW: Municipal Solid Waste collection; BW: Biowaste estimation; PD: Population Density; SN: Senior Index; JN: Junior Index; RI: Retirement index; S1: people working in the primary sector; S2: people working in industry sector; S3: people working in service sector; i: municipality; j: rurality level; m=year

2.3.1 Waste Compositional Analysis

Data from the characterization of the waste generated in different municipalities have been obtained. The analysis of 26 samples of the MSW (collected during July and August 2016) from different municipalities and transfer stations was executed. This characterisation determined the percentage of each waste material in the sample: (i) Food waste, (ii) small vegetal fractions, (iii) wood, (iv) packaging waste, (v) paper, (vi) glass, (vii) clothes, (viii) metals, (ix) plastics and (x) hazardous waste. As a result, with the 26 samples, the waste from 38 municipalities have been characterized (considering the transfer stations). This characterisation does not provide information of the 102 municipalities, so, for those municipalities whose percentage of biowaste is not provided, the percentage of biowaste of another municipality with the same or similar Rurality Index has been ascribed.

2.3.2 Statistical modelling

Considering the availability, characteristics, quantity of data, and the purpose of the study, the chosen model to estimate BW generation in Cantabria was the Multiple Linear Regression Analysis (MLRA) since this method is accurate enough to make the estimation with small economic and time-consuming costs. Data from the Waste Compositional Analysis and a number of socio-economic variables that have influence on BW generation have been used. MLRA provides a tool that allows to estimate the generation of biodegradable waste, regardless of whether the socioeconomic situation changes over time.

Given that the number of municipalities is not high enough to develop one equation per category, only two MLRA have been developed: one for rural municipalities (including municipalities defined as Rural +, Rural and Semi-rural), and another one for urban municipalities (including Urban and Semi-Urban).

In order to obtain a linear relation between the independent and dependent variables, some of them need to be transformed into their logarithmic form. The potential collinearity problems among the independent variables are identified analysing the coefficients related to collinearity among variables: Tolerance and the Variance Influence Factor (VIF). The chosen method to introduce the variables into the equations is the INTRO method, which includes all the considered variables in the analyses.

3. Results

3.1 Rurality Index

In order to obtain a rurality index taken into account the socio-economic characteristics selected, a *Factorial Analysis* has been executed. As a result, the software SPSS provides the rotated component matrix (Table 2), in which the considered variables, as well as their lineal relation are presented.

Table 2
Rotated component matrix

Socio-economic variables	COMPONENT	
	1	2
Senior Index	- 0,914	-
Junior Index	0,900	-
Population Density	0,887	-
People working in agriculture and Livestock	- 0,866	-
Retirement Index	- 0,736	-
Immigration Index	-	-
Economic Dependency Index	-	-
People working in the industry	-	0,882

Table 2 Rotated component matrix

Two different components have been defined. According to the values collected in the rotated component matrix, the rurality index of each municipality is a lineal combination of the variables selected as influential in the *Factorial Analysis*:

$$RI_i = 0,9_{JN_i} + 0,887_{PD_i} + 0,882_{S2_i} - 0,736_{RI_i} - 0,866_{S1_i} - 0,914_{SN_i} (Eq. 4)$$

The immigration index and the economic dependency index are not influential enough in the rurality of Cantabria to be included in the index definition. On the other hand, junior index, population density and people working in the industry have positive influence on the rurality index; while the senior index, retirement index and people working in the agriculture and livestock sector have negative influence. These are the variables that are usually associated to rural areas: aged population that are highly dependent on agriculture and livestock activities. This entails that, the lower the rurality index, the more rural the area is and vice versa.

Using Eq. 4, the rural index of the 100 municipalities that are not defined as urban in Cantabria, have been calculated. To categorise these 100 municipalities, a *Conglomerate Analysis* has been executed, using the rurality indexes calculated with Eq. 4 and having fixed 4 clusters: semi-urban, semi-rural, rural and rural⁺. As a result, the SPSS software provided the classification of the 100 municipalities into the 4 categories that correspond to the fixed clusters. These results are associated to the map of Cantabria, in which the 102 municipalities are represented, in Fig. 2.

As it is shown in Fig. 2, Cantabria is mainly rural, given that the vast majority of the region, the 97% of the total area, is semi-rural, rural or rural⁺, while only the 3% is urban or semi-urban. On contrast, 56% of the population lives in urban and semi-urban areas, while the 44% is located in rural areas. Rural⁺ municipalities are especially unpopulated areas, provided that they span the 64% of the total area of Cantabria but only the 6% of the population lives there.

Figure 2 Classification of the municipalities of Cantabria depending on their rurality index

3.2. Waste Compositional Analysis (WCA)

The percentage of BW in the grey bin (food waste and small vegetal fractions) obtained through this method varies between the 19% and the 68%. In general, the results obtained show that the highest percentages of BW in the grey bin (38%-56%) correspond to urban, semi-urban and semi-rural municipalities, while the lowest ones (< 35%) correspond to rural and rural⁺ municipalities. The maximum, minimum and mean values are presented in Table 3. These values coincide with the percentages provided by the Spanish Ministry of Agriculture and Environment [31]: at a national level the average percentage of BW in the grey bin in Spain is 44%, while the values in the Spanish regions varies between 30% and 65%.

Table 3 Percentage of Biowaste on the MSW of each type of municipalities

	Max	Min	Mean
Urban	56	19	37
Semi-Urban	53	24	37
Semi-Rural	47	25	33
Rural	47	24	33
Rural +	37	24	31

However, there are some outliers in the results that need to be deeply studied. On the one hand, the municipalities with the highest percentages of BW, are 6 rural and 1 semi-rural municipalities in which a high proportion of small vegetal fractions are thrown away (60% of the total MSW generated). Although the reasons why these percentages are so high have not been reported. They might be related to the characteristics of the residential areas of these municipalities,

and to the fact that many people have their second home in these municipalities and may have executed maintenance works in their households during the execution of the WCA (summer). On the other hand, the lowest percentage of BW corresponds to the capital of the region, where almost no small vegetal fractions are thrown away (0,16%), and a low proportion of food is wasted (18%). This value is highly improbable, but since no anomaly has been reported in the sampling, it has been included in the study.

3.3 Statistical modeling (MLRA)

The relation among the BW generation obtained using WCA, and a selection of variables that have influence on it representing the socio-economic situation of the area, have been considered to execute the MLRA: (i) population density (PD, inh/Km²), (ii) senior index (SN, %), (iii) junior index (JN, %), (iv) retirement index (RI, %), (v) people working in agriculture and livestock (S1, %), (vi) people working in the industry (S2, %) and (vii) people working in the services sector (S3, %). In Table 4 of the Appendix, the input data of the MLRA are collected: the value of these variables, as well as the BW generation, that correspond to each municipality in 2016.

