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'ACCOMMODATION SPACE' AT BEACHES IN ANDALUSIA: CALCULATIONS DERIVED FROM THE 2013 SHORELINE DATA MODEL AND THE USE OF SPATIAL DATABASES.

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ABSTRACT

This paper presents the results of an update of the Andalusian shoreline data model with inclusion of the concept of 'accommodation space'. This variable, together with the erosion rates, is essential for understanding the current dynamics and future evolution of Andalusian beaches.

The results calculated for the 2013 shoreline (extracted from the 2013 orthophoto, IECA Institute of Statistics and Cartography of Andalusia) show how 40 % of Andalusian beaches do not have accommodation space, mainly due to occupation of such space by urban development and the existence of cliffs. Conversely, 60 % of Andalusian beaches do have accommodation space, allowing regression of the shoreline and hence adjustment of the beach to erosion and flooding processes. About 85 % of those spaces are situated on the Atlantic façade, where they attain great length, mainly due to less anthropic pressure and the presence of protected natural areas. The beaches on the Mediterranean façade have the smallest accommodation spaces and are consequently more vulnerable to flooding or erosion processes, including, in some cases, higher risk of disappearance in the future.

Keywords: accommodation space, shoreline, data model, Andalusia.

EL "ESPACIO DE ACOMODACIÓN" EN LAS PLAYAS DE ANDALUCÍA: CÁLCULOS DERIVADOS DEL MODELO DE DATOS DE LÍNEA DE COSTA DE 2013 Y EL USO DE BASES DE DATOS ESPACIALES

RESUMEN

El artículo presenta los resultados de la actualización del modelo de datos de línea de costa para Andalucía, incluyendo el concepto de "espacio de acomodación". Dicha variable, junto con las tasas de erosion, es esencial para la comprensión de de la dinámica litoral actual y la evolución future de las playas andaluzas.

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Los resultados de la línea de costa de 2013 (extraídos de la ortofotografía de 2013, Instituto de Estadística y Cartografía de Andalucía) muestran cómo el 40 % de las playas andaluzas no tienen espacio de acomodación, debido, fundamentalmente, a la ocupación de dicho espacio por el desarrollo urbanístico y la existencia de zonas acantiladas.

Por el contrario, el 60 % de las playas andaluzas tienen espacio de acomodación, permitiendo el retroceso de la línea de costa y, por ello, la adaptación de la playa a los procesos de erosión e inundación. En torno al 85 % de las playas con espacio de acomodación están situadas en la fachada atlántica, alcanzando grandes extensiones debido a la escasa presión antrópica y a la presencia de espacios naturales protegidos. Las playas de la fachada mediterránea tienen un espacio de acomodación menor y, por ello, mayor vulnerabilidad ante procesos erosivos y de inundación, incluyendo, en algunos casos, un alto riesgo de desaparición en el futuro.

1. Introduction

Coastal areas currently comprise a high number of resources and therefore present greater population densities (De Andrés and Barragán, 2016). For that reason, they are also among the most vulnerable areas, due to the existence of problems associated to the pressure put on those resources by different activities, which often clash with each other. Such areas are thus affected by multiple phenomena, both natural (storms, shore erosion, rising sea level, etc.) and anthropic (high degree of urbanisation and dune occupation, declining sediment contribution from rivers, overexploitation of aquifers, deterioration of landscape, etc).

In the case of Spain, the littoral area comprises approximately 8000 km of coast, with a mean coastal municipality population density of 350 inhabitants/km^2, 4.5 times higher than the nationwide mean (Seisdedos *et al*., 2016). This figure rises to 1000 inhabitants/km^2 during the summer season (Barragán, 2004). Added to the impacts of this great population density are those stemming from high levels of urbanisation and respective problems (Fernández, 2006; Vera and Rodríguez, 2010; Villar and Ojeda, 2012) and intense competition between uses (tourism, agriculture, fishing, etc), which have led this subject area to be targeted by major investments for maintenance works, restoration, use management, emergency construction, etc. That investment should be higher in the future if we take into account the effects of climate change, which will cause a sea-level rise manifested by an erosive process on beaches, with consequent shift of position or reduction of total useful surface, depending on their respective characteristics (Cendrero *et al*., 2005).

