Modelling the Driving Forces of the Municipal Solid Waste Generation in Touristic Islands. A Case Study of the Balearic Islands (2000 − 2030)

Abstract

The improvement of municipal solid waste (MSW) management in touristic islands has not been sufficiently studied, so that seeking to improve this issue, and using the Spanish Balearics as a study case, a hybrid methodology has been developed which: i) identifies the three more influential variables (driving forces) of the MSW generation system through an econometric model based on the official historical data for a given period (2000 to 2014), ii) develops a System Dynamics (SD) model of the evolution of the MSW generation in this archipelago based on the same data and time period, and iii) forecasts the generation of different types of MSW for a future period (2015 to 2030), considering nine scenarios with different assumptions, objectives and management policies, applying Scenario Analysis to the SD model developed.

The results show that by maintaining the current policies ("business as usual" scenario) it will be impossible to meet the goals set by the Regional and the Spanish National Plans derived from the European MSW Directive. However, by implementing the improvements proposed in the simulated alternative scenarios, the model predicts that by 2030, generation of MSW would be increased by 15% relative to 2014, mainly due to the Tourist Population influence which is 37.5% higher than the Resident Population. In addition, for the most optimistic scenario, the amount of MSW sent to landfills would decrease by 40%, and the selective collection would increase by 30%, compared to 2014. This methodology can be replicated in other territories with similar characteristics to the case study.

Keywords: Municipal Waste; Waste Management; Econometric Model; System Dynamics; Scenario Analysis; Balearic Islands

1. Introduction

The improvement of municipal solid waste (MSW) management systems is an issue of growing importance for the sustainability of any territory, and it is even more important in touristic islands such as the Balearics. An efficient and sustainable MSW management system is essential both for the health of the population and for environmental protection and conservation. Changes in the per capita income levels, consumption patterns, demographic trends, and a population´s sensitivity to environmental issues are directly related to MSW generation, and thus make it very challenging to find an adequate long-term solution (Adamides et al., 2009).

The Balearics are an adequate study case in terms of MSW management in touristic islands, because they are among the most important touristic islands globally, according to the Global Tourist Penetration Index (McElroy, 2003). The contribution of the tourist industry to the total Gross Domestic Product (GDP) of the Balearics reaches 45.8%.

Spain is one of the world´s major tourist destinations, ranking third in terms of international tourist arrivals (UNWTO, 2014). Apart from being amongst the most relevant Spanish regions in terms of international visitors, this topic is also important because, like any other European territory, the Balearic Islands have to comply with the Spanish National Waste Plan, and the Regional Master Plan (2008-2015) derived from the European Directive 2008/98/EC, since all European countries must develop waste prevention plans and programs (articles 28 and 29).

The amount of MSW generated by islands can vary significantly, depending on the levels of affluence and consumption, industrial production, tourism, and other factors. Therefore, it is necessary to identify the main driving forces behind such variations. Changes and incentives in public policies may increase MSW generation. Furthermore, some of the relationships between those driving forces are dynamic and they have not been sufficiently investigated, so that feedback mechanisms may provoke non-intuitive responses.

In addition, to improve MSW management, multiple and interrelated decisions - within extremely uncertain and complex scenarios - have to be taken, for which the Scenario Analysis

method can be of great help to decision makers by making their long-term planning more flexible (Salmeron et al., 2012).

Consequently, the main objective of this research is to analyse and evaluate the current MSW management system of the Balearic Islands, in the short- and long-term, up to 2030, building an econometric model to identify the driving forces affecting the MSW generation in this archipelago, and forecasting its future evolution through System Dynamics (SD) and Scenario Analysis (SA), creating supposed scenarios that determine the behaviour of those driving forces, so that the current MSW collection system and treatment mix can be optimised.

In the study area, the improvement and planning of MSW management has, as yet, been little investigated; only very few authors have studied compliance with the European goals regarding energy consumption and carbon dioxide emissions, as well as tourism and environmental pollution (Rosselló-Batle et al., 2010; Saenz-de-Miera et al., 2014; Bakhat et al. 2011). Other studies have focused on the impact of the tourism industry on MSW generation (Arbulú et al., 2016; Mateu-Sbert et al., 2013; Arbulú et al., 2013). However, the previous studies have not developed SD models to forecast future MSW generation for this archipelago. Therefore, this research aims to bridge this gap.

The main contribution of this paper is the development of a prognostic tool to improve the consistency of decision making and the forecasts of future MSW generation in the Balearic Islands and other similar study areas, applying regression analysis to identify the main driving forces of MSW generation, and SD and SA to forecast the generation of MSW within the study area. Furthermore, it has been demonstrated that by maintaining the current policies, it will be impossible to meet the European Union MSW goals established by the MSW Directive.

Although most islands face many difficulties in managing their MSW, these circumstances can also be seen in a positive light, because barriers to treatment and disposal practices may, at the same time, be incentives to the development of alternative strategies that are environmentally preferable.

2. Literature review

Tourism plays an important role in MSW generation in touristic islands, however the MSW management improvement in islands has not been studied enough. Miller et al. (2015) analyse sustainable tourism (with special emphasis on eco-tourism and eco-resorts) in terms of urban destinations. The tourist´s MSW generation rate can reach up to twice the rate of the resident population (Shanshiry et al., 2011). Furthermore, the impact of tourism may be particularly problematic in insular environments (Deschênes & Chertow, 2004; Douglas, 2006; Diaz, 2007). Lilai et al. (2012) states that the accurate prediction of MSW generation is crucial, and essential for the planning, operation, and optimisation of any MSW management system. Gonzalez-Martínez et al. (2012) suggest that a sustainable MSW management system requires the incorporation of policies and governmental regulations, as well as a model of sustainable consumption, cost containment, and citizen education campaigns.

Many factors influence the MSW management system that should not be only based on adequate technological solutions, but also on environmental, cultural, legal, and economic factors. Vehlow (2007), Su et al. (2007), and Triguero et al. (2016) analyse the relationship between MSW generation and the public policies implemented to improve MSW management. Other authors study the existence of a positive correlation between MSW generation and GDP (Dangi et al., 2011; Johnstone & Labonne, 2004) because economic growth leads to increasing levels of consumption, which in turn cause increased MSW generation, and may thus lead to environmental degradation (Afroz et al., 2011; Márquez et al., 2008). However, environmental problems are not caused solely by consumption. In recent years, a general change of perspectives on the investigation of environmental sustainability can be observed (Grunwald, 2014). A detailed understanding of whom the stakeholders are, and which responsibilities they have, is an important step in establishing an efficient and effective MSW management system (Abarca et al., 2013).