Table 4
Input data of the MLRA

MUNICIPALITY	RI	CATEGORY	BW WCA (t/year)	PD (inh/Km ²)	SN (%)	JN (%)	RI (%)	S1 (%)
39001 - Alfoz de Lloredo	0,027	Rural	362,09	53,26	25,91	10,42	26,16	7,18
39002 - Ampuero	0,048	Rural	740,57	129,44	20,23	15,38	21,55	4,16
39003 - Anievas	0,015	Rural +	95,44	15,02	32,48	5,10	37,26	17,65
39004 - Arenas de Iguña	0,020	Rural +	95,44	19,71	28,35	7,66	28,81	9,84
39005 - Argoños	0,085	Semirural	888,09	312,73	15,17	14,59	16,92	7,04
39006 - Arnauero	0,034	Rural	888,09	84,66	22,00	11,76	22,14	9,87
39007 - Arredondo	0,009	Rural +	66,10	10,26	33,33	7,29	32,50	32,90
39008 - Astillero (El)	0,122	Semi-urban	1743,05	495,46	15,90	16,04	16,27	0,65
39009 - Bárcena de Cicero	0,044	Rural	731,58	112,68	16,68	15,91	19,06	7,01
39010 - Bárcena de Pie de Concha	0,020	Rural +	95,44	23,28	28,31	7,75	27,61	10,04
39011 - Bareyo	0,030	Rural	888,09	61,70	19,96	13,21	20,41	14,65
39012 - Cabezón de la Sal	0,071	Semirural	843,58	248,36	17,62	14,81	19,62	2,63
39013 - Cabezón de Liébana	0,012	Rural +	64,61	7,38	30,78	9,98	26,29	25,15
39014 - Cabuérniga	0,013	Rural +	142,38	11,70	31,82	8,10	27,47	21,43
39015 - Camaleño	0,013	Rural +	177,58	6,04	27,02	8,80	26,92	22,85
39016 - Camargo	0,784	Semi-urban	4468,02	3826,38	16,84	15,79	18,46	0,66
39017 - Campoo de Yuso	0,015	Rural +	100,82	7,76	26,58	12,79	25,72	25,42
39018 - Cartes	0,086	Semirural	427,23	301,74	10,03	20,93	11,32	0,93
39019 - Castañeda	0,052	Rural	347,63	136,40	13,70	17,38	14,55	2,40
39020 - Castro-Urdiales	0,089	Semirural	3557,60	329,90	14,12	16,82	15,32	1,61
39021 - Cieza	0,020	Rural +	32,22	12,64	34,17	9,53	29,86	9,09
39022 - Cillorigo de Liébana	0,019	Rural +	126,93	12,54	21,45	13,28	20,76	12,07
39023 - Colindres	0,275	Semi-urban	693,22	1262,27	16,98	16,43	18,51	4,08
39024 - Comillas	0,039	Rural	365,99	119,78	27,24	10,73	23,38	8,11
39025 - Corrales de Buelna (Los)	0,071	Semirural	917,60	242,36	20,91	14,43	21,24	2,33
39026 - Corvera de Toranzo	0,026	Rural	186,98	41,90	23,72	11,04	24,83	9,05
39027 - Campoo de Enmedio	0,030	Rural	398,41	41,47	22,76	13,31	25,20	4,36
39028 - Entrambasaguas	0,046	Rural	752,23	114,42	12,89	19,16	14,12	8,70
39029 - Escalante	0,025	Rural	888,09	39,11	27,98	12,72	28,11	11,97
39030 - Guriezo	0,027	Rural	395,61	31,66	19,50	15,26	20,26	12,29
39031 - Hazas de Cesto	0,034	Rural	284,22	69,50	17,87	14,45	19,97	11,49
39032 - Hermandad de Campoo de Suso	0,018	Rural +	212,76	7,38	26,35	7,85	23,98	16,50
39033 - Herrerías	0,013	Rural +	79,63	15,91	34,17	7,02	27,30	23,46
39034 - Lamasón	0,001	Rural +	19,27	4,19	41,61	3,69	36,58	45,45
39035 - Laredo	0,187	Semi-urban	4020,01	847,85	25,32	10,87	26,90	2,76
39036 - Liendo	0,028	Rural	200,81	47,19	22,66	15,57	23,06	4,07
39037 - Liérganes	0,030	Rural	888,09	64,63	22,81	10,37	23,65	9,81
39038 - Limpias	0,057	Rural	268,86	178,44	17,87	14,40	18,42	3,28
MUNICIPALITY	RI	CATEGORY	BW WCA (t/year)	PD (inh/Km ²)	SN (%)	JN (%)	RI (%)	S1 (%)

