Will the Balearics and the Canary Islands meet the European Union's targets for municipal waste? A comparative study from 2000 to 2035.

Abstract.

Recycling and selective collection rates in touristic islands are low, and they have to be increased to move them towards a more circular economy. This paper attempts to determine whether it will be possible to achieve the European Union's (EU) legally binding targets regarding the different fractions of municipal solid waste (MSW) in the two Spanish regions with the highest per capita MSW generation rates. After reviewing the MSW generation literature in touristic islands, the driving forces affecting MSW generation in the Balearics and Canary archipelagos from 2000 to 2018 are identified. Their evolution until 2035 is forecasted, using a methodology which combines econometric models, System Dynamics and Scenario Analysis.

Results reveal that the biggest MSW generator in both archipelagos is the touristic population, followed by the resident population in the Balearics, and by the per capita income in the Canaries. Then, by using simulations to create different scenarios, the annual ratios to be reached by 2035 are estimated for each MSW fraction in both archipelagos. The current low recycling rates (15.81% in the Balearics and 11.18% in the Canaries) would have to be increased by an annual average of 2.89% and 3.16% respectively, to achieve the compulsory 65% target established by the MSW EU Directive for 2035. Therefore, both territories are currently far from the right pathway to meet the EU goals. However, the European Green Deal has to promote circular economy projects that help achieve each type of waste targets.

Keywords: Municipal waste management; Waste generation rates; Econometric model; Scenario simulation; Balearic Islands; Canary archipelago.

1. Introduction and aims.

On our planet, islands occupy a total area of 9,963,500 km^2, representing 6.6% of the Earth's total area (Dong et al. 2019). Many of these islands are real natural treasures that must be protected because they receive a growing number of tourists that can seriously affect these territories' sustainability due to the consumption of the local resources and negative environmental impacts, mainly through municipal waste (Cheer, 2020).

The World Bank (Kaza et al. 2018) has stated that our planet generates 2010 million tons of Municipal Solid Waste (MSW) annually, and at least 33% of it is not appropriately managed. The world waste generation per capita varies widely, from 0.11 to 4.54 kg/day, averaging 0.74 kg/day. Usually, the correlation between waste production and the countries' level of income is positive, so it is estimated that the 16% of people living in the wealthiest countries generate around 34% (683 million tons) of the MSW per year. The situation will worsen in the future as the global generation will presumably increase to 3.4 billion tons by the year 2050, mainly due to the increase in Africa and Asia's contribution (Kaza et al. 2018). The MSW management is a very complex task (Kolekar et al. 2016), and it is even more complex in tourist islands because they are often small, limited and isolated spaces.

In 2019 the travel and tourism industry generated 10.3% of the global Gross Domestic Product (GDP), providing around 1 in 10 jobs worldwide (direct, indirect and induced), and more than 4.4% of total investments in the world (WTTC, 2020). Those figures are much higher in archipelagos where tourism and associated businesses, such as hospitality, transportation systems and travel agencies, are the main pillars of their economy. This happens in two of the most famous European touristic archipelagos, the Balearics and the Canary Islands where the tourism industry in 2018, accounted for 44.3% of the total GDP in the Balearics and 35% in the Canaries (IMPACTUR, 2019). These figures are more than double compared with those from Spain (12.3% of the Spanish GDP) (Exceltur, 2019).

As European territories, these two archipelagos, which have the highest per capita MSW generation in Spain, are forced to meet the environmental goals established by the European Union (EU) for the following years. In 2015, the European Commission introduced a Circular Economy Action Plan (COM, 2015) of legislative and non-legislative initiatives, which mapped out 54 actions. More recently, in March 2020, as a result of the European Green Deal development (COM, 2019), a new Circular Economy Action Plan which aims to make Europe more eco-friendly and competitive was adopted (COM, 2020) with four directives containing targets for different MSW fractions. All of them aim to promote the changes approved by the European Green Deal (2019), boosting jobs, economic growth, and investment, so that in 2050 Europe becomes the first climate-neutral and more use-resource efficient continent.

The world economy is transitioning from the traditional linear economy to a circular economic model paradigm, and the tourism industry is not an exception (Vargas-Sanchez, 2018). Recycling rates of touristic islands worldwide are low and need to be radically improved to move towards a more circular economy.

Island destinations such as the Balearics and the Canary Islands are ideal case studies for observing the effect of tourism on MSW generation. They can almost be considered closed systems to provide precise estimations of the impact of tourism on MSW production. The main activities generating MSW are accommodation, transport services, and food and beverages. During the last two decades, the tourism industry had significant growth, and before the COVID-19 pandemic, it was one of the most productive economic activities worldwide. However, the MSW management in touristic islands is particularly challenging and expensive due to their remote locations, orography, having a variable number of residents, and seasonal changes in the amount and constitution of MSW (Ezeah et al. 2015).

For all the reasons mentioned above, it is interesting for both archipelagos, and will be the objectives of our research: (i) to analyse the problems presented by their MSW management system; (ii) to point out the main elements influencing their MSW generation; (iii) to compare the impact of the equivalent tourist population (ETP), and resident population on their MSW generation; (iv) to calculate the changes in the different MSW fractions under a set of selected scenarios; (v) to evaluate the possible fulfilment of the MSW EU targets in these two touristic archipelagos, and (vi) to analyse the most efficient strategies, roadmaps and policies to achieve those targets.

The Balearics and the Canary Islands are the two Spanish autonomous regions with the highest per capita MSW generation. They have to meet the same goals from the European Directives (EU 2018a, EU 2018b, EU 2018c), and the Spanish legislation (Waste Prevention Programme 2014-2020 and National Waste Management Plan 2016-2022). However, they have different locations and different socio-economic characteristics. The Balearics are located in the Mediterranean while the Canaries are found in the Atlantic Ocean. The per capita income of the Balearic Islands is higher, while its population is smaller than that of the Canaries. Both have a significant tourist population, which makes them ideal case studies to find out how to improve MSW management in tourist islands. Besides, recycling is more important in the islands than in non-island territories due to their remoteness from many production centres. It can also become a source of material resources and local job creation. According to the EU waste policy, both archipelagos will have to reduce their per capita MSW generation rate, increase the recycling and selective collection rates, save primary resources, and create markets for secondary products in their territories. The question is how, and at what speed. In response, this study explores the potential for these two tourist islands to meet MSW EU targets by estimating and comparing the current and future MSW generation.

The rest of the article has the following structure: Section 2 discusses the previous publications on touristic islands, especially those concerning these two cases. In Section 3, an overview of these two study areas is presented, and the main problems associated with the MSW generation for both territories are identified. Section 4 shows the sources of the data set collected and the models and methods applied. Section 5 is devoted to presenting the empirical results and their discussion. Sections 6 provides conclusions and policy implications. Finally, Appendices A, B, C for the Balearic Islands; and D, E and F for the Canary Islands show the models, equations, and intermediate results of the calculations in more detail.

2. Previous literature.

2.1 Studies on the MSW-Tourism relationship in touristic islands.

Based on the outcome of our analysis on previous studies, the conclusion is that the relationship between tourism and waste generation in islands has received relatively little attention from the scientific community to date, and even fewer studies have been focused on the two touristic archipelagos mentioned in this article. However, this topic's interest has been increasing in the last decade, mainly by the pressure exerted by tourism on some famous islands and the environmental problems arising in Small Island Developing States (SIDS).

Most of the previous literature focuses on issues such as waste composition, integrated waste management, environmental impact and sustainability issues, and to a lesser extent in treatment and disposal methods, resource utilisation and financial aspects. First, we will show a broad sample of the previous investigations on this topic in touristic islands outside of Spain. Then, we will present all the previous research developed on the two archipelagos.

One of the first investigations on this matter is that of Chen et al. (2005), who raises the problem of exhaustion of space for MSW dumping in Taiwan's Green Island. They conclude that, in the long term, the island will have to transport waste to the continent, but by building an incineration plant, some extra time to find other options can be gained. Gidarakos et al. (2006) provide data on the composition and quantities of the MSW generated during a year at seven landfills and a transfer station on the Mediterranean island of Crete, including their physical and chemical characterization, and seasonal variation. Su et al. (2007) create a model to improve the MSW Taiwan Island strategy. Chertow and Eckelman (2009) apply material flow analysis (MFA) to enhance the long-term sustainability of Oahu island of Hawaii. The MFA results suggest alternatives to take advantage of the resources contained in the MSW as a means to substitute imports and reduce waste generation on the island. Weng et al. (2009) show similarities with our research, as they analyse the ways to achieve less waste disposal on the island of Taiwan, reviewing historical data from its MSW management system, and making MSW projections until 2011, based on scenarios from its national plan.

Foolmaun et al. (2011) describe the MSW system of Mauritius Island, which is a SIDS located in the Indian Ocean and near the south-eastern coast of Africa. They compare its disposal system with those of another SIDS and provide recommendations for its improvement. Shamshiry et al. (2011) investigate practices of MSW management in the island of Langkawi (Malaysia), estimating the MSW composition. Eckelman et al. (2014) review the previous works on MSW management on islands and provide MSW generation data from 41 archipelagos and islands around the world. They used cluster analysis to find the correlation with economic and geographic parameters.