To estimate MSW generation, some models identify the factors that influence specific MSW flows (Beigl et al., 2008). Other studies conclude that the structure of the population (resident

population and floating touristic population) is the main cause of MSW generation (Mazzanti & Zoboli, 2008; Dangi et al., 2011).

Concerning the application of the econometrics models to the improvement of MSW management, several studies must be mentioned: Ali-Abdoli et al. (2011), Weng et al. (2011), and Ojeda-Benitez et al. (2008) develop models based on a multivariate econometric approach that considers the driving forces of MSW generation. Ghinea et al. (2016) forecast MSW generation by using a prognostic tool and a regression analysis. Weng et al. (2009) focus on MSW management and short-term projections of MSW generation. Mota et al. (2015) analyse the determinants of MSW management in Portugal. Sacratess et al. (2013) describe econometric methods based on the Logit and Tobit models, which serve to analyse the willingness to pay for the improvement of MSW management.

Regarding the use of System Dynamics as a modelling tool,

Table **1** presents a wide sample of the studies carried out in different regions and periods.

Table 1: Summary of regional MSW studies based on SD and SA

Author(s)	**City / Region, Country**
Ahmad, K. (2012)	New Delhi, India
Beigl et al. (2010)	Steiermark, Austria
de Oliveira & Löbler (2012)	Southern Brazil
Dyson & Chang-Ni-Bin (2005)	Texas, USA
Inghels & Dullaert (2010)	Flanders, Holland
Kollikkathara et al. (2010)	New Jersey, USA
Marzouk & Azab (2013)	Egypt
Pai et al. (2014)	Karnataka, India
Pune (2009)	India
Purcell & Magette (2009)	Dublin, Ireland
Sufian & Bala (2007)	Dhaka city, India
Wäger & Hilty (2002)	St. Gallen, Switzerland
Yan et al. (2007)	Dhaka City, Bangladesh

3. Material and methods

The methodological approach is divided into three sections, starting with an overview of the study area **(3.1),** followed by the formulation and development of the econometric model (**3.2**), and the System Dynamics model and the use of the Scenario Analysis to forecast the evolution of the different types of MSW up to 2030 **(3.3)**.

3.1 Characteristics of the current MSW management in the Balearic Islands

The Balearics are an autonomous Region of Spain, located near to the Iberian Peninsula. Their four major islands are Majorca, Minorca, Ibiza, and Formentera, with a total population of 1 million residents. However, as can be seen in Figure 1, they currently host more than 13 million tourists per year. The tourist population from 2002 to 2007 increased considerably (38%), followed by a strong decrease of 30% up to 2011 due to the financial crisis, and it then grew vigorously (37%) from the beginning of 2012 up to 2014, mainly due to the improvement in the global economy, tourist preferences, and other external factors such as the current situation of terrorism in competitive touristic areas like Tunisia, Turkey, and Egypt. This increase in tourism affected MSW generation, which serves as a basis for the design and sizing of collection facilities and treatment methods. Conversely, the resident population had slight annual growths until 2009 and few changes between 2010 and 2014.

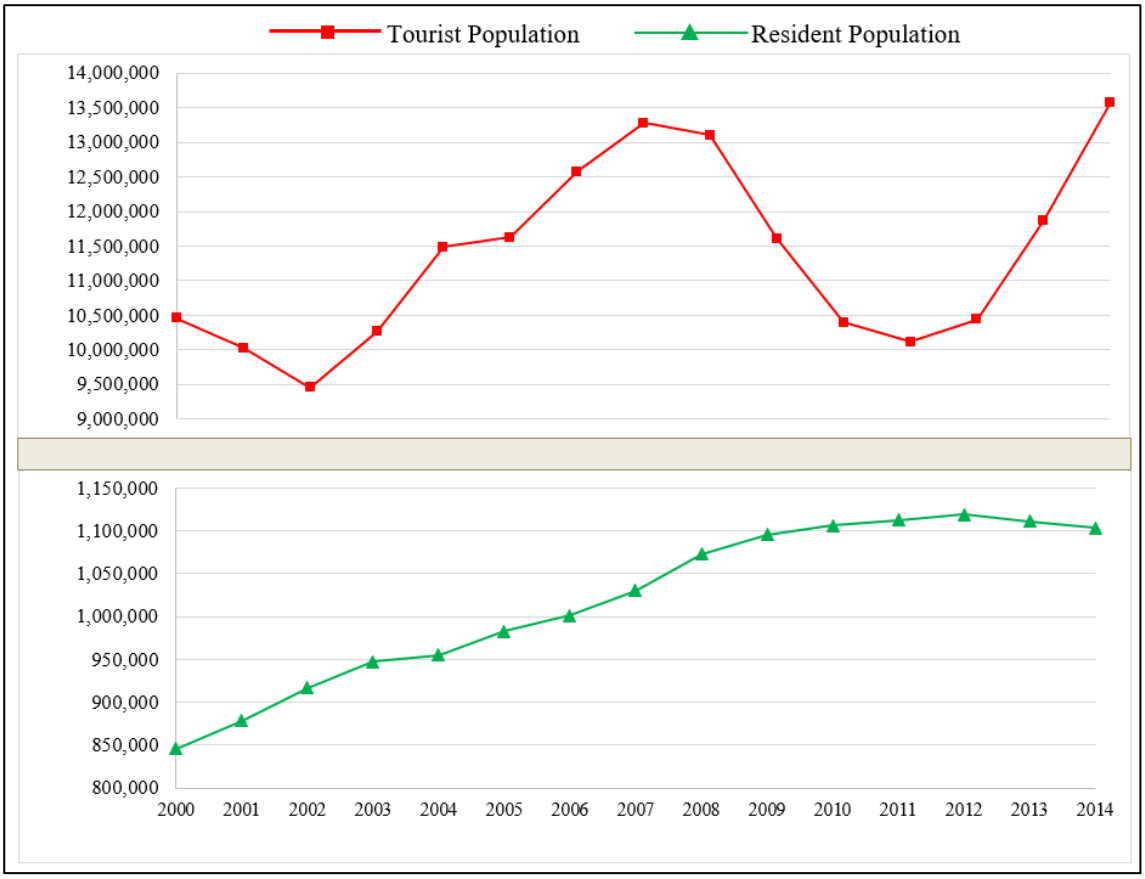


Fig. 1 Evolution of the Touristic population and Resident population

The currently used MSW treatments mix in the Balearic Islands consists of incineration, landfills, recycling, composting, and biomethanation. According to IBESTAT (2014), the following facts on the MSW situation in the Balearic Islands have been identified to build the models:

- Relatively high MSW generation rate: 711.3 kg/person/year (2014).
- The two existing incineration plants in the islands are both located in Majorca, and they have a current capacity of 732,000 tonnes of MSW per year.
- In order to make the incineration facilities more profitable, the Balearic Islands import MSW from Ireland and Italy. This is provoking a high level of rejection from many citizens of the islands.