MUNICIPALITY	RI	CATEGORY	BW WCA (t/year)	PD (inh/Km ²)	SN (%)	JN (%)	RI (%)	S1 (%)
39039 - Luena	0,009	Rural +	42,34	6,80	33,82	5,85	35,45	26,56
39040 - Marina de Cudeyo	0,055	Rural	868,57	181,54	20,82	12,31	23,13	5,12
39041 - Mazcuerras	0,027	Rural	264,42	38,11	20,06	13,21	20,48	7,78
39042 - Medio Cudeyo	0,078	Semirural	1056,17	279,18	17,09	15,00	18,34	3,00
39043 - Meruelo	0,049	Rural	362,66	119,82	12,47	17,00	9,77	6,33
39044 - Miengo	0,060	Rural	995,26	193,51	17,63	13,08	18,52	2,09
39045 - Miera	0,012	Rural +	35,45	11,69	31,65	5,32	36,96	20,00
39046 - Molledo	0,017	Rural +	95,44	22,35	32,28	7,61	32,03	15,23
39047 - Noja	0,075	Semirural	1578,60	278,48	17,99	14,25	17,37	1,99
39048 - Penagos	0,034	Rural	273,22	65,05	20,78	13,40	20,78	5,98
39049 - Peñarrubia	0,009	Rural +	36,22	3,90	37,54	6,59	22,92	26,23
39050 - Pesaguero	0,009	Rural +	22,10	4,44	32,48	10,61	33,44	25,74
39051 - Pesquera	0,020	Rural +	6,94	0,88	35,21	4,23	28,17	11,11
39052 - Piélagos	0,080	Semirural	2165,91	277,36	12,30	19,72	13,60	1,68
39053 - Polaciones	0,006	Rural +	16,46	2,64	32,91	6,33	25,32	49,25
39054 - Polanco	0,072	Semirural	820,40	236,49	14,45	17,88	15,74	1,21
39055 - Potes	0,052	Rural	269,22	178,95	25,59	10,37	23,01	2,01
39056 - Puente Viesgo	0,037	Rural	401,20	79,70	20,09	15,61	19,74	5,40
39057 - Ramales de la Victoria	0,037	Rural	283,85	85,67	21,72	12,20	23,56	5,52
39058 - Rasines	0,018	Rural +	95,62	22,35	25,86	10,84	27,32	22,05
39059 - Reinosa	0,480	Semi-urban	1466,42	2316,10	28,68	9,93	29,43	1,05
39060 - Reocín	0,074	Semirural	1328,92	259,13	16,77	15,76	17,67	2,35
39061 - Ribamontán al Mar	0,042	Rural	1193,66	119,84	20,15	14,11	18,70	9,18
39062 - Ribamontán al Monte	0,028	Rural	888,09	52,87	21,92	12,82	23,08	12,33
39063 - Rionansa	0,012	Rural +	144,93	8,97	35,35	5,77	30,81	13,66
39064 - Riotuerto	0,027	Rural	213,42	52,79	23,54	11,68	26,27	13,42
39065 - Rozas de Valdearroyo (Las)	0,018	Rural +	31,93	4,79	26,18	6,91	14,91	10,71
39066 - Ruate	0,020	Rural +	116,35	15,84	24,52	11,21	21,55	10,62
39067 - Ruesga	0,012	Rural +	102,87	9,89	30,80	5,98	31,95	26,53
39068 - Ruiloba	0,024	Rural	285,95	50,66	26,80	8,89	26,14	7,53
39069 - San Felices de Buelna	0,034	Rural	160,97	65,77	21,84	13,78	22,51	4,13
39070 - San Miguel de Aguayo	0,007	Rural +	14,29	4,44	26,25	8,13	23,75	48,84
39071 - San Pedro del Romeral	0,000	Rural +	23,37	7,89	33,55	7,51	66,45	44,44
39072 - San Roque de Riomiera	0,013	Rural +	35,48	10,87	27,20	8,03	17,62	31,67
39073 - Santa Cruz de Bezana	0,169	Semi-urban	1385,43	732,89	13,88	16,30	15,01	0,85
39074 - Santa María de Cayón	0,062	Rural	1076,67	189,92	15,55	16,16	17,20	4,36
39075 - Santander	-	Urban	10563,14	4933,03	23,42	11,93	22,95	0,46
39076 - Santillana del Mar	0,052	Rural	544,79	164,08	20,79	12,81	21,77	5,27
MUNICIPALITY	RI	CATEGORY	BW WCA (t/year)	PD (inh/Km ²)	SN (%)	JN (%)	RI (%)	S1 (%)
39077 - Santiurde de Reinosa	0,011	Rural +	37,06	8,55	36,60	4,91	26,42	35,71
39078 - Santiurde de Toranzo	0,026	Rural	156,31	41,29	25,47	9,93	25,53	10,29

MUNICIPALITY	RI	CATEGORY	BW WCA (t/year)	PD (inh/Km ²)	SN (%)	JN (%)	RI (%)	S1 (%)
39079 - Santofía	0,212	Semiurbano	2110,77	963,91	20,88	13,04	24,80	4,75
39080 - San Vicente de la Barquera	0,035	Rural	578,10	102,34	22,76	10,68	24,14	12,61
39081 - Saro	0,017	Rural +	27,21	28,76	29,49	9,57	30,47	29,31
39082 - Selaya	0,025	Rural	168,26	49,13	23,82	10,56	26,51	17,00
39083 - Soba	0,006	Rural +	119,16	5,83	28,74	6,57	31,31	52,69
39084 - Solórzano	0,021	Rural +	151,99	39,69	23,22	11,76	26,09	25,07
39085 - Suances	0,091	Semirural	1569,04	348,74	18,13	15,06	17,90	2,69
39086 - Tojos (Los)	0,011	Rural +	45,59	4,46	30,08	6,77	23,31	28,04
39087 - Torrelavega	-	Urban	9465,93	1487,86	23,30	12,45	23,84	0,99
39088 - Tresviso	-	-						
39089 - Tudanca	0,009	Rural +	13,93	2,81	29,93	1,36	27,89	29,27
39090 - Udías	0,029	Rural	67,31	46,07	17,61	13,62	19,93	8,31
39091 - Valdáliga	0,019	Rural +	497,32	23,23	25,44	11,05	24,82	15,85
39092 - Valdeolea	0,013	Rural +	117,07	11,79	33,94	5,37	37,69	16,67
39093 - Valdeprado del Río	0,012	Rural +	38,91	3,71	33,84	5,14	21,75	21,15
39094 - Valderredible	0,010	Rural +	191,27	3,36	29,77	8,09	24,08	30,64
39095 - Val de San Vicente	0,028	Rural	379,67	54,28	21,25	13,21	21,46	12,65
39096 - Vega de Liébana	0,008	Rural +	52,30	5,91	35,03	7,61	33,76	30,23
39097 - Vega de Pas	0,012	Rural +	54,32	9,09	29,31	8,30	31,32	26,45
39098 - Villacarriedo	0,019	Rural +	246,76	32,27	27,57	10,45	26,89	27,29
39099 - Villaescusa	0,050	Rural	310,49	138,68	17,95	15,22	16,04	3,20
39100 - Villafufre	0,021	Rural +	130,49	33,79	25,27	10,32	26,75	21,16
39101 - Valle de Villaverde	-	-						
39102 - Voto	0,025	Rural	419,33	35,07	22,64	11,78	23,63	16,00

Given that these variables are expected to have very different relations to BW generation depending on the rurality of the municipalities, different equations must be developed. However, only two equations have been developed, one for urban municipalities and other for rural ones due to the amount of data is not enough to develop one equation per type of municipality.

After different analyses to identify co-linearity problems, and the need of transformation to normal distributions of the variables, different mathematical methods (INTRO, STEPWISE) have been tested. After these analyses, the need to transform the variables into their logarithmic form was identified, the exclusion of some variables for urban municipalities due to co-linearity problems and the choice to use the method INTRO were made. As a result, the following statistical parameters, for the two MLRA have been obtained (Table 5):

Table 5
Coefficients for BW generation estimation

MODEL	COEFFICIENTS		TOLERANCE		VIF		R ²	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Independent term	4,628	0,805	-	-	-	-	0,849	0,828
Ln PD	0,144	0,613	0,473	0,157	2,116	6,365		
Ln SN	-	- 0,879	-	0,111	-	9,000		
Ln JN	-	0,551	-	0,277	-	3,614		
Ln RI	-	0,413	-	0,237	-	4,227		
Ln S1	- 0,219	0,207	0,494	0,189	2,025	5,287		
Ln S2	- 0,876	- 0,027	0,323	0,733	3,096	1,364		
Ln S3	1,158	0,594	0,316	0,721	3,162	1,386		

The R^2 values obtained for both analyses are upper to 0,8, which means that the existing correlation among the variables is adequate in both cases, so the two models are well adjusted considering the aim of the study.