Vaz et al. (2015) present a case study of the implementation of separate collection of biological waste and composting in São Tomé and Príncipe, which is a SIDS located in western Africa. Mohee et al. (2015) provide a statistical comparison among the MSW generation rates, and the composition and technologies employed by many SIDS, classified into three regions. Camilleri-Fenech et al. (2018) apply Material Flow Analysis and Carbon Footprint jointly to estimate the flows involved in MSW management, using official data for 2012, and projected data for 2018, obtained from three scenarios of the Maltese Islands Waste Management Plan for the 2014-2020 period.

Kapmeier and Gonçalves (2018) develop a robust System Dynamics model for analysing the roadmaps up to 2050 of the Maldive Islands using simulations, under three sets of policies. These authors found that policies oriented solely on improving waste management are counterproductive because they promote the arrival of visitors, causing an increase in MSW generation and negatively impacting the tourist attraction and its subsequent growth. However, the island can boost its economy and environment by implementing policies that limit tourism demand. Zand and Heir (2019) analyse the effect of four waste disposal alternatives on Kish, a well-known tourist island in Iran. They apply the Rapid Impact Assessment matrix tool, finding that the best option is where 50% of waste is recycled and 50% incinerated.

Sekito et al. (2019) provide waste generation statistical data for Gili Trawangan island in Indonesia. Millette et al. (2019) focus on plastics in Trinidad and Tobago, developing a material flow analysis (MFA) methodology designed for countries with an insufficient statistical capacity and developing countries. The authors identify circular economy project opportunities and find that the landfilled plastic comes from imported products rather than from domestic use. Neehaul et al. (2020) employ a multi-criteria decision method to find the best waste-to-energy technology for Mauritius Island, considering technical and sustainability criteria. Incineration, gasification, pyrolysis and anaerobic digestion alternatives were compared. Iuras et al. (2020) applied dispersion and regression analysis to statistical data from a Ukrainian touristic region, finding that the number of tourists, the GDP per capita and the population are the main MSW generation factors within Ukraine.

Nguyen et al. (2020) study the relationship between waste composition and socio-economic factors using econometric models, finding that the higher the household's rent, the more complex the waste composition is. Furthermore, there are differences in kitchen waste between urban and rural communities, and plastic and glass waste generation decrease when the GDP increases. Taktak et al. (2020) compare the MSW quantities generated by tourists in hotels and by the local population on the island of Djerba in Tunisia. Elgie et al. (2021) quantify waste flows in Grenada, located in the Caribbean Sea, using Material Flow Accounting (MFA). Grenada generated 1.14 kg/pers/day of waste in 2017. These authors also propose improving the statistics on waste, implementing the polluter pays principle.

2.2 Studies on the MSW-Tourism relationship in the Balearic Islands.

There are few previous works focused on the Balearic Islands. Among the forerunners, Rosselló-Batle et al. (2010), study the waste generation from tourists in a small number of tourist lodgings in the Balearic Islands. Mateu-Sbert et al. (2013) provide data on the MSW selective collection and recycling in Menorca, the Balearics' second-biggest island. They also estimate the effect that visitors had on the MSW generation during the period 1998-2010 through dynamic regression models. They discovered that each additional tourist produces 1.31 kg/day, while one more resident generates 1.48 kg/day. Ezeah et al. (2015), through interviews with some of the islands' interest groups, contributed to identify and analyse the problems caused by tourism in four famous European tourist islands, among them Mallorca and Tenerife from our case study.

Arbulu et al. (2016, 2017) analyse the impact of tourism on the performance of the waste-to-energy (WTE) utilities in Mallorca, finding out that this factor strongly influences the management costs of WTE facilities, and therefore recommend to change the tariff system of the public-private partnerships contracts to improve the performance of the public service. The same authors (Arbulu et al. 2017a) develop a STIRPAT model for the island of Mallorca, finding that a 1% increase in tourist arrivals would cause a 1.25% rise in waste generation. There are also studies (Weber et al. 2018) on a single municipality such as Esporles, in Mallorca. They found that local environmental organisations' participation increases the involvement and commitment of the resident population in favour of the implementation of more sustainable waste management policies. Finally, Estay-Ossandon and Mena-Nieto (2018) provide MSW data for the Balearics and identify the most significant MSW production drivers in this archipelago (2000-2014) and foresee the MSW management system performance from 2015 to 2030. This last work was the starting point for the research developed in this paper.

2.3 Studies on the MSW-Tourism relationship in the Canary Islands.

There are also very few studies on the impact of tourism in the Canary archipelago. Two decades ago, Garcia-Falcon and Medina-Muñoz (1999) proposed a methodology for the identification of strategic priorities for sustainable development in Gran Canaria, which is one of the main islands of the Canary archipelago. Their paper examines socio-cultural, environmental and economic aspects, with emphasis on tourism. Santamarta et al. (2014) analyse the Canaries' MSW management deficiencies between 2005 and 2011 and propose new guidelines to improve its administration, although lacking mathematical support. Estay-Ossandon et al. (2018) rank and find the best MSW treatments to improve the MSW management and planning system in the Canary archipelago applying the Delphi method and fuzzy TOPSIS. Quesada-Ruiz et al. (2019) apply discriminant analysis and Geographical Information Systems (GIS) to map the illegal landfills located on two islands of the Canary archipelago, identifying 286 and 153 locations in Gran Canaria and La Palma, respectively. They found that agriculture, greenhouse density and urban sprawl are the primary drivers of their emergence. Uche-Soria and Rodriguez-Monroy (2019) estimate the potential of MSW recovery on the island of La Gomera and provide data on the composition and characteristics of the MSW through samples taken on this small island. As a result, they recommend a solution Waste to Energy-based (WtE) to recover energy (up to 26,000 MWh per year) as a suitable and sustainable alternative to landfill deposition. The same authors (Uche-Soria and Rodríguez-Monroy, 2019a) investigate how to improve the MSW management in the main ports of the Canaries, developing a more circular waste management model which increases the recycled waste fraction, generating energy for those ports and reducing their environmental impact.

Ramos-Suárez, et al. (2019) evaluate the potential for generating biogas from animal manure in farms on the Canary archipelago's seven islands. Additionally, they estimate the savings in Greenhouse Gases (GHG) emissions (0.68%) and their contribution to renewable energy generation in the archipelago, which could supply 8.56% of the energy needs in 2016. More recently, Diaz-Farina et al. (2020) studied the contribution of tourists to MSW generation in the city of Santa Cruz de Tenerife, which has the second-biggest population of the Canary Islands. They used data from 2004 to 2015, adopting a mixed demand-supply approach and providing MSW daily-generation rates for tourists and residents.

2.4. Research gap and novelty

This paper is different from previous research in the following points:

1. As far as we know, this is the first comparative analysis between the Balearics and the Canary Islands regarding the MSW generation over the last two decades.
2. As shown, few articles have studied the impact of tourism on the MSW generation in the Balearic archipelago, and even less in the Canary Islands. The period studied, the research objectives, and the goals considered until 2035 are different, because they derive from the EU's circular economy objectives, recently revised in 2020.
3. In addition to a broad sample of the most important papers on MSW generation in the main tourist islands of the world, and a comprehensive literature review on these two famous Spanish islands, this paper provides to the scientific community the impact of the different driving forces over time and the historical and current ratios of the different fractions of the MSW for both archipelagos. It also estimates their foreseeable evolution until 2035, under different hypotheses and scenarios, to better plan the slow transition from a linear to a circular economy in these or other touristic islands.

3. Overview of the study areas.

Both archipelagos are two of the seventeen Spanish autonomous regions of Spain. On the one hand, the Balearic Islands are located east of mainland Spain, and on the other, the Canaries are southwest of the Iberian Peninsula, but much further away, closer to the west of Africa. Both economies are highly dependent on the tourism industry, representing 44.3% of the Balearics' GDP and 35% of the Canaries' (IMPACTUR, 2019).

The Balearics are the main tourist destination in Spain, and the leader in the per capita MSW production (INE, 2019). The largest isles of the archipelago are Mallorca, Menorca, Ibiza and Formentera. As shown in Table 1, the Balearic Islands received more than 16 million tourists in 2018, while having 1.2 million residents. They have a high waste generation rate of 2.08 kg/pers/day and 759 Kg/pers/year in 2018 (IBESTAT, 2019), with incineration (55.40%) and controlled landfilling (20.64%) being their primary methods of treatment. Regarding their recycling rate, although it has been rising in recent years, it is still very deficient (15.81%). The rest of the MSW (8.15%) is treated by composting, and a small fraction is rejected material.

Seven islands constitute the Canary archipelago in Spain. These islands are home to 2.2 million residents, which produce waste at a rate in 2018 of 1.54 kg/pers/day or 564 kg/pers/year (ISTAC, 2019). In recent decades, the tourism growth has caused an increase in the MSW production, which has not been matched by an increase in infrastructure and treatment facilities, mainly in their two biggest islands, Tenerife and Gran Canaria. Consequently, the archipelago has not met the targets established by the Spanish National Framework of Waste Management Plan (PEMAR 2016-2022). According to ISTAC (2019), in 2018, the MSW treatment mix in the Canary Islands was landfilling (80%), recycling (11.18%), composting (4.92%) and rejected material (3.9%). There are no incineration facilities, and there is no separation at the source because all the mixed MSW is deposited in grey containers.

Table 1. Comparative MSW generation and other variables between the Balearics and the Canary Islands.