Hence, for example, in a rising sea-level situation, each beach's response will be different and depend on various factors: beach width, slope, presence of dunes that can be used as sediment resource, etc. One of the main factors for estimating and assessing the associated impacts concerns the existence of accommodation spaces. Thus, the existence of accommodation space for dunes would allow them to migrate inland in the face of sea level rise or extreme storms (Servera and Rodríguez, 2009; Psuty and Silveira, 2010; Suanez *et al.*, 2011). In the same way, the existence of inlet/outlet tidal channels could provide a large accommodation space in the face of extreme events, and maintain the equilibrium profile of the beach (Choowong *et al.*, 2009).

According to Jiménez *et al.* (2017), the existence of accommodation space at beaches is also one of the main factor for the beach. This concept is related to a basic question: when the sea level rises, is there enough interior space toward which the beach can migrate? If the answer is no, the beach will erode and gradually diminish until it disappears.

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To configure coastal planning that includes proper appraisal and management of those impacts there is a need for not just detailed information about the coast and its physical and geomorphic characteristics and shore dynamics, etc, enabling analysis of past and prospective trends; it is also indispensable to develop strategies that foster dissemination of that information, ensuring that it can be accessed by scientists and planners.

It is especially important to have detailed information about the coast in Andalusia, where tourism's influence on the economy is greater than in other regions of Spain, comprising around 13 % of regional GDP (Department of Tourism and Sports, 2016a). Its total of 372 beaches means it can be described as a sun and beach destination. Indeed, the most common activities of coastal tourists during their stay at destination in 2016 were, first, use and enjoyment of the beach, undertaken by 71.4 % of them (Department of Tourism and Sports, 2016b). Any adverse natural event at beaches or tourism installations may therefore imply, beyond multiple impacts on the natural environment, a high economic loss for the region.

For more than a decade various members of research group RNM-177 on Coastal Management and Territorial Information Technologies of the University of Seville (http://www.gis-and-coast.geographica.gs/) have been working with the REDIAM Environmental Information Network of the Department of Environment of the Regional Government of Andalusia to develop strategies based on the design of data models and uses of spatial relationship databases to produce, manage and disseminate information stemming from photo-interpretation of the Andalusian shoreline at detailed scale, using different proxies (wetline and backshore/foredune boundary) and calculation of erosion rates on the Andalusian coast for different periods.

The aim of this paper is to present the first results of a new update of the shoreline data model which enables analysis and characterisation of the respective 'accommodation space' of beaches on the Andalusian coast.

In this regard, this paper's specific goals are two:

1. Identify and typify accommodation space at Andalusian beaches;
2. Place at the disposal of various users (scientists, managers and planners) the results obtained via the web. The research group has therefore been working for years on the design of various web viewers (Díaz *et al.*, 2015; Álvarez *et al.*, 2017), although they are not subject to study in this article.

The present paper is divided into several sections. Section 2 provides a context for the work and describes the Andalusian shoreline data model, paying special attention to its evolution and recent update by including the table on accommodation space. Section 3 describes the study area, materials, methods and data used. Section 4 provides an overview of the main results obtained, which are discussed in Section 5. The conclusions are presented in Section 6.