Co-linearity problems can be identified through the analysis of the *Tolerance*, and the *Variance Inflation Factor* (VIF). *Tolerance* represents the proportion of the variance of each independent variable that is not explained by the remaining independent variables [23]. For both types of municipalities, none of the *Tolerance* values are close to zero, which allows to initially reject the existence of co-linearity problems among the variables. The VIF, which is the inverse of the *Tolerance*, must have low values in order to definitely conclude that there is no co-linearity among variables. For urban municipalities, these values are inferior to 5.0, as well as the majority of variables for rural municipalities. Although, VIF values that correspond to Ln PD, Ln SN and Ln S1 for rural municipalities oscillate between 5.0–9.0, co-linearity problems are rejected, so no variables have to be excluded from the model.

Using these coefficients, equations 4 and 5 have been developed. According to the equations, in urban municipalities only four variables have influence on BW generation, while in municipalities that tend to rurality are seven the variables with influence.

$$LnBW_{Urban_{i,j}} = 4,628 + 0,144 * LnPD_{i,j} - 0,219 * LnS1_{i,j} - 0,876 * LnS2_{i,j} + 1.158 * LnS3_{i,j} \text{ (Eq. 4)}$$

$$LnBW_{Rural_{i,j}} = 0,805 + 0,613 * LnPD_{i,j} - 0,879 * LnSN_{i,j} + 0,551 * LnJN_{i,j} + 0,413 * LnRI_{i,j} + 0,207 * LnS1_{i,j} - 0,027 * LnS2_{i,j} + 0,594 * Ln$$

$$LnBW_{CANTABRIA} = \sum_{j=4,5}^9 LnBW_{Urban_{i,j}} + \sum_{j=1,2,3}^{93} LnBW_{Rural_{i,j}} \text{ (Eq. 6)}$$

Where i = municipality, j = rurality category

If equations 4 and 5 are compared, the number of socio-economic variables, as well as their influence on BW generation are higher in rural than in urban municipalities. This is because urban municipalities have intrinsic socio-economic characteristics that make them prone to generate wastes of any kind, diminishing the weight of other aspects that may influence BW generation. This is properly reflected in the equations, through the weight of the variable part (socio-economic variables) and the fixed part (independent term). This is represented in Fig. 3, where the weight of the socio-economic variables and the independent term are shown.

Figure 3 Influence of the socio-economic variables on BW generation depending on rurality

According to the model, for rural municipalities, the values of the socio-economic variables affects more the level of BW generation. The idiosyncrasy of these municipalities is much more varied than in the case of urban ones, and this is reflected in the variability of the values of the socioeconomic variables, and therefore in the amount of BW generated.

The population density (PD) has the most positive influence on BW generation. It coincides with the studies of Ghinea et al. [18] and Azadi and Karimi-Jashni [19], that also conclude that population density and working population have a positive influence on MSW and BW generation. On the other hand, the senior index (SN), is the variable with the most negative influence on BW generation level. Older people have another model of consumption and try to make the most of the food leftovers. This agrees with Grazdhan [20] who concluded that population of more than 65 years, has a negative influence on MSW generation.

Other variables with positive influence are junior index (JN), retirement index (RI), people working in agriculture and livestock (S1) and people working in the services sector (S3). Generally, families with young people have a higher consumption of food per household and therefore of food waste. Regarding occupation, different studies conclude that working population has a positive effect on waste generation. However, the type of occupation is not studied in their work [18]. The agriculture and livestock is very representative of rural areas, and a high proportion of population are part of this sector, which can generate vegetal fractions as well as food waste. Although the services sector is not as important in rural areas as in urban areas, due to the nature of its activity, it contributes to BW generation.

In Fig. 4, it is graphically shown how the weight of these variables will influence the BW generation for urban and rural municipalities, presenting a mean value that increases as the municipalities are analysed in increasing order of rurality index. (the more urban the municipality is, the greater the generation of BW will be in it).

Figure 4 Influence of the socio-economic variables on BW generation

3.4. Biowaste estimation using MLRA models

The BW generation in Cantabria was estimated using the model equations for the period 2012–2017 (Fig. 5). It varies in this period between 61.800 and 66.900 tons per year, which corresponds to a generation ratio from 106 to 115 Kg/capita/year.

These estimated ratios have a similar magnitude to the ones obtained by Qusted et al. [32] for United Kingdom, Kranert et al. [33] for Germany, Edjabou et al. [34] for Denmark, and Braütingam and Priefer [35] for Spain, given that they oscillate between 100 and 118 Kg/capita/year.

Using this method, the lack of homogenesis of the BW generation in the different types of municipalities is clear, as it is shown in Fig. 5. During the studied period, the 37% of the BW is generated in urban and semi-urban municipalities, while the 63% is generated in semi-rural, rural and rural+ municipalities. This means that the 37% of the total BW is generated by the 56% of the total population in Cantabria, who are concentrated in the 3% of the area of the region. Provided that the remaining 63% of the BW generation is produced in the 97% of the area, the efforts to introduce the separate collection and management of

BW in the point of production, as well as the assessment of their performance, must not be made only in urban and semi-urban areas, but also in rural and low populated areas.

Figure 5 BW generation in Cantabria estimated using MLRA models

However, this distribution varies along the years. The trend followed by BW generation in the different municipalities in Cantabria, is associated to the evolution of the most relevant socio-economic variables used in the MLRA. As it is shown in Table 6 in the Appendix, population density has changed differently through the years, depending on the rurality of the municipalities. In urban, semi-urban and rural + municipalities, PD has gradually decreased, but with a higher intensity in urban and semi-urban municipalities. On the other hand, PD has oscillated in semi-rural and rural municipalities, finishing the studied period with a slight increase in relation to the previous year.

Due to technical limitations, Table 6 is only available as a download in the supplementary files section.

According to the values collected in Table 6 in the Appendix, job market has also suffered variations during the studied period. The evolution of the percentage of people working in the primary sector through the years is quite different depending on the rurality of the municipalities. In urban municipalities, S1 has oscillated during the studied period, ending it with a decrease in relation to the year 2016. In semi-urban, semi-rural and rural municipalities S1 increased during the beginning of the studied period, to decrease gradually till 2017. Only in rural+ municipalities S1 has increased during the majority of the studied years. However, it decreased in 2017.

The percentage of people working in the industry sector has followed a similar trend in the whole region. During the years 2012–2016, S2 has decreased gradually, except in 2014 in rural municipalities, to finish the studied period with an increase in every type of municipality.

As a consequence, the percentage of people working in the service sector has gradually increased in the 5 categories of municipalities, during the years 2012–2016 to finish the studied period decreasing in 2017.

Through the analysis of the trend followed by these variables and its link with the one followed by the distribution of BW, the strong connection between the socio-economic variables of the different areas that form a region and the BW generated in each one of them is proved, as well as their consideration when decisions related to BW collection and management must be made.