Variables		2000	2006	2012	2018
Total Population [pers/year]	Balearics	845,630	1,001,062	1,119,439	1,187,808
	Canaries	1,672,689	1,968,280	2,126,769	2,207,225
Total MSW generated [t/year]	Balearics	761,664	743,264	783,690	901,452
	Canaries	1,243,837	1,397,206	1,310,231	1,245,102
Total MSW generated per capita [kg/year]	Balearics	901	742	700	759
	Canaries	744	710	616	564
Mixed MSW [t/year]	Balearics	690,438	620,754	659,799	789,614
	Canaries	1,114,598	1,105,084	1,162,173	1,096,600
GDP per capita [€/year]	Balearics	19,300	24,600	23,372	26,671
	Canaries	14,200	19,595	19,792	20,018
Tourist population arrivals [tourist/year]	Balearics	10,457,122	12,577,829	10,442,838	16,583,654
	Canaries	9,855,592	9,276,963	10,318,178	14,752,624
Equivalent tourist population [pers/year]	Balearics	338,252	400,425	447,776	475,123
	Canaries	334,538	393,656	425,354	441,445
Selective MSW collected [t/year]	Balearics	71,226	122,510	123,891	111,838
	Canaries	129,239	292,122	148,058	149,247
Main mix collected Balearics [t/year]	Glass	16,940	22,877	29,039	39,612
	Paper/Cardboard	13,058	65,370	38,865	39,097
	Packaging	1,044	16,278	27,905	23,729
Main mix collected Canaries [t/year]	Glass	11,967	20,414	29,126	38,888
	Paper/Cardboard	11,771	76,863	33,507	31,954
	Packaging	2,457	29,347	21,830	20,143

In 2018 (see Table 1), the per capita generation rate in the Canary Islands is lower than the Balearics' (564 versus 759 kg/pers/year). However, its recycling rate is worse than the Balearics' (11.18% versus 15.81% in 2018). Other differences are that the Balearics receive more tourists per year and that its seasonal tourism has a higher GDP per capita than the Canaries'. Conversely, in the Canary Islands, tourism is more homogeneous throughout the year, and its tourists have a significantly lower GDP per capita than the Balearics'. The main problems identified for both archipelagos are:

a) Low selective collection rates: 15.81% in the Balearics and 11.18% in the Canaries.

b) There is not a generalised selective collection of the organic fraction.

c) High costs of waste transportation.

d) Insufficient financing of the annual collection and treatment of MSW and low investment in new infrastructures and treatment processes.

Regarding the waste charges, these do not cover collection and treatment costs of the household and business waste in 57% of the Spanish municipalities (Puig-Ventosa, 2020). They are usually regulated through each municipality's fiscal ordinances, presenting a high variability throughout the Spanish territory and even between neighbouring populations. Traditionally these charges are conceived as flat rates and are independent of the amount of generated waste. In this aspect, few studies discuss the funding of waste services in Spain (Chamizo-González et al. 2016, 2018; Puig-Ventosa and Sastre Sanz, 2016, 2018, 2020; Alzamora et al. 2020). One of the most relevant is the one carried out periodically by The Observatory on Waste Taxation (please, see https://www.fiscalidadresiduos.org/) promoted by Fundació ENT of Catalonia. The characteristics of the waste charge depend on which stratum the city belongs to. Five strata have been established for Spain:

- G1 <1000 inhabitants,

- G2 1001-5000 inhabitants,
- G3 5001-20000 inhabitants,
- G4 20001-50000 inhabitants and
- G5 > 50000 inhabitants.

The big cities of both archipelagos (Palma de Mallorca, Santa Cruz de Tenerife and Las Palmas) which are in the G5 stratum, had a domestic average annual waste charge of €95.9 in 2018 and €98.6 in 2020, while the average charge per household of the five strata considered in global was €83.8 in 2018 and €86.5 in 2020 (Observatorio de la Fiscalidad de los Residuos, 2020).

An excellent environmental protection policy concerning control, inspection, and sanction in the MSW production and management involves providing the administrative bodies in charge of economic instruments necessary to stop non-compliance with environmental regulations about the generation, transport, treatment and disposal of waste. However, municipal waste charges are insufficient in both territories because they do not cover collection, transport, and treatment costs. They are generally not linked to the amount of waste generated, so that those charges are not an incentive for enhanced separate collection and recycling. A separate door-to-door system has been applied only in a small number of municipalities in both archipelagos. Spain is the fifth-lowest country regarding environmentally related taxes in the EU-28. Revenues from these taxes amounted to only 1.83 % of GDP against an EU average of 2.40 % (European Commission, 2019).

4. Material and methods

4.1. Methodological approach

Figure 1 summarises the methodological approach followed for both cases of study.

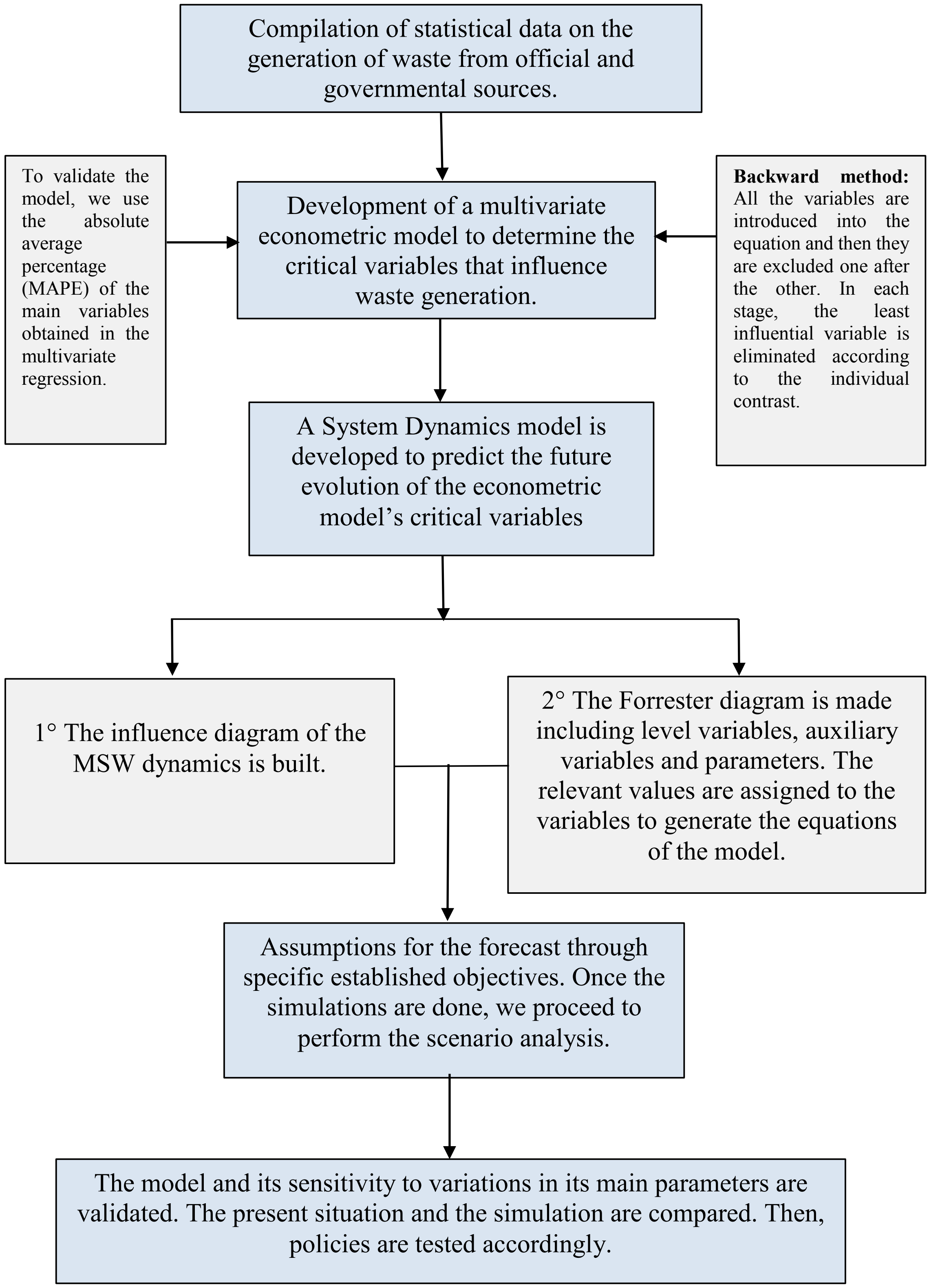

Fig. 1. High level description of the methodological approach

First, a compilation of detailed statistical data from several official and governmental sources was collected for all the variables involved in the MSW management systems for the 2000-2018 period. The data set for the research was extracted from the following official sources:

- The Balearic Islands Statistics Institute (IBESTAT, 2019)
- The Canaries Statistics Institute (ISTAC, 2019)
- the Spanish National Statistics Institute (INE, 2019)
- EUROSTAT (Eurostat, 2020)
- the Spanish National Framework of Waste Management Plan (PEMAR 2016-2022)

Regarding the selection of the simulated scenarios, the EU MSW targets for 2025, 2030 and 2035, the European Directives (EU 2018a, EU 2018b, EU 2018c), and the Spanish National Framework for Waste Management Plan (PEMAR 2016-2022) were taken into account.