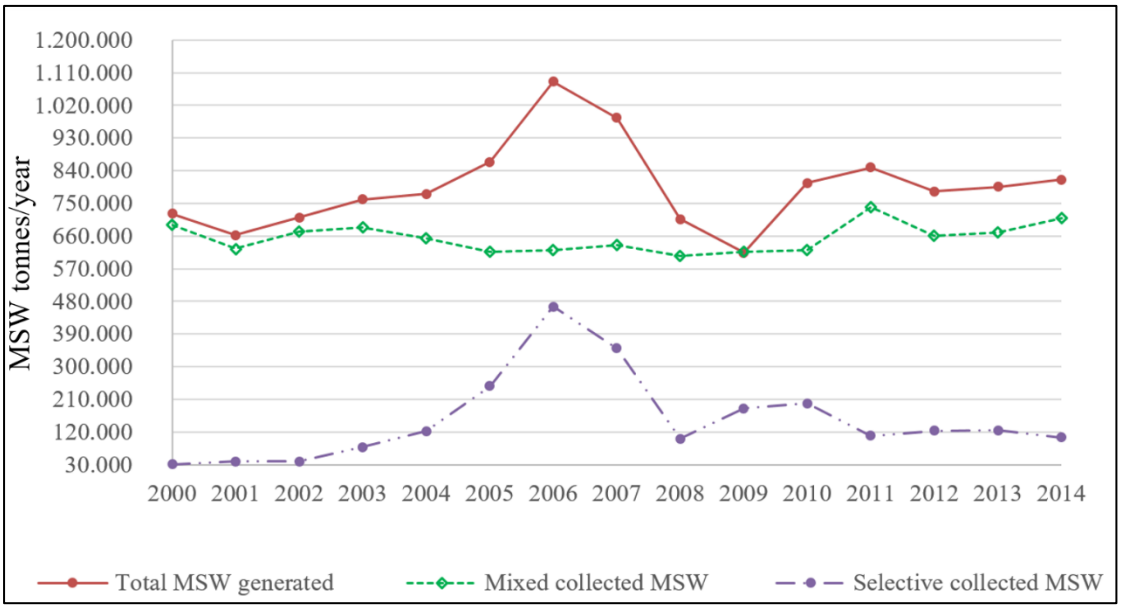


Fig. 2: Evolution of MSW generation in Balearics Islands

Figure 2 shows the evolution of MSW generation from 2000 to 2014. The total MSW generated has two components: separate collection and mixed collection. The separate collection is composed of two subgroups: a) the collection of paper/cardboard, glass, and packaging, and b) the collection of organic waste. The mixed collection consists solely of the remaining fraction of waste, which goes straight to landfills.

Regarding the variable total MSW generated, it shows an increase of 68.18% from 2001 to 2006, due to a great economic growth based on the tourist industry and mainly provoked by the selective collected component. However, from 2006 to 2009, it experiences a decrease of 45.93%, due to the economic slowdown (financial crisis). Finally, from 2009 to 2011, the total MSW once again experiences significant annual increases (28.57%), due the economic reactivation of the tourism industry, and continuing to grow until 2014.

Figure 3 shows the different MSW treatment methods in the Balearic Islands from 2000 to 2014. It can be seen that the landfill shows a weak linear upward trend from 2000 to 2009, but as of the end of 2009, incineration began to take on greater importance and underwent a strong growth. This was due to the opening of a second incineration facility, which increased the operational incineration capacity to 732,000 tonnes/year. The methods of recycling and

compost/ biomethanation show a different trend: they do not experience major changes in the studied period.

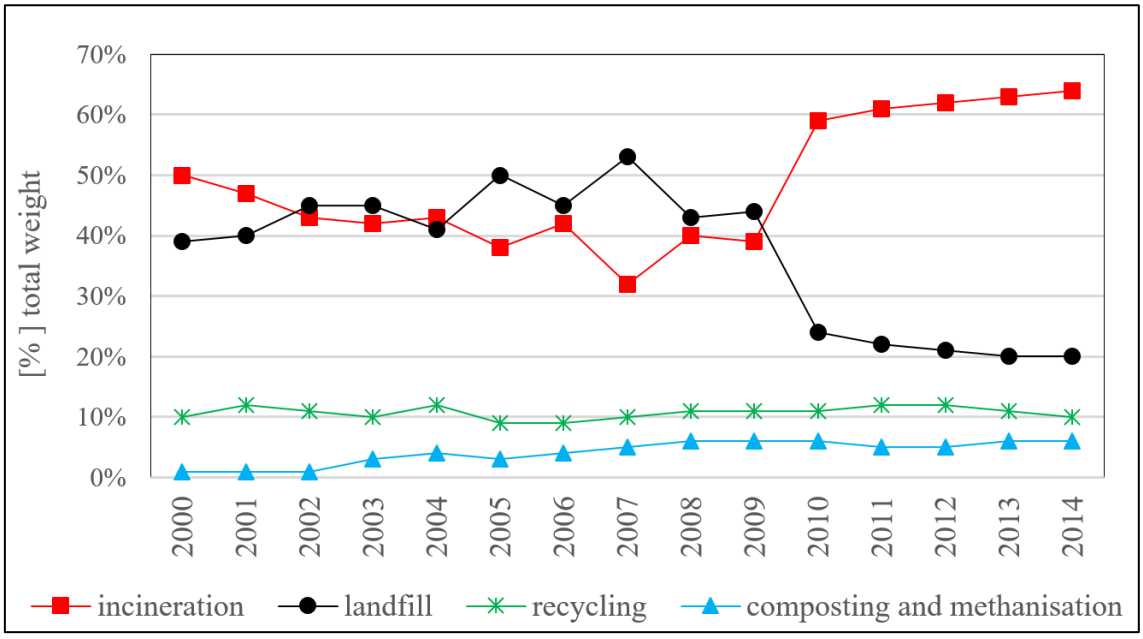


Fig. 3 Methods of treatment.