The estimations obtained through the model, are compared to other made using WCA (2016) ratios and MSW collection data of the same period (Fig. 6). These values are collected in Table 7 of the Appendix. The estimations have lower values during the whole studied period, with a percentual difference between 9% and 21%.

Table 7
Estimation of BW generation in Cantabria using WCA and MLRA

MUNICIPALITY	CATEGORY	Estimation of BW generation in Cantabria using WCA and MLRA									
		2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39001 - Alfoz de Lloredo	Rural	393,74	367,34	395,00	367,33	396,28	360,72	345,33	345,36	362,09	346,21
39002 - Ampuero	Rural	865,39	727,91	874,25	750,06	877,68	738,59	818,38	706,44	740,57	689,75
39003 - Anievas	Rural +	96,32	116,15	96,10	116,73	96,44	109,03	96,43	108,65	95,44	97,92
39004 - Arenas de Iguña	Rural +	180,49	146,01	174,12	149,19	175,75	146,72	95,47	140,75	95,44	144,52
39005 - Argoños	Semirural	850,77	1837,40	838,02	1801,74	840,02	1732,99	907,01	1703,55	888,09	1612,48
39006 - Arnauero	Rural	1074,21	554,34	1051,17	565,33	1048,51	589,88	894,30	611,10	888,09	584,66
39007 - Arredondo	Rural +	65,87	104,62	64,71	104,20	64,97	106,57	61,26	101,88	66,10	107,12
39008 - Astillero (El)	Semi-urban	1758,11	1998,20	1767,33	2079,74	1766,22	2253,78	1742,50	2246,62	1743,05	2275,60
39009 - Bárcena de Cicero	Rural	795,60	906,38	754,52	895,30	753,96	887,37	744,68	887,64	731,58	864,87
39010 - Bárcena de Pie de Concha	Rural +	60,15	177,78	59,43	175,06	59,70	191,00	95,80	179,89	95,44	168,72
39011 - Bareyo	Rural	1048,19	558,98	1027,62	561,57	1027,78	579,12	884,53	570,29	888,09	542,75
39012 - Cabezón de la Sal	Semirural	988,65	1046,33	981,22	1089,90	982,42	1083,65	823,68	1078,26	843,58	1087,76
39013 - Cabezón de Liébana	Rural +	78,82	107,21	77,50	108,47	77,35	102,96	67,41	105,71	64,61	100,31
39014 - Cabuérniga	Rural +	296,17	133,66	291,40	128,69	292,32	133,19	145,97	124,33	142,38	120,97
39015 - Camaleño	Rural +	257,72	103,08	252,68	101,65	251,11	101,92	169,49	99,11	177,58	99,26
39016 - Camargo	Semi-urban	4809,14	2921,93	4789,23	3133,79	4792,83	3257,45	4385,43	3405,78	4468,02	3533,34
39017 - Campoo de Yuso	Rural +	91,40	118,78	92,10	114,14	91,98	111,24	102,56	125,93	100,82	131,60
39018 - Cartes	Semirural	500,82	1470,32	510,18	1571,61	484,79	1566,02	419,70	1571,13	427,23	1631,76
39019 - Castañeda	Rural	314,27	742,46	304,74	795,73	319,18	838,77	341,87	837,90	347,63	880,03
39020 - Castro-Urdiales	Semirural	3518,86	1572,86	3450,17	1597,93	3545,13	1601,58	3492,00	1528,26	3557,60	1488,30
39021 - Cieza	Rural +	50,87	99,65	54,69	102,51	47,59	107,74	32,73	102,22	32,22	103,92
MUNICIPALITY	CATEGORY	2012	2013		2014		2015		2016		
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39022 - Cillorigo de Liébana	Rural +	109,61	213,21	104,24	215,41	111,42	222,70	125,91	211,02	126,93	202,81
39023 - Colindres	Semi-urban	674,65	1064,22	671,07	1118,79	676,35	1123,45	699,80	1114,28	693,22	1141,39
39024 - Comillas	Rural	380,65	557,06	351,30	579,78	395,82	569,73	347,80	561,91	365,99	582,32
39025 - Corrales de Buelna (Los)	Semirural	1468,82	943,10	1617,27	949,39	1367,72	911,02	1079,75	908,45	917,60	886,46
39026 - Corvera de Toranzo	Rural	189,84	358,00	221,62	368,81	215,69	347,78	174,09	331,45	186,98	336,40

MUNICIPALITY	CATEGORY	2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39027 - Campoo de Enmedio	Rural	423,34	302,50	426,20	304,96	426,07	303,53	395,22	294,18	398,41	303,44
39028 - Entrambasaguas	Rural	581,19	1006,42	616,55	1086,03	622,24	1135,53	731,66	1166,29	752,23	1156,86
39029 - Escalante	Rural	386,44	319,62	378,22	310,67	378,38	310,22	891,43	308,92	888,09	317,94
39030 - Guriezo	Rural	438,17	339,51	458,86	348,73	458,93	347,92	406,87	347,74	395,61	356,10
39031 - Hazas de Cesto	Rural	245,23	616,57	237,13	655,69	238,34	652,60	279,07	664,06	284,22	655,87
39032 - Hermandad de Campoo de Suso	Rural +	285,73	89,60	275,38	91,87	258,84	86,31	218,01	85,58	212,76	86,44
39033 - Herrerías	Rural +	102,71	94,80	103,04	108,85	102,08	109,11	79,92	111,92	79,63	111,88
39034 - Lamasón	Rural +	21,49	36,30	21,40	38,59	21,33	40,20	19,66	41,44	19,27	35,70
39035 - Laredo	Semi-urban	4537,83	1652,43	4434,01	1719,86	4407,34	1738,69	3983,14	1762,53	4020,01	1737,15
39036 - Liendo	Rural	180,82	431,26	173,06	424,26	173,44	431,68	189,70	421,07	200,81	396,85
39037 - Liérganes	Rural	1043,07	481,25	1123,77	493,40	1119,95	468,51	892,71	460,01	888,09	434,35
39038 - Limpias	Rural	354,03	1058,93	371,17	1046,57	370,69	975,18	255,80	972,51	268,86	921,16
39039 - Luenas	Rural +	106,20	71,55	60,70	71,24	68,03	74,28	40,88	70,18	42,34	73,84
39040 - Marina de Cudeyo	Rural	1031,11	999,09	1034,00	985,57	1042,01	953,83	876,03	933,00	868,57	894,57
39041 - Mazcuerras	Rural	246,71	330,91	246,46	318,88	244,52	339,95	254,14	345,40	264,42	341,67
39042 - Medio Cudeyo	Semirural	1159,85	1309,03	1136,88	1296,81	1132,01	1289,17	1036,49	1255,75	1056,17	1243,52
MUNICIPALITY	CATEGORY	2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39043 - Meruelo	Rural	444,53	700,12	457,67	825,13	452,35	861,96	355,27	857,22	362,66	863,01
39044 - Miengo	Rural	1083,09	861,62	1080,58	861,43	1078,99	856,39	1008,54	840,62	995,26	857,12
39045 - Miera	Rural +	39,32	88,90	35,33	105,89	33,69	112,55	37,31	105,13	35,45	97,46
39046 - Molledo	Rural +	304,81	168,96	302,54	179,76	301,72	170,41	95,71	169,83	95,44	160,91
39047 - Noja	Semirural	1819,20	1265,31	1821,80	1214,90	1814,34	1192,57	1604,29	1129,93	1578,60	1116,64
39048 - Penagos	Rural	339,37	425,86	338,65	449,80	340,49	441,75	251,56	459,76	273,22	449,12
39049 - Peñarrubia	Rural +	29,15	41,59	28,90	43,18	28,69	46,21	33,04	46,19	36,22	44,64
39050 - Pesaguero	Rural +	18,76	74,29	18,64	76,53	18,86	83,96	21,91	85,59	22,10	84,46
39051 - Pesquera	Rural +	9,92	7,50	9,40	8,02	9,28	9,56	6,36	9,80	6,94	9,40
39052 - Piélagos	Semirural	2131,87	1562,43	2146,77	1610,58	2152,84	1620,85	2173,94	1589,85	2165,91	1596,50
39053 - Polaciones	Rural +	19,34	25,31	19,56	22,47	19,21	39,13	17,03	35,61	16,46	35,40
39054 - Polanco	Semirural	838,45	1050,63	842,80	1123,23	844,85	1143,54	811,54	1150,44	820,40	1112,95
39055 - Potes	Rural	381,72	710,43	376,98	751,09	375,91	638,00	263,49	616,53	269,22	606,17