The data sets for both archipelagos are compared in Table 1, and in the three graphs of Figure 2. Table 1 highlights the primary data of both archipelagos for 2000, 2006, 2012 and 2018 years. The resident population (Fig. 2a) in the Canaries (blue line with squared dots) is almost double than in the Balearics (black line with triangle dots). However, the ETP and touristic arrivals (Fig 2b) are higher in the Balearics than in the Canaries throughout the studied period. An average stay in 2018 of 10.2 days for the Balearics and 8.8 days for the Canaries have been observed. The Balearics' GDP per capita has always been higher than the Canaries', and their difference has increased in recent years (Fig. 2c).

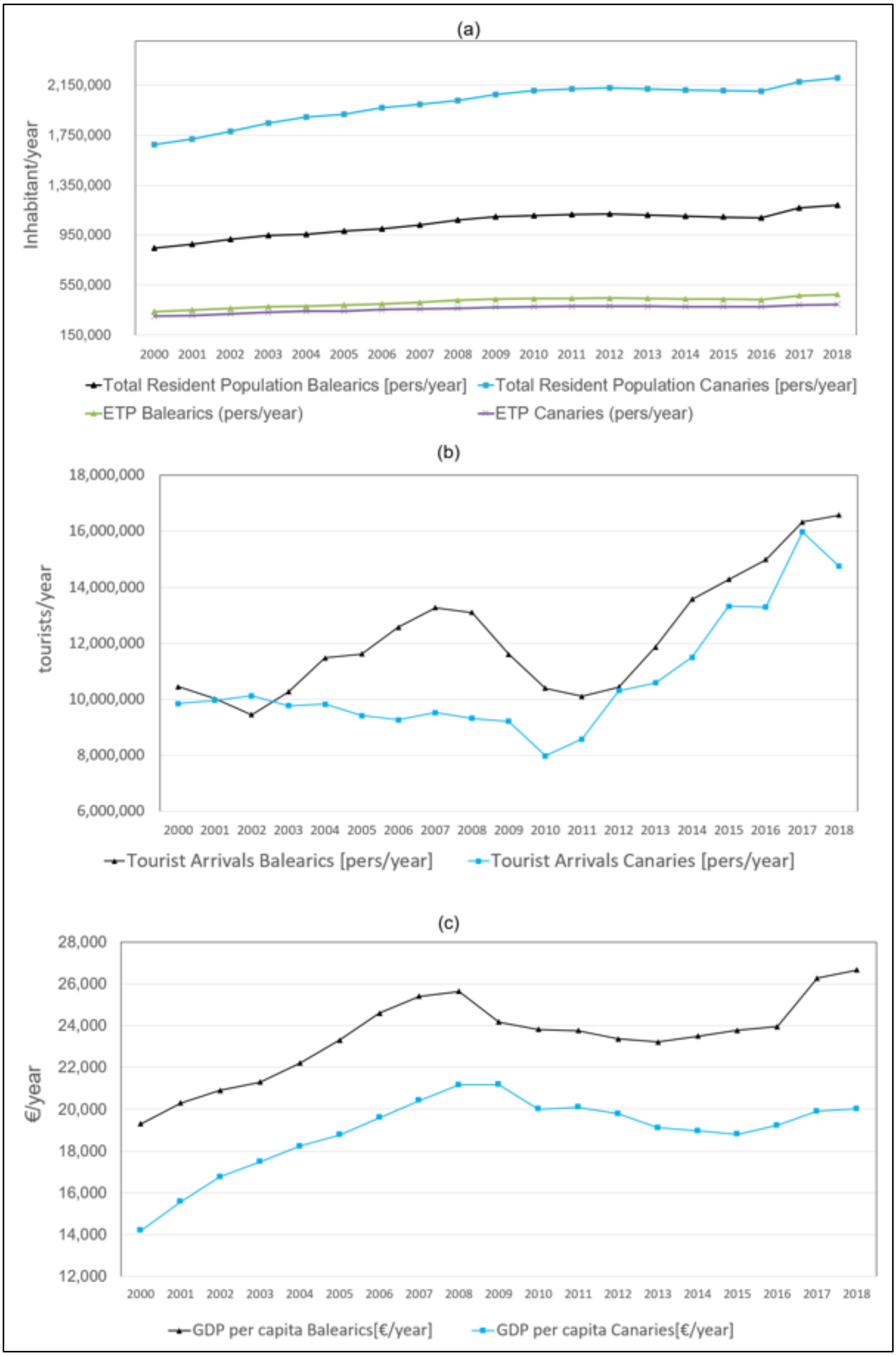

Fig. 2. Comparison of the evolution of *Resident population and ETP* (a), *Tourist arrivals* (b) and *GDP per capita* (c) from 2000 to 2018.

4.2 Construction of the econometric model for both cases of study

In this step, the socioeconomic and MSW production statistics (2000-2018) were employed to find the driving forces responsible for the MSW generation in both study areas through multivariate regression analysis. Twelve variables were selected from the previous literature (Beigl et al. 2008; Ojeda-Benítez et al. 2008; Gupta et al. 2015; Estay-Ossandon and Mena-Nieto, 2018; Nguyen et al. 2020, among others), and local experts from the regional Governments confirmed them. Then, the "Backward method" was applied, estimating the regression coefficients of all those twelve variables and eliminating, step by step, the non-significant ones following their order of importance. For more details, please see Appendices A, B, C, D, E and F.

4.3. Setting the main targets for the forecast

All the simulations were developed following the MSW goals established by the EU Directives (EU 2018a, EU 2018b, EU 2018c), which modified the previous Directive (2008/98/EC), and by the Spanish National Framework of Waste Management Plan (PEMAR 2016-2022). These targets are:

- Recycle at least 55% of the MSW for 2020, 60% in 2030, and 65% in 2035.
- Reduce landfilling to 35% in 2020 and 10% in 2035.
- Totally suppress of paper, glass and mixed packaging landfilling by 2030.
- Reduce organic waste by 30% in 2025 and 50% in 2030.

To diminish the inconsistencies, isolate the outliers, and make more appropriate estimations, the Hodrick-Prescott filter was used for both case studies. The smoothing parameter λ was made equal to 100, on the recommendation of Hodrick and Prescott (1997).

4.4 Development of the System Dynamics (SD) model for both cases of study.

After reviewing the current MSW management systems, SD and Scenario Analysis were applied to build a descriptive mathematical model of the behaviour of their variables during the 2000-2018 period. Then, using these models, it was possible to make predictions on the evolution of MSW generation from 2019 to 2035 for both archipelagos. The methods to assess the impact of MSW policies are very suitable due to the complexity and uncertainty associated with the MSW management system, in which multiple and interrelated decisions have to be taken (Salmeron et al. 2012). First, a causal loop diagram for each region was drawn (see Appendix B, Fig B.1 and Appendix E, Fig E.1) presenting the interactions between the variables that influence MSW generation in both case studies. Second, the proposed Forrester model for both case studies was constructed (see Appendix B, Fig B.2 and Appendix E, Fig E.2). Having found the critical drivers in the previous step, now their relationships are mathematically formulated by equations in the Forrester diagram. The goal of the analysis is not to precisely predict the future (2019-2035); instead, it aims at adopting the proposals of MSW issued by the EU to improve the MSW management process. Finally, a Scenario Analysis was employed to study the evolution of the system.

Table 2 summarises the features and hypotheses of the four scenarios selected for the simulations. The Sc2 scenario has been designed to estimate the quantities required to meet the EU *recycling targets*, the Sc3 seeks to analyse the effect of the *population growth* on MSW production, and the Sc4 aims to discover the effect of including the *selective collection* of organic waste. Zero-waste simulations have not been included because the situation in these archipelagos is still very far from that objective.

Table 2.

Explanation of the main scenarios, their assumptions and targets.