3.2 Development of the Econometric Model

Both the socio-economic and the MSW generation data (2000-2014) used in this study were extracted from the official statistical data of the Balearic Government (IBESTAT, 2014). The data were used to determine, through a multivariate regression analysis, the most significant key variables that directly affect the MSW generation in the study area. To reach this objective, the "*backward*" method was applied, as it estimates the regression coefficients of all the variables, and eliminates, step by step, the non-significant variables in their order of importance. Detailed information about the calibration of the econometric model, the calculations, and detailed results, can be found in ***Appendix B***. As a result, equation (1) shows the final econometric model and the six driving forces that explains the MSW generation ($MSWg$) in the Balearics (see in ***Appendix B*** the operational definition of the variables):

$$MSWg = (\beta_0 + \beta_1 * 1.295 + \beta_2 * 1.514 + \beta_4 * 1.781 + \beta_9 * (-0.184) + \beta_{10} * 0.559 + \beta_{11} * 0.795) + \mu_i \quad (1)$$

Where:

β_1 = Resident Population,

$\beta_2 = GDPpercapita$,

β_4 = Tourist Population,

β_9 = Education Level,

β_{10} = Number of Companies,

β_{11} = Number of Houses

The missing sub-index numbers ($\beta_3, \beta_5, \beta_6, \beta_7, \beta_8$) correspond to variables of insignificant influence on the MSW generation. Thus, they are not included in the equation. Also, it must be highlighted that the three main influences on MSW generation are Tourist Population, GDP per capita, and Residential Population.

3.3 Development of the System Dynamics model and the Scenario Analysis

The developed econometric model is static because it is based on cross-sectional data and all the variables refer to the same period. For this reason, and in order to forecast the behaviour of the key variables found, SD and SA methods were applied. These allow us to predict and analyse possible future developments considering different scenarios, with the aim of devising different strategies for each possible scenario that is considered. Thus, this analysis, which is a primary method of projections, does not intend to forecast an exact image of the future, but rather, it deliberately presents several alternative future scenarios, in order to improve the decision-making processes.

First, a casual loop diagram was built (see Fig. 1C in ***Appendix C***), showing how the variables influencing MSW generation interact with each other in the Balearic Islands MSW management system.

Subsequently, due to the historical data of some of the variables showing fluctuations, the Hodrick-Prescott (HP) filter was applied. The HP filter serves to remove the cyclical component of raw data time series, and thus helps to obtain a smoothed curve representation of a time series

(Harvey et al., 2008). By applying the HP filter, the time series tendencies for each variable were determined and used as a basis for the setting of the MSW scenarios (see ***Appendix A***). Then a Forrester diagram model for MSW management in Balearic Islands was constructed using the VENSIM software tool (see Figure 4), the equations for which are shown in ***Appendix C***. It is the basis for the simulations and estimates on the future behaviour of the variables in the nine scenarios generated, taking into consideration the objectives of the Spanish Waste Integrated National Plan (2008-2015), the Regional Master Plan for Municipal Waste Management, the current European Union policies on landfilling, and the Directive 1999/31/EC.

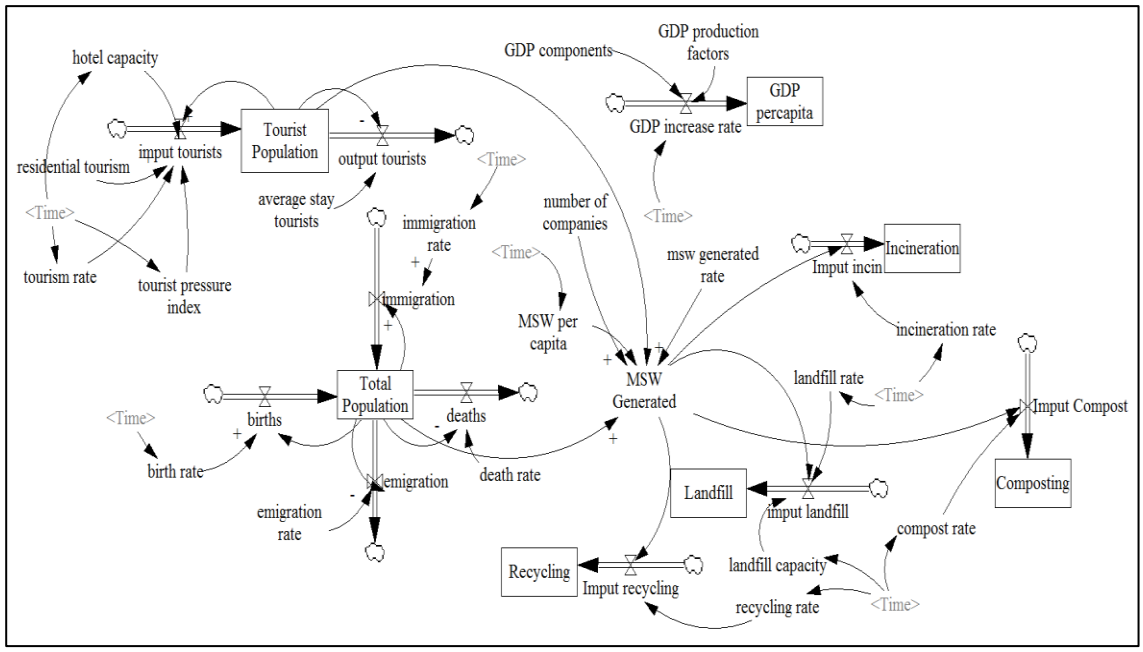


Fig. 4: Forrester diagram for the MSW management in the Balearic Islands (own elaboration).

The next question is: what might happen to MSW generation if the driving forces experience variations.

The scenarios were selected based on the objectives and assumptions described in Table 2, as well as on experiences obtained from other more efficient European countries in terms of MSW management (e.g. Germany and the Netherlands). The resulting strategies were adapted to the peculiarities of the Balearic Islands, such as the insularity, the impossibility of reaching economies of scale, and the region's high dependence on the tourist industry.

Table 2 defines the nine scenarios (Sc), comparing them with the baseline scenario (business as usual or BAU), which represents the MSW generation development with no variation in the variables affecting it.