MUNICIPALITY	CATEGORY	2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39056 - Puente Viesgo	Rural	465,79	534,91	479,32	532,06	476,06	555,23	415,67	545,49	401,20	548,67
39057 - Ramales de la Victoria	Rural	299,17	488,12	303,52	503,29	301,25	518,74	280,22	523,16	283,85	513,12
39058 - Rasines	Rural +	105,41	237,91	103,85	238,69	103,57	245,69	96,92	240,24	95,62	225,62
39059 - Reinosa	Semi-urban	1643,05	1652,43	1647,16	1702,75	1653,38	1772,56	1474,13	1780,55	1466,42	1790,05
39060 - Reocín	Semirural	1392,78	1127,59	1375,24	1172,45	1382,08	1186,79	1324,50	1167,92	1328,92	1155,67
39061 - Ribamontán al Mar	Rural	2284,65	895,37	2306,28	860,20	2224,38	864,49	1145,09	813,44	1193,66	810,86
39062 - Ribamontán al Monte	Rural	1083,96	458,77	1065,07	451,10	1062,86	447,94	907,54	467,46	888,09	466,09
MUNICIPALITY	CATEGORY	2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39063 - Rionansa	Rural +	148,27	62,83	149,79	68,69	150,61	63,35	139,89	67,78	144,93	74,31
39064 - Riotuerto	Rural	256,38	478,19	268,39	487,47	274,99	460,29	222,85	458,61	213,42	435,21
39065 - Rozas de Valdearroyo (Las)	Rural +	31,00	58,83	32,20	58,07	33,27	65,35	32,76	60,83	31,93	52,12
39066 - Ruate	Rural +	126,58	190,67	127,87	192,23	127,29	191,16	110,23	183,11	116,35	170,25
39067 - Ruesga	Rural +	237,88	97,35	235,70	96,71	237,24	94,80	101,66	93,69	102,87	92,14
39068 - Ruiloba	Rural	256,09	377,94	257,68	383,74	259,86	363,09	311,05	337,51	285,95	296,79
39069 - San Felices de Buelna	Rural	178,96	365,39	178,66	382,64	179,33	395,27	156,80	399,10	160,97	414,05
390070 – San Miguel de aguayo	Rural +	8,87	73,16	9,36	74,00	9,95	79,59	5,71	80,33	14,29	73,11
39071 - San Pedro del Romeral	Rural +	28,07	115,73	27,97	113,45	27,91	112,62	21,61	115,30	23,37	114,27
39072 - San Roque de Riomiera	Rural +	32,20	127,03	33,93	115,12	34,06	113,74	33,51	109,69	35,48	106,53
39073 - Santa Cruz de Bezana	Semi-urban	1415,71	2980,96	1420,11	3261,69	1427,77	3408,90	1406,26	3581,44	1385,43	3568,85
39074 - Santa María de Cayón	Rural	1190,95	1070,34	1186,68	1090,37	1188,64	1115,52	1068,89	1076,56	1076,67	1071,91
39075 – Santander	Urban	11683,75	6438,17	11618,83	6836,29	11592,23	6907,86	10427,96	6876,62	10563,14	6974,39
39076 - Santillana del Mar	Rural	538,15	851,99	536,03	870,56	540,18	857,43	535,48	855,59	544,79	846,67
39077 - Santiurde de Reinosa	Rural +	40,13	74,09	40,21	77,50	40,23	64,28	37,17	66,03	37,06	54,98
39078 - Santiurde de Toranzo	Rural	143,07	243,28	144,28	257,38	143,90	271,71	158,42	280,79	156,31	280,25
39079 - Santoña	Semiurbano	2085,19	1176,15	2076,38	1224,15	2067,27	1231,98	2143,05	1320,90	2110,77	1326,10