<table>
<tr><th colspan="2">Scenarios</th><th>Simulation Conditions</th><th>EU targets</th></tr>
<tr><td>Sc1</td><td>Business as usual scenario (BAU): Based on historical data (2000-2018)</td><td>The average of the last nineteen years of these variables has been taken.
<table>
<tr><th>Ratios of growth applied</th><th>Balearics</th><th>Canaries</th></tr>
<tr><td>MSW generated</td><td>1.35%</td><td>0.78%</td></tr>
<tr><td>Selective collected</td><td>1.12%</td><td>1.35%</td></tr>
<tr><td>Resident population</td><td>1.92%</td><td>1.78%</td></tr>
<tr><td>Touristic population</td><td>2.53%</td><td>1.95%</td></tr>
<tr><td>GDP per capita</td><td>1.90%</td><td>1.71%</td></tr>
</table></td><td>EU targets are not taken into account</td></tr>
<tr><td>Sc2</td><td>Achieving the EU goal in terms of recycling rate by study horizon 2035 (ceteris paribus other factors involved)</td><td>Increase in selective collection's main fractions ratios up to 2035 are estimated.
Current ratios (2018):
Balearics = 15.81% and Canaries= 11.18%</td><td>To recycle at least 55% of MSW by 2020, achieve at least 60% in 2030 and 65% in 2035.</td></tr>
<tr><td>Sc3</td><td>Assessing the influence of the increase in total population growth (Resident and Tourist population) on MSW generation (ceteris paribus other factors involved)</td><td>The average of the last five years has been taken.
Low resident population growth
• 1.38% annual for the Balearics
• 0.86% annual for the Canaries.
Moderate increase in the tourist population arrivals ratios.
• 7.01% annual for the Balearics
• 7.34% annual for the Canaries</td><td>International tourism will rise by 3.3% between 2010 and 2030, according to the WTO.</td></tr>
<tr><td>Sc4</td><td>Separate collection of organic waste and remaining fraction likely (ceteris paribus other factors involved)</td><td>Full separate organic waste collection by 2023.
Limit landfilled waste to 10% in 2035.
0% landfilling of paper, glass and mixed packaging by 2030.
Current amounts in 2018:
Organic fraction Balearics = 311,878 t/year
Rest fraction Balearics = 77,970 t/year
Organic fraction Canaries= 448,416 t/year
Rest fraction Canaries = 672,623 t/year</td><td>The target for organic waste reduction will be 30% in 2025, and 50% in 2030.</td></tr>
<tr><td>Sc5</td><td>Plausible Scenario: Evaluating variation of the rate in the recyclable fraction.
Current amounts of the three type of fractions (t) in 2018.
<table>
<tr><th></th><th>Balearics</th><th>Canaries</th></tr>
<tr><td>Glass</td><td>39.612</td><td>38.888</td></tr>
<tr><td>P/Card</td><td>44.521</td><td>31.954</td></tr>
<tr><td>Packaging</td><td>21.410</td><td>20.067</td></tr>
</table></td><td>This scenario assumes the following generation growth rates (2019-2035)
<table>
<tr><th></th><th>Balearics</th><th>Canaries</th></tr>
<tr><td>Glass</td><td>1.0%</td><td>1.0%</td></tr>
<tr><td>P/Card</td><td>-0.5%</td><td>0.1%</td></tr>
<tr><td>Packaging</td><td>-1.0%</td><td>-0.5%</td></tr>
</table></td><td>The EU opts for a progressive increase in the recovery of the recycling mix: Glass: 75% by 2030; paper/cardboard: 85% by 2030 and Packaging: 70% by 2030.</td></tr>
</table>

5. Results and Discussion

5.1 Results from the econometric model

Table 3 displays the econometric equations of the final models (without standardization of the coefficients), the standardised coefficients for the four main drivers of MSW generation and the Mean Absolute Percentage Error (MAPE) values estimated for the Balearic and the Canary archipelagos (see Appendix A and D):

Table 3.

Econometric model equations, driving forces and MAPE values of both study areas.

Econometric Model before the standardisation of the coefficients	
Balearics	$MSW\_g = \beta_0 + \beta_1 * 0.5535 + \beta_2 * 0.3873 + \beta_4 * 0.6820 + \beta_9 * 0.3479) + \mu i$
Canaries	$MSW\_g = \beta_0 + \beta_1 * 0.4425 + \beta_3 * 0.4902 + \beta_5 * 0.5740 + \beta_6 * -0.1977) + \mu i$

Standardised coefficients				
	Res_Pop	Tour_Pop	GDP_per capita	Educ_level
Balearics	1.194	1.712	1.132	- 0.136
Canaries	1.162	1.658	1.425	- 0.221

MAPE values						
	MSW_g	GDP_per capita	Res_Pop	Tour_Arrivals	ETP	Educ_level
Balearics	3.1	2.1	2.3	9.8	5.3	0.9
Canaries	2.8	2.4	1.8	8.7	5.8	2.2

In the Balearics econometric model (a), the four driving forces obtained are: $\beta_1 =$ *Resident Population*, $\beta_2 = GDPpercapita$, $\beta_4 =$ *Tourist Population*, $\beta_9 =$ *Education Level* (this variable indicates an inverse relationship). The missing sub-index numbers ($\beta_3, \beta_5, \beta_6, \beta_7, \beta_8, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14}, \beta_{15}$) correspond to variables of little or minimum significance in the MSW generation, therefore they have not been included (see Appendix A).

In the Canaries econometric model (b), the four driving forces found are: β_1 = *Res_Pop*, β_3 = *GDP per capita*, β_5 = *Tourist Population* and β_6 = *Education Level*. The missing sub-index numbers ($\beta_2, \beta_4, \beta_7, \beta_8, \beta_9, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14}, \beta_{15}$) have little or insignificant influence on the MSW generation (see Appendix D).

According to these results, the four main variables which have a more decisive influence on MSW generation in both territories are Resident Population, Tourist Population, GDP per capita, and Educational level, since they are those with the highest standardised coefficients shown in Table 3. The Tourist population is the main driving force in both regions. However, it is followed by the resident population in the Balearics, but by GDP per capita in the Canary Islands. Table 3 shows the MAPE values obtained to test the robustness and reliability of the models. They can be classified as excellent (<10), fair (10), acceptable (20-50), and unacceptable (>50) (Lewis, 1982).

More specifically, the econometric models find that each additional tourist produces 0.682 t/year (1.87 kg/day) of MSW in the Balearics and 0.574 t/year (1.57 kg/day) in the Canary Islands, while each additional resident generates 0.553 t/year (1.52 kg/day) in the Balearics and 0.443 t/year (1.21 kg/day) in the Canaries. Regarding GDP per capita, an increase of 1% in the Balearic Islands increases the waste generated by 0.387 t/year (1.06 kg/day), while in the Canary Islands, it is 0.490 t/year (1.34 kg/day). On the contrary, an increase of one year in the education level reduces the MSW generation by 0.348 t/year (0.95 kg/day) in the Balearics and 0.198 t/year (0.54 kg/day) in the Canaries.

5.2 Results from the System Dynamics model and Scenario Analysis.

In the following figures, samples of the simulations' results for the Balearics (black curve) and the Canaries (blue curve) are shown to compare the evolution of both archipelagos. Figure 3 shows that the total MSW generation trend in the Business as usual (BAU) scenario (Sc1) will continually rise from 2019 to 2035 in both territories without taking any action to meet European targets. For the Balearics, waste generation would reach 1.10 million tonnes/year in 2035, i.e., an 18.04% increase compared to 2018 (901,452 tonnes/year), while for the Canary Islands, that increase would go from 1.24 million tonnes/year in 2018 up to 1.42 million tonnes/year in 2035 (equivalent to a 14.04% increase in 2035).

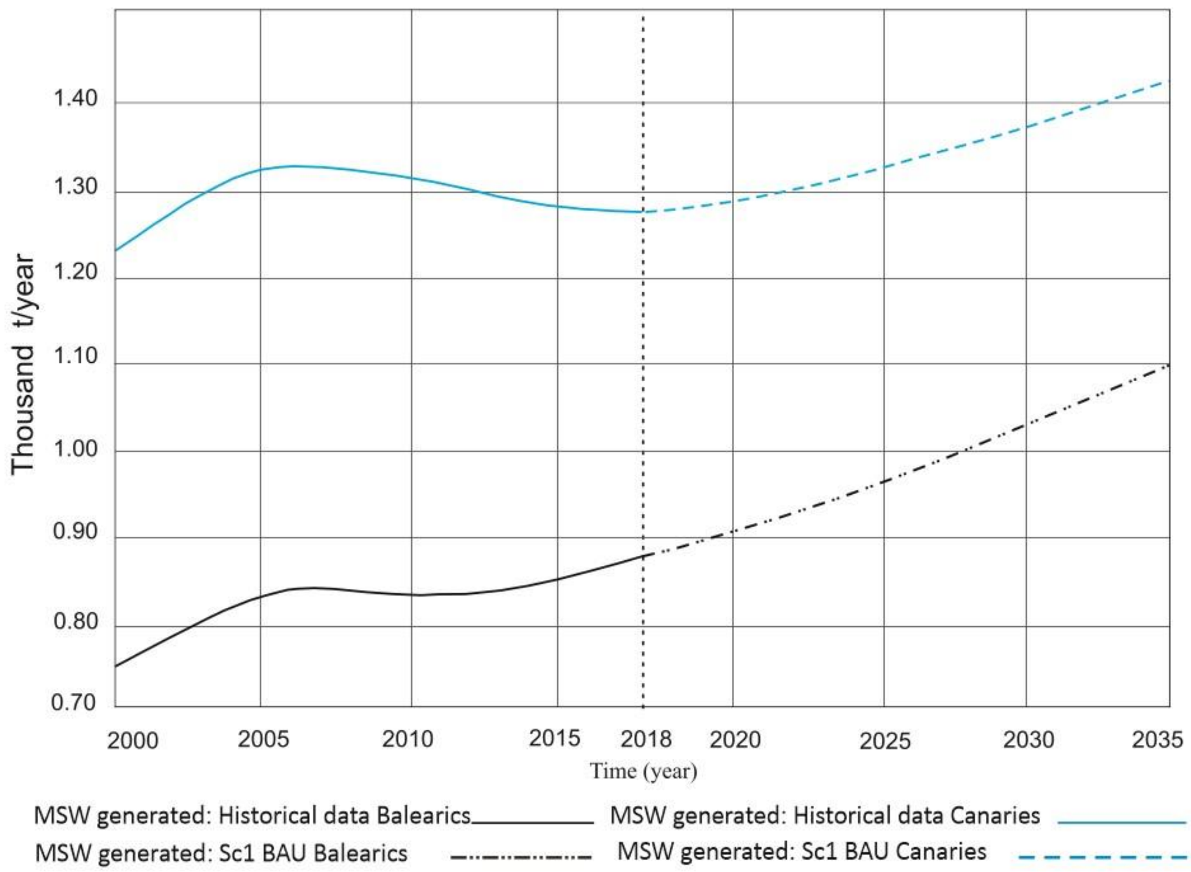

Fig. 3. Evolution of the MSW generation in the Balearics and the Canaries (2000-2018-2035)

In 2018, the Balearic Islands received 16.58 million tourists and the Canary Islands 14.75 (see Fig. 4a). However, their expected projection in the BAU Sc1 for 2035 is 17.85 million tourists for the Balearics (1.35 million more tourists than 2018), and 16.5 million tourists in the Canary archipelago, equivalent to a 10.9% increase (1.8 million more tourists than 2018). These results suggest that both regions must increase their investment in management and infrastructure to solve the problems derived from MSW generation growth.