Table 2: Main assumptions and targets of the simulated scenarios. (Ceteris paribus, conditions have been considered to study the influences of the individual variables)

Scenario	Driver	Assumptions and targets
Baseline Scenario BAU	Business as usual (BAU) ↓ MSW generation	In this scenario, the MSW treatment mix of 2014 is kept constant until 2030. MSW generation in 2014: 816,393 tonnes/year. Main average increase rates for the period 2000-2014: MSW generation (2.71%), Residential Population (1.92%), Tourist Population (2.53%), GDP per capita (1.47%) Treatment mix in 2014: 23% derived to landfills, 61% incinerated, 12% recycled and 4% composted.
Sc1	Population ↓ MSW generation	This scenario evaluates the influence of possible increases of the resident and the tourist population. There are two sub-scenarios: **Sc 1.1**: Assuming a low annual growth of 1.26% of the resident population (ResPop), ceteris paribus as in the BAU scenario. **Sc 1.2**: Assuming a high annual increase of 2.5% in the tourist population (TourPop) ceteris paribus as in the BAU scenario.
Sc2	GDP per capita ↓ MSW generation	This scenario evaluates the influence of the possible evolution of the GDP. There are two sub-scenarios: **Sc 2.1**: Assuming a low economic growth rate (GDP per capita) of 1%, ceteris paribus as in the BAU scenario. **Sc 2.2**: Assuming a higher economic growth rate (GDP per capita) of 1.47%, ceteris paribus as in the BAU scenario.
Sc3	Selective collection of recyclable fraction ↓ Treatment mix	This scenario evaluates the influence of possible changes in the selective collection rate of paper/cardboard, glass, and mixed packaging. There are two sub-scenarios: **Sc 3.1**: Assuming low rates of selective collection of 15%, ceteris paribus as in the BAU scenario. **Sc 3.2**: Assuming high rates of selective collection (e.g. deposit refund system) of 30%, ceteris paribus as in the BAU scenario.

Sc4	Selective collection of organic fraction ↓ Treatment mix	This scenario evaluates the influence of a possible implementation of a selective collection of the organic fraction. **Sc 4.1**: Assuming high rates of selective organic collection (e.g. door-to-door system, separating at the origin), ceteris paribus as in the BAU scenario.
Sc5	Incineration and Recycling ↓ Treatment mix	This scenario evaluates the influence of possible changes in the rates of incineration and waste depositing in landfills. **Sc 5.1**: Assuming a high annual increase of incineration of 65% (current rate 45%-50%), ceteris paribus as in the BAU scenario. • BAU scenario projected for incineration and recycling treatments. • Proportion of MSW to landfill and MSW generation in BAU scenario and BAU scenario projected.

4. Results

Regarding the econometric model, the main result is the identification of the three main driving forces of the Balearics MSW system, which are the variables with higher calculated coefficients: Tourist Population (ceteris paribus, each additional unit of tourists causes an increase of 1.781 kg/day in MSW generation), GDP per capita (an increase of 1% causes an increase of 1.514 kg/day) and Residential Population (an additional unit of inhabitants causes an increase of 1.295 kg/day of MSW).

With respect to the SD simulations, the BAU scenario simulates the 2000–2014 period trend, without incorporating improvements to the MSW management system until 2030. The following figures show the obtained results.

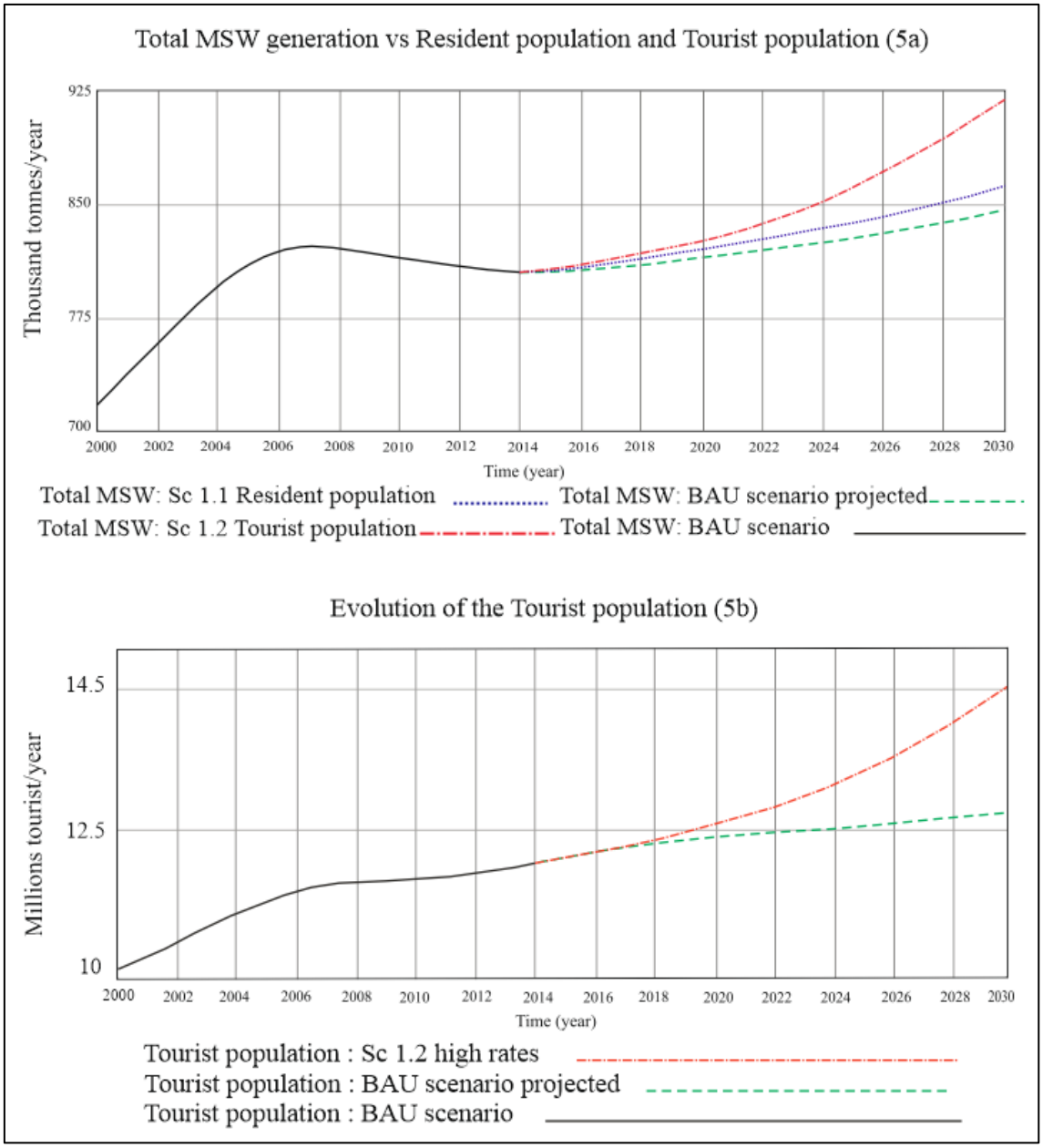


Fig. 5a MSW versus Residential Population and Tourist Population and **Fig**. **5b** Evolution of the Tourist Population

In Figure 5a it can be seen that the influence on the MSW generation of the Tourist Population is higher than that of the Residential Population. The Scenario 1.2 simulations suggest that the increases in the tourist population lead to higher MSW generation, reaching 105,000 tonnes/year (15% more in 2030 when compared with 2014). In addition, Figure 5b shows a sustainable growth of the Tourist Population throughout the period of inquiry, with an average

ratio of 2.5% per year, which provokes a total increase of 37.5% in 2030 (Scenario 1.2) when compared with 2014, equivalent to 5.5 million more tourists in 2030.