MUNICIPALITY	CATEGORY	2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39080 - San Vicente de la Barquera	Rural	887,16	721,87	880,21	721,00	877,78	715,48	562,42	678,15	578,10	654,70
39081 - Saro	Rural +	28,37	223,48	28,33	234,03	28,20	219,13	27,48	216,34	27,21	232,22
39082 - Selaya	Rural	179,03	381,97	178,37	399,78	177,65	399,79	158,78	378,81	168,26	377,93
MUNICIPALITY	CATEGORY	2012		2013		2014		2015		2016	
		BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)	BW WCA (t/year)	BW MLRA (t/year)
39083 - Soba	Rural +	140,81	64,09	137,15	60,65	138,54	62,89	119,51	64,96	119,16	66,54
39084 - Solórzano	Rural +	158,67	340,45	160,39	348,92	162,92	342,75	150,43	360,81	151,99	385,52
39085 - Suances	Semirural	1654,64	1310,61	1641,41	1344,73	1640,89	1346,42	1525,26	1323,61	1569,04	1331,32
39086 - Tojos (Los)	Rural +	53,45	56,98	52,77	59,15	52,53	62,33	40,41	60,51	45,59	59,88
39087 - Torrelavega	Urban	10837,34	2298,47	10744,39	2617,57	10748,87	2757,43	9567,78	2828,81	9465,93	2807,36
39088 - Tresviso	-										
39089 - Tudanca	Rural +	16,53	18,33	16,37	15,83	16,14	17,27	13,61	17,76	13,93	18,26
39090 - Udías	Rural	59,40	361,22	58,91	392,61	58,52	401,79	65,85	423,17	67,31	458,73
39091 - Valdáliga	Rural +	326,21	217,26	325,60	228,43	325,30	230,85	493,60	237,25	497,32	233,21
39092 - Valdeolea	Rural +	152,41	104,29	152,03	102,60	149,98	95,56	115,50	89,69	117,07	93,35
39093 - Valdeprado del Río	Rural +	44,65	34,01	44,58	32,24	44,50	33,19	39,17	32,15	38,91	36,93
39094 - Valderredible	Rural +	190,00	63,89	189,62	59,84	190,59	61,46	197,33	56,35	191,27	57,15
39095 - Val de San Vicente	Rural	410,34	505,54	416,06	490,66	419,39	504,76	371,74	507,06	379,67	491,77
39096 - Vega de Liébana	Rural +	56,36	76,80	56,16	75,94	56,33	74,16	52,19	72,44	52,30	77,93
39097 - Vega de Pas	Rural +	54,33	123,89	54,01	118,09	53,78	126,12	52,43	124,58	54,32	114,60
39098 - Villacarriedo	Rural +	299,94	280,92	321,72	284,87	351,28	290,74	235,49	261,78	246,76	272,65
39099 - Villaescusa	Rural	209,32	725,65	188,65	729,36	164,35	715,48	307,01	725,98	310,49	743,31
39100 - Villafufre	Rural +	233,79	339,82	263,75	331,31	302,49	299,98	123,76	301,68	130,49	294,33
39101 - Valle de Villaverde	-										
39102 - Voto	Rural	338,15	305,09	310,75	306,77	283,58	298,97	418,31	299,77	419,33	303,41

Figure 6 Comparative BW generation WCA and MRLA

These differences lie in the fact that the WCA was executed during summer season (2016), when population, tourism and the intensity of the services sector's activity grows exponentially. On the contrary, the statistical data used to make the estimations using MLRA correspond to the whole year, and do not include people from outside the region who have their second home in Cantabria.

It is expected that the values of the BW estimated using the ratio obtained in the WCA will be worse the further away from the year in which it was obtained, since the evolution of the economic crisis of the last decade, as well as the greater awareness of society with food waste, have changed the consumption patterns. This is one of the reasons why it is not recommended to use static ratios and it is recommended to use models that allow including socioeconomic changes in the estimation of waste generation.

4. Conclusions

European countries must develop a new biowaste (BW) management strategy in the coming years due to changes in the regulations. In this sense, it is necessary to be able to quantify the generation of this waste at the municipal level.

In this paper, a methodology to estimate BW generation at municipal level has been established. The methodology takes into account the characteristics of the region, the Municipal Solid Waste (MSW) management applied, and different socio-economic variables that define the level of rurality of a municipality. A model to estimate the BW generation for each type of municipality (urban or rural) has been developed using Multiple Linear Regression Analysis (MLRA). As input data has been used, on the one hand, results from a Waste Compositional Analysis used for estimating the BW fraction of the mixed waste collected; and on the other hand, data of socioeconomic variables that have demonstrated to influence the generation of waste.

It has been proved that MLRA is an easy-to-use and accurate enough tool, according to the aim of this paper, to model the distribution of BW generation in the region. On the other hand, it has been identified that socio-economic variables have a different effect on the BW generation depending on the type of municipalities: urban or rural. In fact, the number of socio-economic variables, as well as their influence on BW generation are higher in rural than in urban municipalities, given that urban municipalities have intrinsic characteristics that make them prone to generate wastes of any kind, diminishing the weight of other aspects that may influence BW generation. This coincides with the fact that the variable part of the equation is more relevant for rural municipalities than for urban municipalities.

According to the model, the BW generation in Cantabria during the 2012–2017 period varies between 61.800 and 66.900 tons per year, which corresponds to a generation ratio of 106 and 115 Kg/capita/year. However, as it was expected, the distribution of BW generation is not homogeneous: the 37% of the BW is generated in urban and semi-urban municipalities, while the 63% is generated in semi-rural, rural and rural+ municipalities. Therefore, the efforts to introduce the separate collection and management of BW in the point of production, as well as the assessment of their performance, must not be made only in urban and semi-urban areas, but in rural and low populated areas too. This means that the biowaste generation around the region must be studied at a municipal level, and not at a regional one.

After comparing the value of BW production obtained using the models, with those obtained using single ratios, differences were found among both values. The evolution of the economic crisis of the last decade, as well as the greater awareness of society with food waste, have changed the consumption patterns. This is one of the reasons why it is not recommended to use static ratios and it is recommended to use models that allow including socioeconomic changes in the estimation of waste generation.

Declarations

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Compliance of ethical standards

Conflict of interest. The authors declare there is no conflict of interest.

References

1. European Parliament, C.: Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives. Off. J. Eur. Union **L312**, 3–30 (2008)
2. European Parliament, C.: Directive 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/CE on waste. Off. J. Eur. Union **L150**, 109–140 (2018)
3. Spanish, Government, Ministry for the Ecological Transition and the demographic challenge: What is biowaste?. MITECO. <https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/prevencion-y-gestion-residuos/flujos/biorresiduos/Default.aspx> (2020) Accessed 12 September 2019
4. Oviedo-Ocaña, E.R., Domínguez, I., Komilis, D. Sánchez, A.: Co-composting of Green waste mixed with unprocessed and processed food waste: Influence on the composting process and product quality. Waste. Biomass. Valor. **10**, 63–74 (2019). <https://doi.org/10.1007/s12649-017-0047-2>
5. BIO Intelligence Service: Preparatory study on food waste across EU 27 October 2010. European Commission. https://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf (2010) Accessed 23 February 2020
6. Panaretou, V., Malamis, D., Papadaskalopoulou, C., Sotiropoulos, A., Valtas, K., Plevri, A., Margaritis, M., Moustakas, K., Loizidou, M.: Implementation and Evaluation of an Integrated Management Scheme for MSW in Selected Communities in Tinos Island, Greece. Waste. Biomass. Valor. **8**, 1597–1616