Concerning Figure 4b, the current Canary Islands population (2.207 million inhabitants), is much larger than in the Balearic Islands. Following the same annual birth and immigration rates (BAU Sc1), the Canaries' projected population in 2035 will be close to 2.807 million inhabitants, equivalent to 27.18% more than the year 2018. In the Balearics case, the population, which was 1.187 million in 2018, will rise to 1.857 million inhabitants by 2035, which is a 56.44% increase.

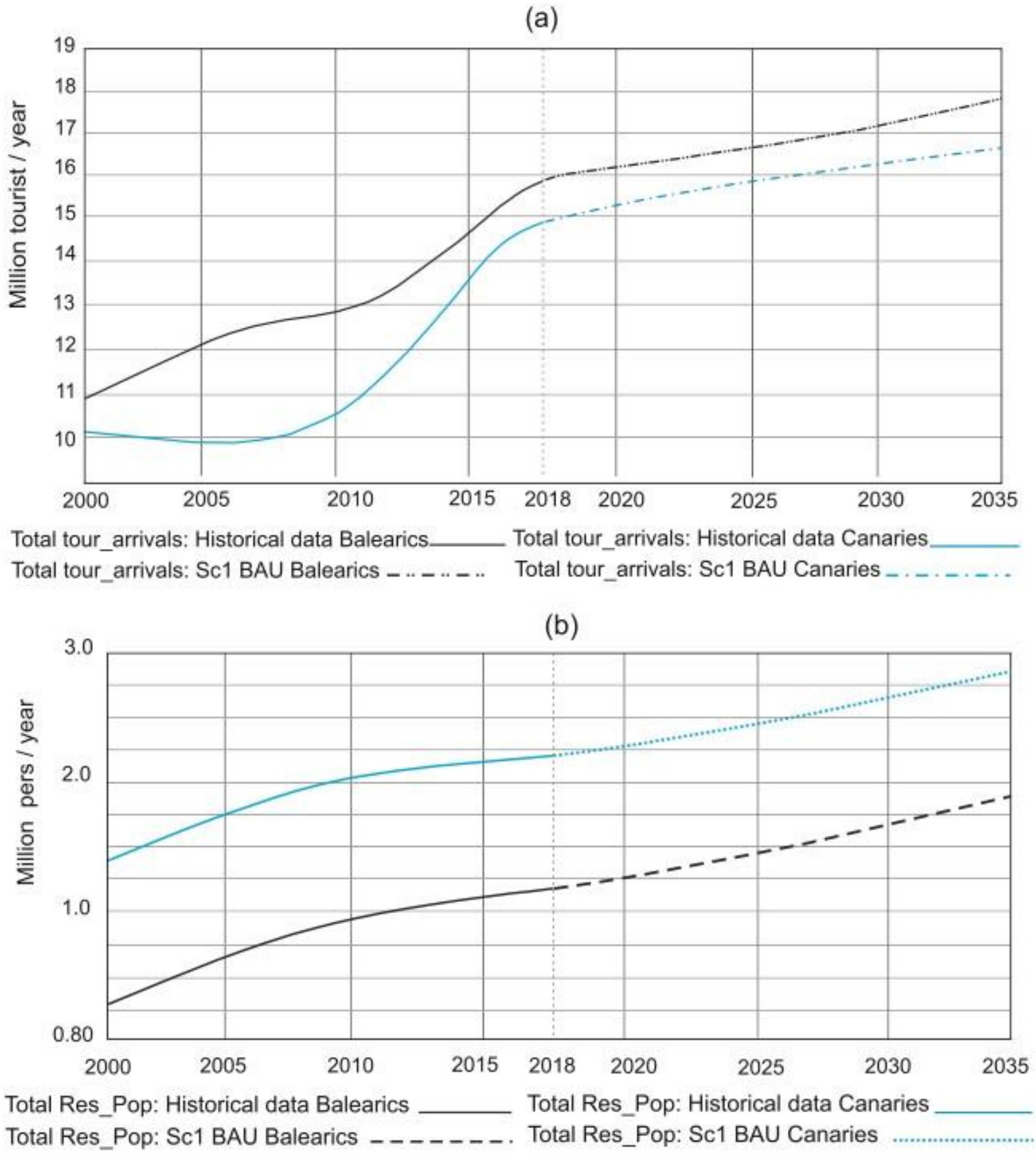

Fig. 4. Evolution and projection of the total touristic arrivals (a) and the resident population (b) in the Balearics and the Canaries (2000-2035).

In Figure 5, changes in the GDP per capita, ceteris paribus the rest of the variables, are analysed. Two scenarios were simulated: high growth of the GDP per capita (0.5 points more than the historical increase in the BAU Sc1, which was 1.90%) and low growth (0.5 points less than the historical increase in GDP in BAU Sc1, i.e. 1.71%).

In the Balearic Islands, under a scenario with a high GDP increase (2.40%), MSW generation is increased by 11.42% compared with the 2035 year of the BAU Sc1, while in the Canary Islands, under a scenario with a high GDP increase (2.21%), the increase in MSW generation is only of 6.85%.

Regarding the low GDP per capita growth scenarios (increases of 1.40% in the Balearics and 1.21% in the Canaries), compared to the 2035 year of the BAU Sc1, the Balearic Islands MSW generation decreases by 14.54%, while in the Canary Islands it decreases only by 7.73%.

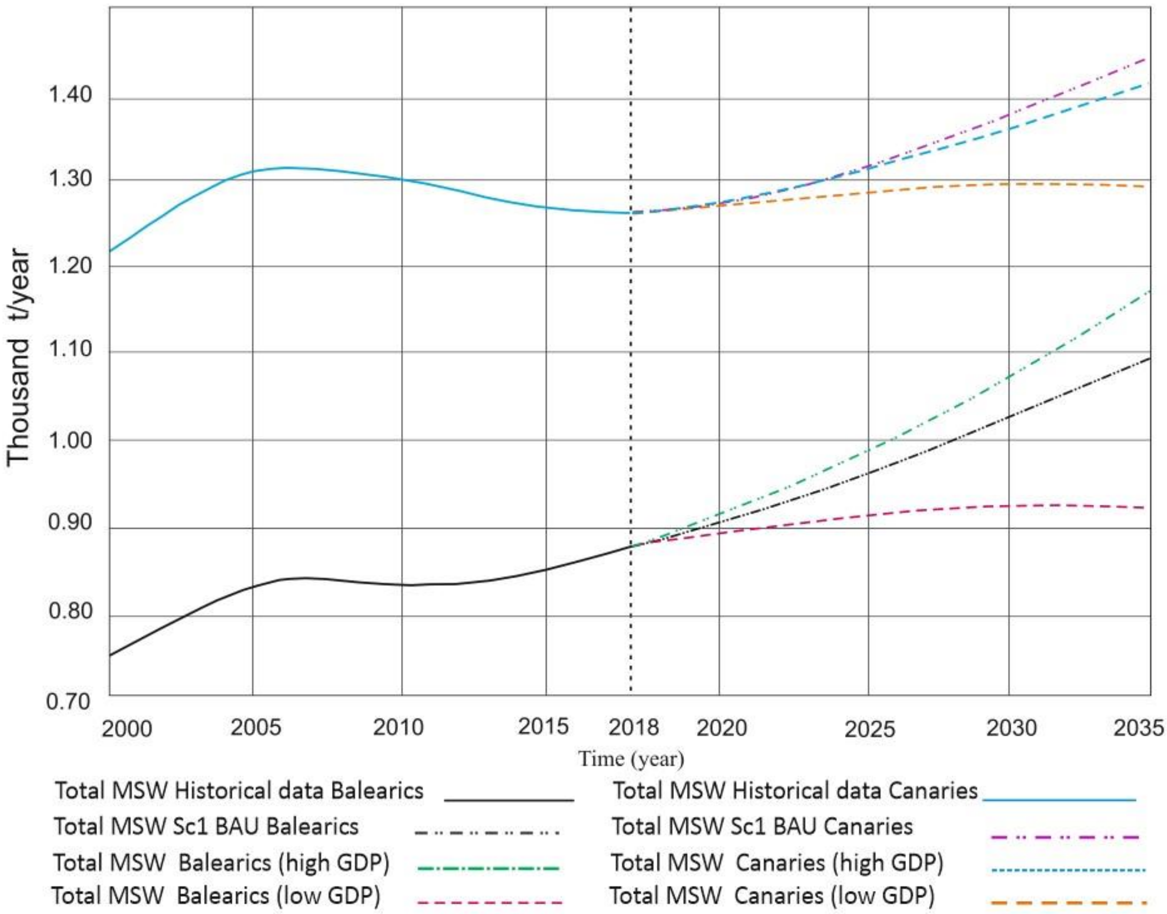

Fig. 5. MSW forecasting versus GDP per capita in the Balearics and the Canaries (2019-2035).