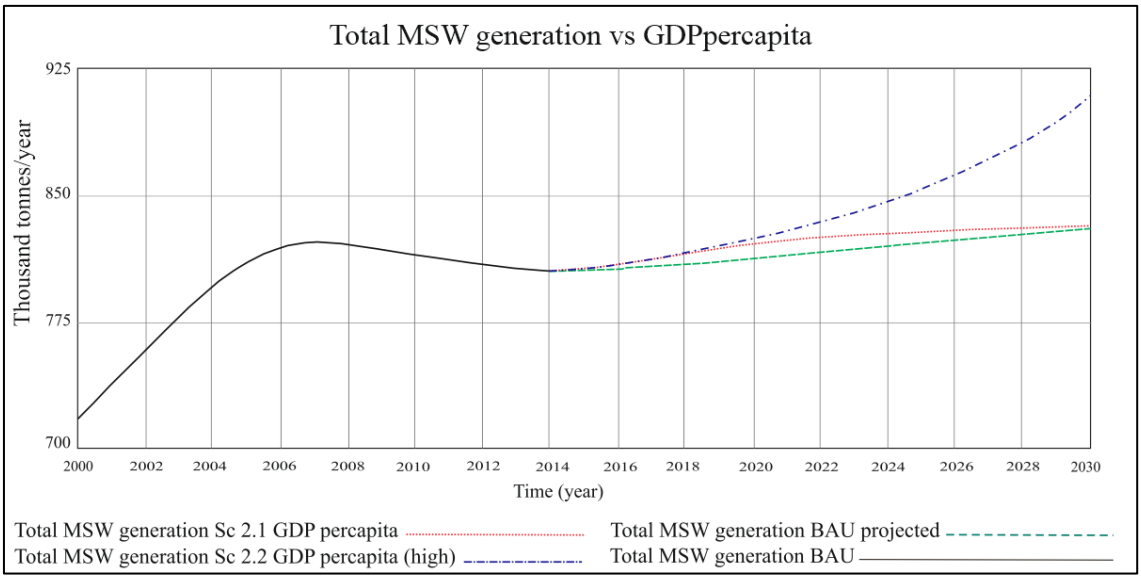
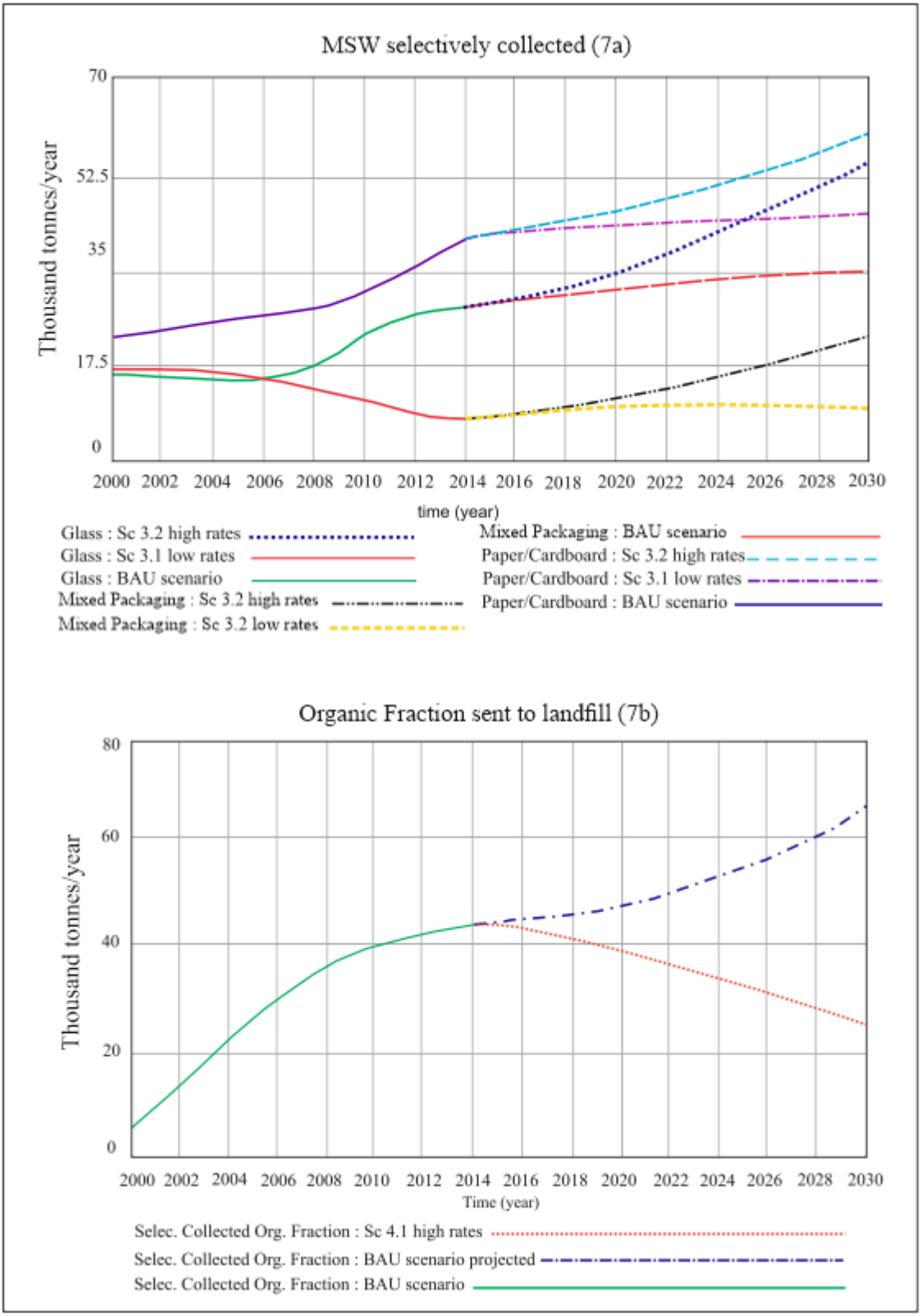


Fig. 6. MSW forecasts versus GDP in the BAU scenario, Sc2.1 and Sc2.2

Figure 6 shows that small increases in the GDP per capita level lead to higher MSW generation. In the BAU and Sc2.1 scenarios, this increase is 9%. However, the increase reaches 15% for Scenario 2.2 in 2030 for the more optimistic projection (with an average increase rate of 1.47 % per year until 2030).