- (2017). <https://doi.org/10.1007/s12649-016-9632-z>
7. Prieto-Lara, E., Ocaña-Riola, R.: Updating rurality index for small areas in Spain. *Soc. Indic. Res.* **95**, 267–280 (2010). <https://doi.org/10.1007/s11205-009-9459-0>
 8. Sancho Comíns, J., Reinoso Moreno, D.: La delimitación del ámbito rural: una cuestión clave en los programas de desarrollo rural. *Estud. Geogr.* **73**, 599–624 (2012). <https://doi.org/10.3989/estgeogr.201221>
 9. United Nations: Principles and recommendations for population and housing censuses. Economical and social Affairs, New York (1998)
 10. Organisation for Economic Co-operation and Development: Creating rural indicators for shaping territorial policy. OCDE Publications and Information Centre, Paris (1994)
 11. Spanish, Government: Ministry of Agriculture, Fishing and Feeding: El libro blanco de la agricultura y el Desarrollo rural / The white book of agricultural and rural development. Ministry of Agriculture, Fishing and Feeding, Madrid (2003)
 12. López-Ratón, M., Pérez, S.: I.: Construcción de un índice de ruralidad y clasificación de los municipios gallegos / Construction of a rurality index and classification of municipalities of Galicia. Extended paper in: I Congresso de Estatística e Investigação Operacional da Galiza e Norte de Portugal.
 13. https://www.ige.eu%2Festatico%2Fgrupo_de_traballo_urbanizacion%2FRural.doc&usg=AOvVaw2ltwKpYs-tNpoiW8rqFfvi (2005) Accessed 25 May 2008
 14. Ocaña-Riola, R., Sánchez-Cantalejo, C.: Rurality index for small areas in Spain. *Soc. Indic. Res.* **73**, 247–266 (2005). <https://doi.org/10.1007/s11205-004-0987-3>
 15. Xue, L., Liu, G., Parfitt, J., Liu, X., Van Herpen, E., Stenmarck, Å, O'Connor, C., Östergren, K., Cheng, S.: Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data. *Environ. Sci. Technol.* **51**, 6618–6633 (2017). <https://doi.org/10.1021/acs.est.7b00401>
 16. WRAP: Household food and drink waste in the UK. WRAP, Banbury
 17. <https://> (2009) Accessed 15 February 2020
 18. Malamis, D., Moustakas, K., Bourka, A., Valta, K., Papadaskalopoulou, C., Panaretou, V., Skiadi, O., Sotiropoulos, A.: Compositional Analysis of Biowaste from Study Sites in Greek Municipalities. *Waste. Biomass. Valor.* **6**, 637–646 (2015). <https://doi.org/10.1007/s12649-015-9406-z>
 19. Tostivint, C., de Veron, S., Jan, O., Lanctuit, H., Hutton, Z.V., Loubière, M.: Measuring food waste in a dairy supply chain in Pakistan. *J. Clean. Prod.* **145**, 221–231 (2017). <https://doi.org/10.1016/j.jclepro.2016.12.081>
 20. Ghinea, C., Drăgoi, E.N., Comăniță, E.D., Gavrilăscu, M., Câmpăan, T., Curteanu, S., Gavrilăscu, M.: Forecasting municipal solid waste generation using prognostic tools and regression analysis. *J. Environ. Manage.* **182**, 80–93 (2016). <https://doi.org/10.1016/j.jenvman.2016.07.026>
 21. Azadi, S., Karimi-Jashni, A.: Verifying the performance of artificial neural network and multiple linear regression in predicting the mean seasonal municipal solid waste generation rate: A case study of Fars province, Iran. *Waste Manag.* **48**, 14–23 (2016). <https://doi.org/10.1016/j.wasman.2015.09.034>
 22. Graždani, D.: Assessing the variables affecting on the rate of solid waste generation and recycling: An empirical analysis in Prespa Park. *Waste Manag.* **48**, 3–13 (2016). <https://doi.org/10.1016/j.wasman.2015.09.028>
 23. Owusu-sekyere, E., Harris, E.: Forecasting and Planning for Solid Waste Generation in the Kumasi Metropolitan Area of Ghana: An ARIMA Time Series Approach. *Int. J. Sci.* **2**, 69–83 (2013)
 24. Mwenda, A., Kuznetsov, D., Mirau, S.: Time series forecasting of solid waste generation in Arusha city – Tanzania. *Math. Theory Model* **4**, 29–39 (2014)
 25. Guisande González, C., Liste, V., Barreiro Felpejo, A., A.: Tratamiento de datos con R, STATISTICA y SPSS / Data treatment with R, STATISTICA and SPSS. Ediciones DíazdeSantos: (2013)
 26. Statistics Office of Cantabria (ICANE): Cantabria en cifras 2019/ Cantabria in Figs. 2019. https://www.icane.es/c/document_library/get_file?uuid=f6d323a9-7fb6-4c6a-90cb-239458c7a27b&groupId=10138 (2020) Accessed 17 January 2020
 27. Villaverde Castro, J., San Emeterio, A., Maza Fernández, A., A.: El desarrollo económico de Cantabria: Análisis e instrumentos / The economic development of Cantabria: Analysis and tools. SODERCAN: (2017)
 28. BOE: Spanish lay 22/2011, of 28 July on wastes and contaminated soils. Head of State (2011)
 29. BOC: Decree 14/2017, of 23 March, which approves the Waste Plan of Cantabria 2017–2023. Government of Cantabria. 63 (2017)
 30. Quintá, F.X.A., Arce, X.C.M.: Reflexiones acerca de la delimitación y definición del medio rural. Diseño de un índice de ruralidad para Galicia. *Finisterra.* **52**, 85–101 (2017). <https://doi.org/10.18055/Finis9955>
 31. Lasarte-López, J., Rodero-Cosano, M.L., Salinas Pérez, J.A.: La medición de la ruralidad y sus dimensiones en Andalucía a través de un modelo de indicadores sociales. Extended paper in: International Conference on Regional Science: (2016)
 32. Castañeda, M.B., Cabrera, A.F., Navarro, Y., de Vries, W.: Procesamiento de datos y análisis estadísticos utilizando SPSS. Editora Universitária da PUCRS, Porto Alegre (2010)
 33. Ministry of Agriculture, Feeding and Environment: Gestión de biorresiduos de competencia municipal: Guía para la implantación de la recogida separada y tratamiento de la fracción orgánica / Guidelines for the implementation of biowaste separate collection and biowaste management. Ministry of Agriculture, Feeding and Environment, Madrid (2013)
 34. WRAP: Household food and drink waste in the United Kingdom 2012. WRAP, Banbury
 35. <https://wrap.org.uk/sites/files/wrap/hhfdw-2012-main.pdf.pdf> (2013) Accessed 15 February 2020
 36. Kranert, M., Hafner, G., Barabosz, J., Schneider, F., Lebersorger, S., Scherhauser, S., Schuller, H., Leverenz, D.: Determination of discarded food and proposals for a minimization of food wastage in Germany. Institute for Sanitary Engineering, Water Quality and Solid Waste Management University Stuttgart. (2012)

- ## Figures

Figure 2

Classification of the municipalities of Cantabria depending on their rurality index

Figure 3

Influence of the socio-economic variables on BW generation depending on rurality

Figure 4

Influence of the socio-economic variables on BW generation

Figure 5

BW generation in Cantabria estimated using MLRA

Figure 6

Comparative BW generation WCA and MRLA

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