Figure 6a shows the evolution of the Selective Collection fraction, which is a part of the total recycling fraction. The current amounts of the selective collection are still low, due to externalities such as waste badly deposited or sent to uncontrolled landfills.

In Figure 6b, the evolution of the organic waste fraction in both territories, under Sc4 and BAU Sc1 are compared. It can be seen that it will be impossible to achieve the compulsory 65% EU target recycling rate. For example, in the Canaries, simulations estimate an increase from 11.18% to 48.82% in 2035, still below the 65% EU target. Therefore, it is not enough with only recycling paper-cardboard, glass and packaging fractions; organic fraction collection has to be implemented too. The current recycling rates in 2018 are 15.81% in the Balearics and 11.18% in the Canaries and to reach the 65% milestone, the former should increase its rate by 2.89% annually, while in the Canaries, by 3.16% during the next 17 years. For the Balearic Islands, if a selective collection is not applied, the amount will reach 374,128 tonnes/year in 2025, and 415,112 tonnes/year in 2035, an increase of 33.06% compared to 2018. In the Canary Islands BAU Sc1, the generation of organic waste will reach 543,236 tonnes/year in 2025, and 567,062 tonnes/year in 2035, an increase of 24.88% compared to 2018.

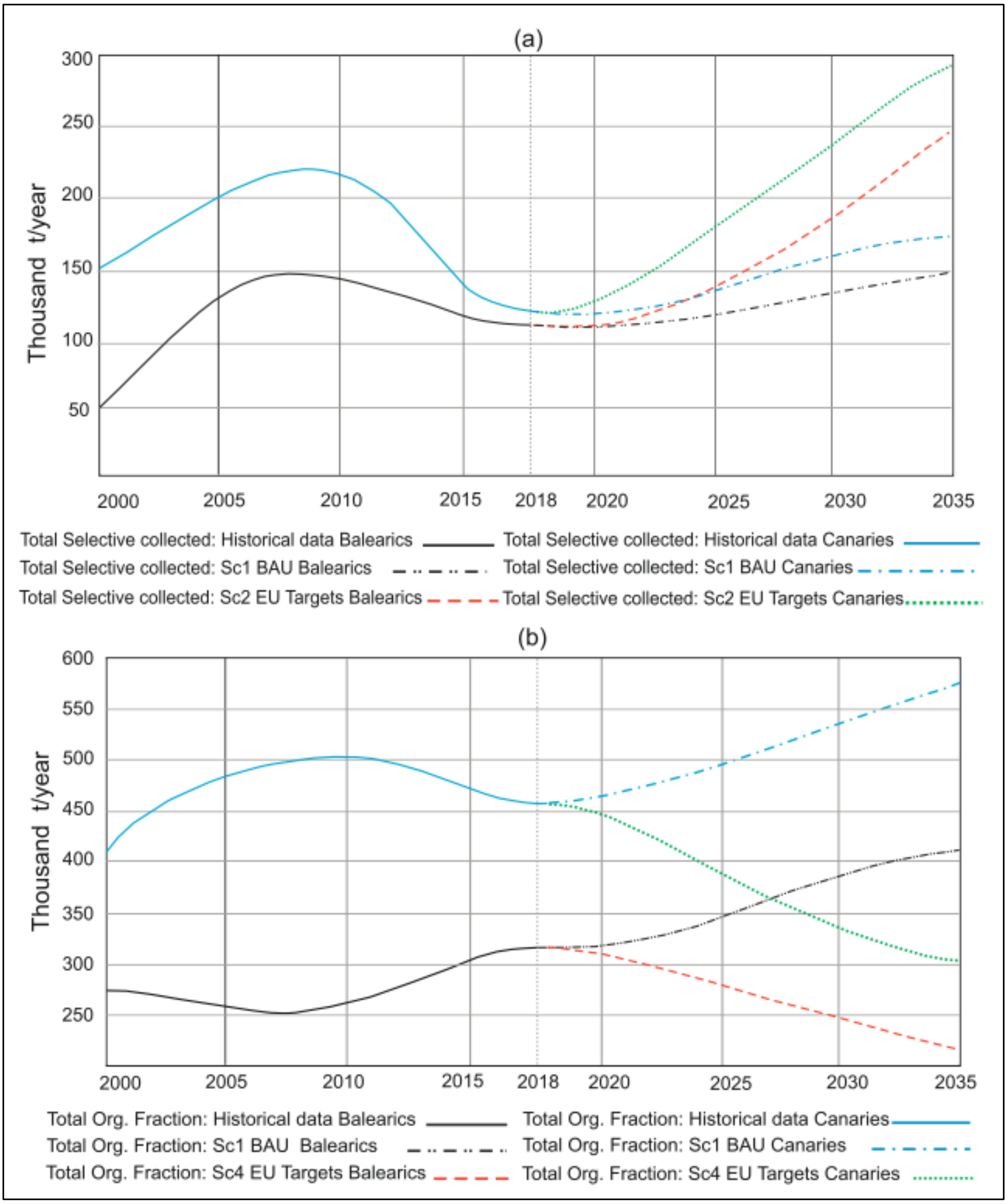

Fig. 6. Evolution and projection of selective collection (a) and total organic fraction (b) in the Balearics and the Canaries (2000-2035).

For the EU objectives scenario (Sc2), we have to take into account the organic and food waste reduction established in 2018 by the EU Directive (EU 2018b), which proposes a reduction of 30% of this waste by 2025 and 50% by 2030. Also, what is proposed for 31.12.2023 by the EU is mandatory separate collection of organic fraction to advance towards a circular economy. For the Balearic Islands, the amount in 2025 should drop to 273,071 tonnes/year, and by 2030 it should be at 250,618 tonnes/year. For the Canary Islands, the amount should be reduced to 374,128 tonnes/year in 2025, and 341,912 tonnes/year by 2030. Furthermore, it is crucial to consider that by 2035, in the European Union, only 10% of the MSW generated can be deposited in landfills. This implementation of separate collection of organic fraction for subsequent recycling treatment will help to achieve this target.

Figure 7 shows the future projection of three main types of selectively collected waste (2019-2035). For these future scenarios, we have defined a slight and moderate growth in the ratios (see table 2, Sc5). The primary hypothesis suggests that there is environmental awareness and consumption of recyclable/reusable material priority over materials that are harmful to the environment. Figure 7a shows the paper/cardboard (curve decreasing significantly from 44.31 tonnes in 2018 to 28.18 tonnes in 2035. For glass, the curve increases from 39.10 tonnes to 53.02 tonnes, while the packaging decreases from 31.42 to 16.87 tonnes. In figure 7b, the paper/cardboard curve comes down from 43.97 tonnes in 2018 to 29.51 tonnes in 2035, while glass changes from 38.61 to 50.07 tonnes and the packaging decreases from 20.12 to 12.21 tonnes.