1 **Fig. 7a** MSW selective collection and **Fig. 7b** showing the projection of the organic fraction

Figure7a (Scenario 3.2) shows a considerable increase in the three main types of waste for high rates of selective collection of 30% (optimistic case) compared to Scenario 3.1 (current rate 15%). This could be a consequence of the incorporation of the deposit refund system.

The incorporation of the organic fraction selective collection (Figure 7b, Scenario 4.1) would reduce the amount of waste deposited in landfills by 22,000 tonnes/year (a decrease of 40%) for 2030, compared to 2014.

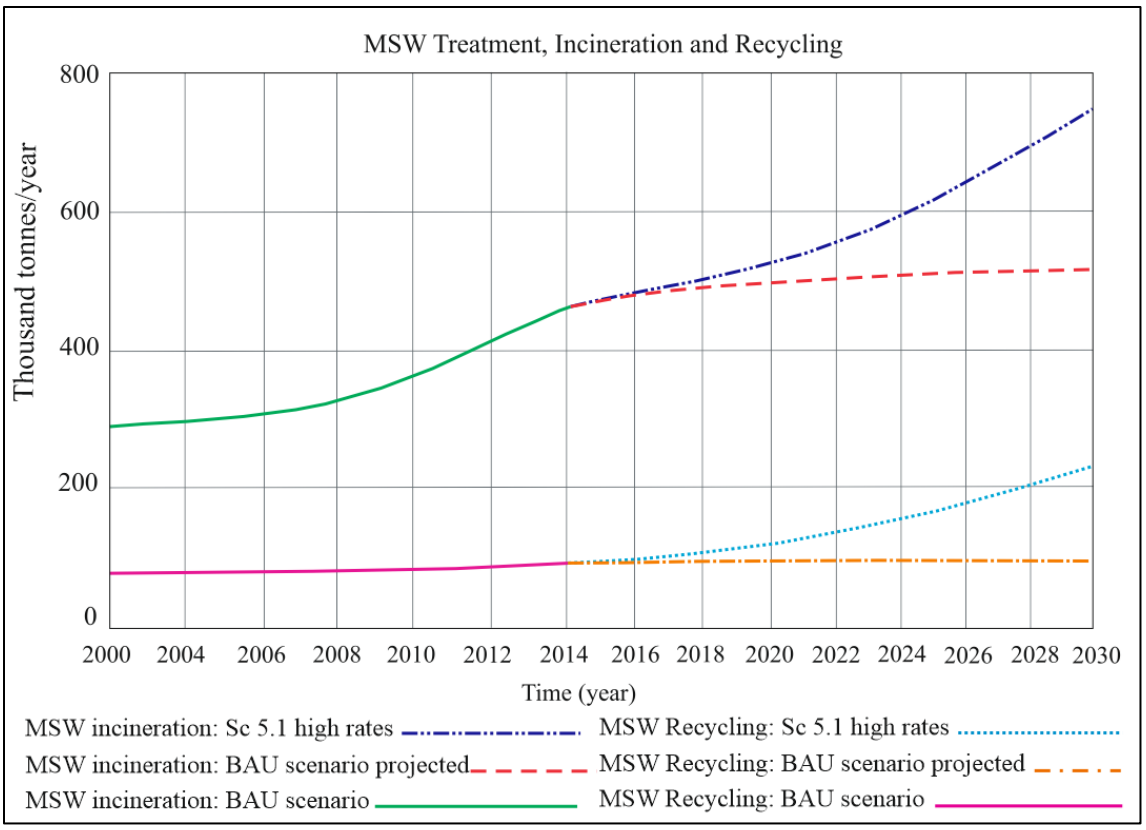


Fig. 8 Projection of MSW treatment, incinerated, and recycling waste.

Figure 8 shows that the recycling and incineration rates will continue to grow (Scenario 5.1), contributing to a decrease in the weight/ volume of MSW sent to landfills, considering an average incineration ratio of 65%, (15% more than the current rate) which is the ratio recommended by the MSW Regional Plan. In addition, in this optimistic scenario, the MSW incinerated will be close to the maximum operating capacity of the facilities (730,000 tonnes/year).

4.1 Model validation

The data were adjusted using the Hodrick-Prescott (HP) filter (see ***Appendix A***), which allows the isolation of outliers (financial crises, random behaviour, etc.) of the time series under study. After that, it is possible to determine the trend of the time series, and to perform estimations that are more appropriate. The smoothing parameter, λ, of the filter, which penalises acceleration in the trend relative to a cycle component, is stated equal to 100. Most of the business cycle literature uses this value for the λ parameter, as has been suggested by Hodrick & Prescott (1997).

Also, in order to validate the model, to test its robustness and reliability (Hyndman et al., 2006; Robalino-López et al., 2015) the MAPE (mean absolute percentage error) values for the main variables of the model were calculated. These values are defined as follows:

$$\frac{\sum|(y_t - \hat{y}_t)/y_t|}{n} * 100, (y_t \neq 0) \quad \text{Eq. (2)}$$

Table 3 shows the MAPE values calculated (see ***Appendix D***) that measure the average percentage error size of the driving forces obtained in the multivariate regression.

Table 3. MAPE´s result

Variables	MAPE
MSW generation	3.29%
Tourist Population	1.18%
GDP per capita	4.22%
Residential Population	2.60%

The low values obtained indicate that the forecasts are good, because they are under 5%, and an allowable error interval of [0; 10%] is recommended by the literature.

5. Discussion and Policy implications

The results of this study indicate that the total MSW generation of the Balearic Islands is expected to increase during the next 15 years due to economic growth, population size, and socio-economic influences.

The local market of the Balearic Islands is limited, and its economy depends on the tourist sector and services. Fluctuations in the tourist population and in the level of income determine the patterns of consumption in a region that has one of the highest GDP per capita of Spain.