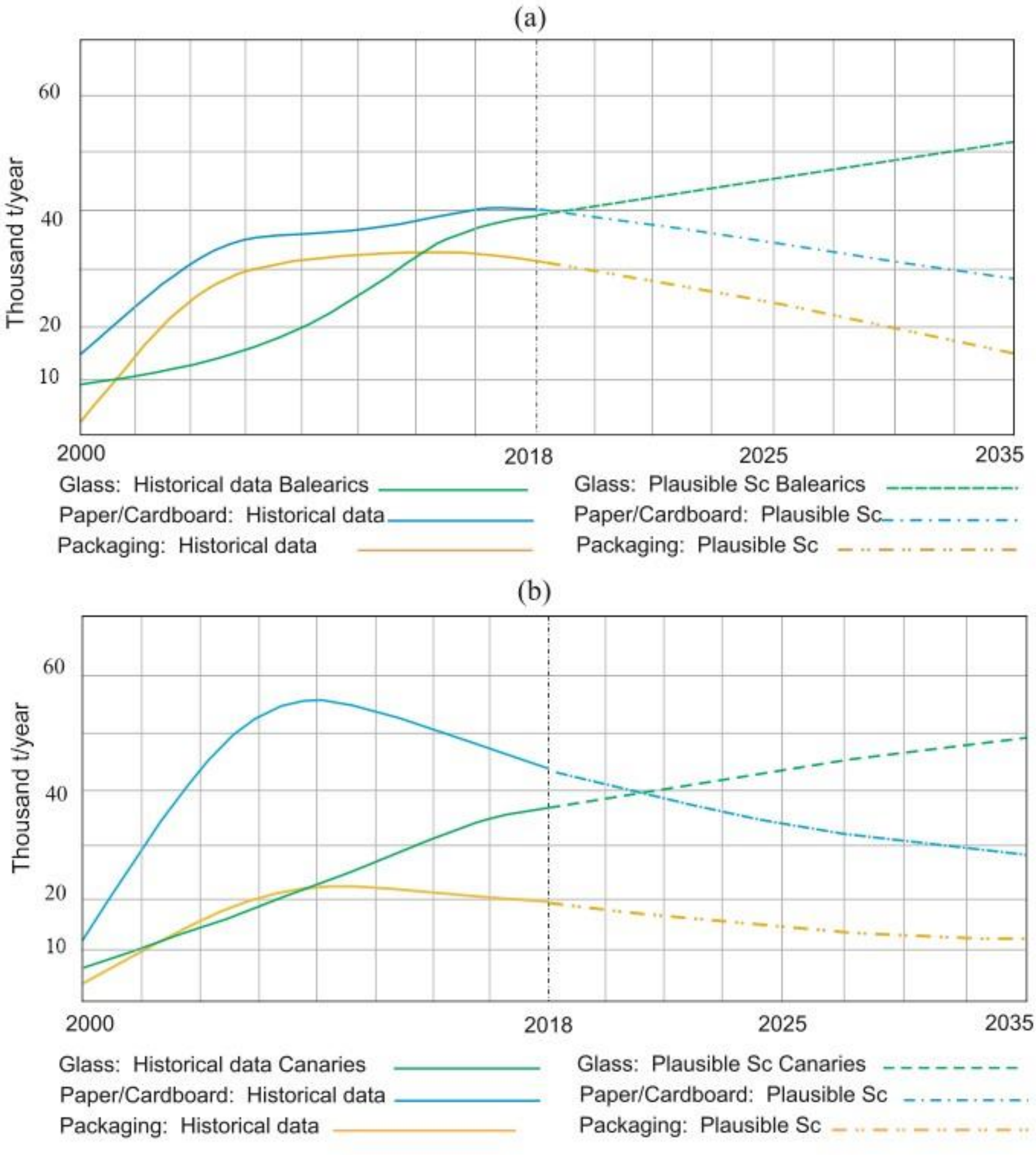

Fig. 7. Evolution and projection of the three main types of selectively collected waste in the Balearics (a) and the Canaries (b) from 2019 to 2035.

5.3 Discussion.

Currently, the Balearics' main disposal methods include landfilling and incineration (including energy recovery) while in the Canaries landfilling is the predominant treatment. These autonomous regions are leaders regarding waste generation per capita. In 2018, the Canaries' annual per capita generation was lower than the Balearics' (564 kg/pers/year or 1.54 kg/pers/day, versus 759 kg/pers/year or 2.08 kg/pers/day respectively).

Historical data also prove that MSW management has improved in recent years in the two archipelagos, and better practices are being adopted. It is necessary to understand that in terms of recycling rates, both territories, on average, are very far from mainland Spain's rates (11.18% for the Canaries and 15.81% for the Balearics, with the Spanish average being 33.9% in 2018). Our results in terms of MSW generation rates for the Balearic archipelago (four islands) are higher than those found by Mateu and Sbert et al. (2013) for the island of Menorca. Each additional tourist in the Balearics produces 1.87 kg/day, which is higher than 1.31 kg/day in Menorca. However, each additional resident in the Balearics produces 1.59 kg/day, but in Menorca, it is 1.48 kg/day.

Regarding the Canary Islands, our findings show that each additional tourist adds 1.57 kg/day and each additional resident 1.21 kg/day, which are similar results to those from the Tenerife municipality provided by Diaz-Farina et al. (2020).

From another point of view, the total per capita MSW rate generated jointly by the resident and the tourist population in the Balearic Islands reached 2.08 kg/day in 2018, the highest of all the Spanish autonomous regions, while in the Canaries it was 1.54 kg/day. Those rates are higher than those found by Mohee (2015) for islands located in the three SIDS regions which averaged 1.29 kg/pers/day, although they varied from 1.61 kg/pers/day in the Caribbean SIDS, to 0.82 kg/pers/day in the Pacific SIDS.

It is imperative to decrease the landfilling of MSW and promote separation at the source and selective waste collection to increase recycling and composting rates (Rupani et al. 2019). In the Balearics' case, a good part of the waste is incinerated, but in the Canaries', it is sent to landfills which is the worst alternative (Estay et al. 2018), and although the Canarian administration has made an effort to implement other methods, such as biomethanisation and others (Estay and Harsch, 2015), as a result of a negative public opinion, those treatments could not be implemented. This demonstrates the importance of involving all interested parties on the islands to find the best solution to the problem (Ezeah et al. 2015; Soltani et al. 2015; Triguero et al. 2016). Another strategy, often not sufficiently valued, is the promotion of environmental education (De Feo, 2014), especially among the youth.

Meeting the legally binding targets of the EU will imply higher costs in the beginning, but in the medium and long term, it will generate environmental benefits. There are also empirically proven alternatives that would improve the MSW management, such as implementing return and refund systems for containers and the door-to-door collection model (this system allows to recover around 75% of waste in Sweden and 98.5% in Germany). These arguments justify the need to implement changes for the adequate MSW disposition in these archipelagos.

6. Summary, conclusions and policy implications.

The improvement of MSW management and planning is crucial to achieving a more sustainable tourism development and advancing from a linear economy to a more circular one. As the research documented in this article shows, the methodology we propose provides a solid foundation for decision-making and it can be applied to other territories without necessarily having to be islands. This is the case, because the steps and the methods used are easily implementable as long as the appropriate variables are selected from the literature and context-specific data is collected.

From an environmental point of view, the effect of the EU MSW targets implementation in both territories has been very positive. For example, the municipalities with more than 5,000 inhabitants are advancing to fulfil the organic fraction's selective collection goal by the end of 2021 instead of waiting for December 2023; uncontrolled landfills have been closed or rehabilitated on some islands. Also, extended producer responsibility schemes (e.g. regarding electronic waste) have been improved, and both regions have set out limitations on single-use plastic items. Besides, as the rates of separate collection and recycling increase and landfilling decreases, greenhouse gas emissions (mainly methane and carbon dioxide) into the atmosphere and subsoil pollution problems go down.

Despite this, other key issues remain unresolved. In particular, there seems to be little political coordination between the central government, the autonomous regions, and the local entities in Spain, one of the few EU countries with no state-wide tax. Local waste charges and tax rates on landfills vary depending on the region or neighbouring municipalities where they are applied. Similarly, waste treatment capacities are not shared or planned jointly between regions.

The results obtained in this paper demonstrate that:

1. Three main driving forces increased the amount of MSW generated during the period studied (2000-2018). They are the tourist population, resident population and per capita GDP. By contrast, the education level contributed to reducing it. In both archipelagos, the most influential factor was the tourist population (each additional tourist produces 1.87 kg/day of MSW in the Balearics and 1.57 kg/day in the Canary Islands). However, in the Canaries, the per capita GDP's influence is more significant than in the Balearics (an increase of 1% in this variable increases the waste generated by 1.34 kg/day in the Canaries, versus 1.06 kg/day in the Balearics). In the Balearics, the resident population has more impact (1.57 kg/day) than the income level (1.06 kg/day).

2. The use of System Dynamics has allowed understanding this complex system in its dynamics and detail. The evidence shows that a system's structures hardly change in the short term without acting on the driving factors that determine its behaviour. The simulations carried out predict that waste generation will continue to increase in both areas, mainly due to the future growth in tourist arrivals and the foreseeable increase in GDP (mainly in the Canary Islands).

3. The analysis of the MSW data evolution in the last two decades reflects insufficient improvements. Concerning the EU intermediate and final targets for recycling by 2025 (50%), 2030 (60%) and 2035 (65%) and the limit of waste dumped (10% in 2035), there is still much work to be done, specifically in the Canary Islands where the landfilling treatment method predominates over others. In 2018, approximately 80% of the waste collected was taken to landfills, and only 11.18% was recycled. On the contrary, in the Balearics, the annual rate of dumping was 0.64%, the incineration rate was 55.40%, and the recycling rate was 15.81%, which indicates that the dumping target is closer to being met. Besides, as these areas suffer a significant tourist impact, special attention should be paid to factors such as tourism seasonality, which increase the waste generation in summer and cause the saturation of communal containers and landfills. This problem requires a resize of the MSW management infrastructure and facilities, especially in the Balearic Islands.

4. Therefore, without relevant changes in the current MSW management and planning, it will be complicated for both archipelagos to fulfil the objectives in terms of what the European Waste Framework Union requires by 2035, following the waste hierarchy (prevention, preparation for reuse, recycling, recovery and disposal).

5. It is imperative to establish the collection of the organic fraction in both areas since it represents between 38-40% by weight of the waste generated and would help to increase recycling rates in the short term, to meet the EU goals in the short term, and reduce the saturation of landfills and greenhouse gas emissions.

More research is necessary to i) determine additional measures to improve circularity, adapted to each archipelago's characteristics; ii) implement the polluter-pays-principle and extended producer responsibility; iii) update the current waste charges to cover the actual costs of the service; iv) implement more effective tax incentives that involve all stakeholders in the achievement of European goals; v) capture more detailed statistical data to improve the monitoring and control of the European goals and other indicators of the circularity of the economy.

The objectives set out in the Introduction have all been achieved. Now, it is possible to answer the question posed in the title of this paper. Both territories are currently very far from the right pathway to meet EU goals, especially regarding recycling and selective organic fraction collection. If the current strategies are followed in the projected scenarios, both territories will not meet, the EU MSW targets.

Only a cooperative and rigorous MSW policy will help to improve waste management comprehensively. Investments are required to reach full compliance with EU municipal waste targets. Therefore, regional and local administrations must establish a solid financial basis for the MSW management system because the achievement of the EU's demanding goals for 2025, 2030 and 2035 will only be possible if they have sufficient economic resources to respond to this challenge. The European Green Deal can be an excellent opportunity to take these targets on.

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