Concerning the optimisation of the MSW management, although incineration is currently prioritised before other methods, it has provoked a deficit of 23 million Euros between the cost and the taxes paid by the citizens in recent years. Therefore, the authorities have begun to import MSW from other countries in order to exploit the maximum operational capacity of the two incineration facilities. This has caused several controversies.

Concerning selective collection, especially the collection of the MSW organic fraction, it would lead to a considerable minimisation of the MSW deposited in landfills. The potential resulting from the treatment of this type of MSW is that each 100 kg of adequately treated organic waste leads to 30 kg of compost, which is consistent with the results of Freire et al. (2008) concerning the valorisation of organic waste. It is necessary to increase recycling, reuse, and energy recovery to reduce the amount of MSW sent to landfills. To achieve this, it is imperative to increase the ratios of selective and non-selective collection, and to promote recycling in households, as described by De Feo et al. (2010) and Andraca et al. (2010).

Nevertheless, with the implementation of the system of deposit and return of containers, very significant results are obtained to increase selective collection (see Scenario 3.2, Figure 7a). This was also proposed and analysed by Lavee (2010).

The Balearic Islands need to implement new sustainable management models to curb and control the high MSW generation of their main industrial sector in the context of a more efficient circular economy, as can be seen in Ilić et al. (2016) in Serbia.

Based on the modelling results, several policy implications can be identified. Firstly, the current decrease in tourism in unsafe areas such as Tunisia, Egypt, and Turkey provokes an increased tourism demand in the Balearic Islands. This leads to increases in MSW generation in the archipelago as simulated in Scenario1.2. Both the public and the private sector should invest more in the deployment of a sustainable MSW management system by implementing projects

such as the public encouragement of selective collection, the start-up of biomethanation plants despite public controversy, or other alternative measures with the same direction as simulated in Scenario 4.1, in terms of organic and remaining fraction waste. Furthermore, this would help to restrain global warming because the methane emissions (methane is a greenhouse gas with a global warming potential 25 times greater than carbon dioxide) escaping from landfills would be reduced (Hoornweg & Bhaza-Tata, 2012).

Finally, as the tourist industry is the main revenue source for the archipelago, it also has one of the major influences in the generation of MSW (as shown in Scenario 1, Figure 5a) because in the Balearic Islands, tourism represents approximately 45.8% of the GDP and 32 % of the direct employment (IBESTAT 2014). Thus, policies should focus on the control of the touristic MSW generation and its management.

6. Conclusions

Since the issue of MSW management is quite complex, with many interacting variables, it is valuable to apply an analytical-empirical methodology that provides mathematically consistent results in order to facilitate decision-making.

The main conclusions drawn from this study are:

1. The current MSW management system in the Balearics is nowadays clearly unsustainable. It is clear that without changes (BAU scenario), it will be very difficult for the Balearic Islands to fulfil their objectives of MSW minimisation and prevention, especially in terms of the current requirements of the European Union (European Directive 2008/98/EC, article 11).

2. Once the driving forces of the MSW generation have been shown using the econometric model, the developed model offers a quantifiable base for the optimisation of MSW management. With this, the stakeholders can make better decisions about the necessary dimension and infrastructures for the Balearic Islands. For example, in summer the influx of tourists increases MSW generation and causes more MSW to be sent to landfills. This requires a resizing of the infrastructure and the facilities in order to improve MSW management.

3. The expected forecasts of the MSW trend scenario (BAU) until 2030 show a situation that becomes more difficult to control each year, due to the low rates of MSW separation, incineration, recycling, and valorisation, especially due to an insufficient collection of the MSW organic fraction.

4. The current method of incineration should be prioritised before landfill. The optimal combination of incineration and recycling is the first step towards "zero MSW" policies, which minimise the amount of MSW sent to landfills, avoiding their saturation.

5. Another important point is that, having relatively small domestic markets, islands have a high need to import products, which involves a lot of packaging material and the related MSW.

6. Also it should be borne in mind for future studies that the tourist population has a greater impact on the MSW generation than the resident population, although in the current official statistical data, the resident population and the tourist population are considered jointly for the total MSW generation. However, they should be considered separately to improve the design and sizing of new MSW management facilities.

In any case, it must be recognised that MSW management is a critical factor to achieve a more sustainable model of tourism development, especially in the Balearic Islands and in many other tourism sectors in the world.

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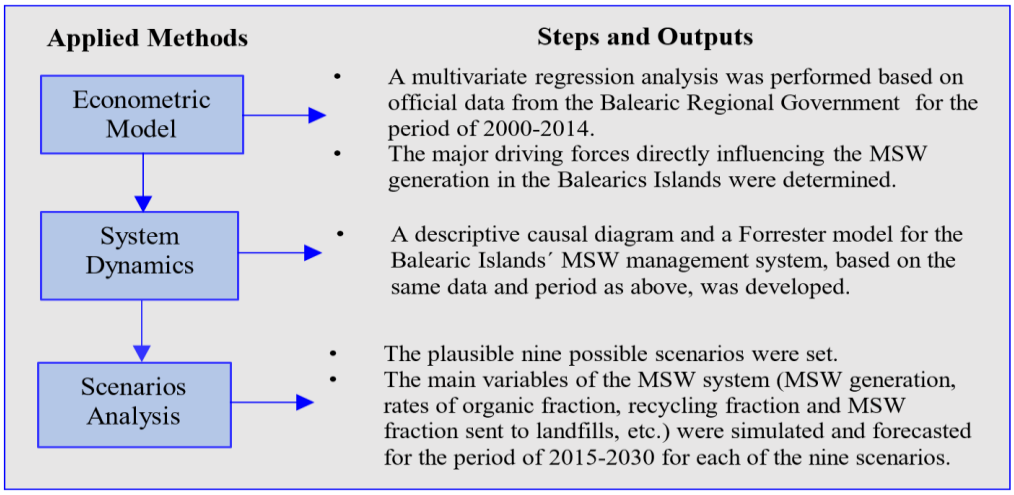
Graphical Abstract



Highlights

- Balearics are among the most important touristic islands in the European Union (EU).
- An econometric model was built based on historical data for the period 2000-2014.
- The model allowed identifying the key factors of the MSW generation.
- A System Dynamics model and Scenario Analysis was used to forecast future MSW generation.
- Maintaining current policies it will be impossible to meet the MSW EU goals.

Title page

• ***Title.*** **Modelling the Driving Forces of the Municipal Solid Waste Generation in Touristic Islands. A Case Study of the Balearic Islands (2000 − 2030)**

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