2. The Andalusian shoreline data model. Ten years of work and recent update: accommodation space.

With implementation of the Andalusian initiative for integrated management of coastal zones (Barragán *et al.*, 2008) and the necessary establishment of information instruments and management tools enabling governance of such areas, the Department of Environment and Land-use Planning has been developing the Coastal and Marine Environment Information Subsystem as part of the Environmental Information Network of Andalusia. Its main aim is to become the central core of standardised homogenous information about the coastal and marine environment, accessible to all players involved in the respective governance: planners, scientific community, local players, citizens, etc. To achieve that aspiration, it is consequently necessary

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to gather, arrange and place in service the information, in a manner consistent with that Environmental Information Network (Frieyro *et al.*, 2010).

During the last decade research group RMN-177 on Coastal Management and Territorial Information Technologies of the University of Seville (http://www.gis-and-coast.geographica.gs/) has taken on a large part of the production, management and dissemination of information concerning the Andalusian coastline; it is one of the main groups supplying detailed and comprehensive spatial information about the Andalusian coastline for the Coastal and Marine Environment Subsystem.

Digitalisation and photo-interpretation at detailed scale (1:2500) of the Andalusian coast was for several years defined based on an associated data model applied in the PostgreSQL/PostGIS open-code database management system. It formed the origin of those strategies for producing information about the Andalusian coast and enabled generation of various indicators on environmental follow-up and status which for the first time described at such detailed scale the entire coast and therefore enabled the respective comparability: typology of beaches, percentage of cliff coastline, of beaches with dunes, of anthropised coast, etc. (Ojeda *et al.*, 2010).

The research group later carried out multiple updates of that model. Hence, for example, the delimitation of a multifunctional or multipurpose shoreline enabled new indicators to be generated, among which the calculation and evolution of the useful beach stands out, very important for tourist carrying capacity, as already presented in previous papers (Díaz *et al.*, 2012; 2013). The calculation and interpretation of erosion rates for the entire Andalusian coast and for various time periods likewise enabled, among other analyses, calculation of the beaches' sensitiveness with respect to accessibility by potential tourist users (Díaz *et al.*, 2014, Fernández *et al.*, 2015, Prieto, 2017), characterisation of the Andalusian coast with respect to beach erosion processes in the new Coast Law of 2013 (Ojeda *et al.*, 2015a), comparison of erosion rates with the presence of foredunes (Prieto *et al.*, 2017) and assessment of the influence of coastal infrastructures on erosion rates (Díaz *et al.*, 2017).

One of the latest updates of this shoreline/erosion rates data model is constituted by inclusion of the concept of 'accommodation space', understood to mean the availability of free space with sedimentary substrate that allows migration of the coastal system toward the interior in the event of coastal regression (see Figure 1). This information projects a definition very close to the concept of resilience (Jiménez *et al.*, 2017) and is essential for understanding the future evolution of Andalusian beaches.

The lack of accommodation space would therefore impede a response of natural adjustment to erosion or flooding processes, leading to its gradual disappearance. Such beaches would therefore be more vulnerable to those processes, leading to their potential disappearance if no regeneration process is set in motion.

A beach without accommodation space therefore presents a relatively rigid shoreline. Such beaches are not active, owing to two types of causes:

- Natural (rocky cliffs);
- Anthropic (infrastructures, roads, seafront promenades, etc).

For their part, the beaches with accommodation space are those that allow fluctuation of the shoreline (proxy backshore/foredune) and which therefore, because they have accommodation space, could respond with natural adjustment to the stated phenomena. In this regard, it might be considered that one of the problems of the Andalusian coast, as with most of the Mediterranean coast (Jiménez *et al.*, 2017), is that a large part of it is very urbanised and as a

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result most beaches are backed by fixed infrastructures such as promenades and transportation links or other rigid limits that mark off the space used for housing.

This adjustable response is nevertheless also directly associated to the width and type of substrate of the accommodation space. Regarding substrate type, while coastal dunes and other sandy sedimentary formations allow maintenance of not just the beach but also its respective quality, the deltas and other associated fluvial and colluvial formations, as well as unstable cliffs, though allowing regression and perpetuation of the beach, may entail degradation of their quality from the tourism standpoint due to changes in grain size.

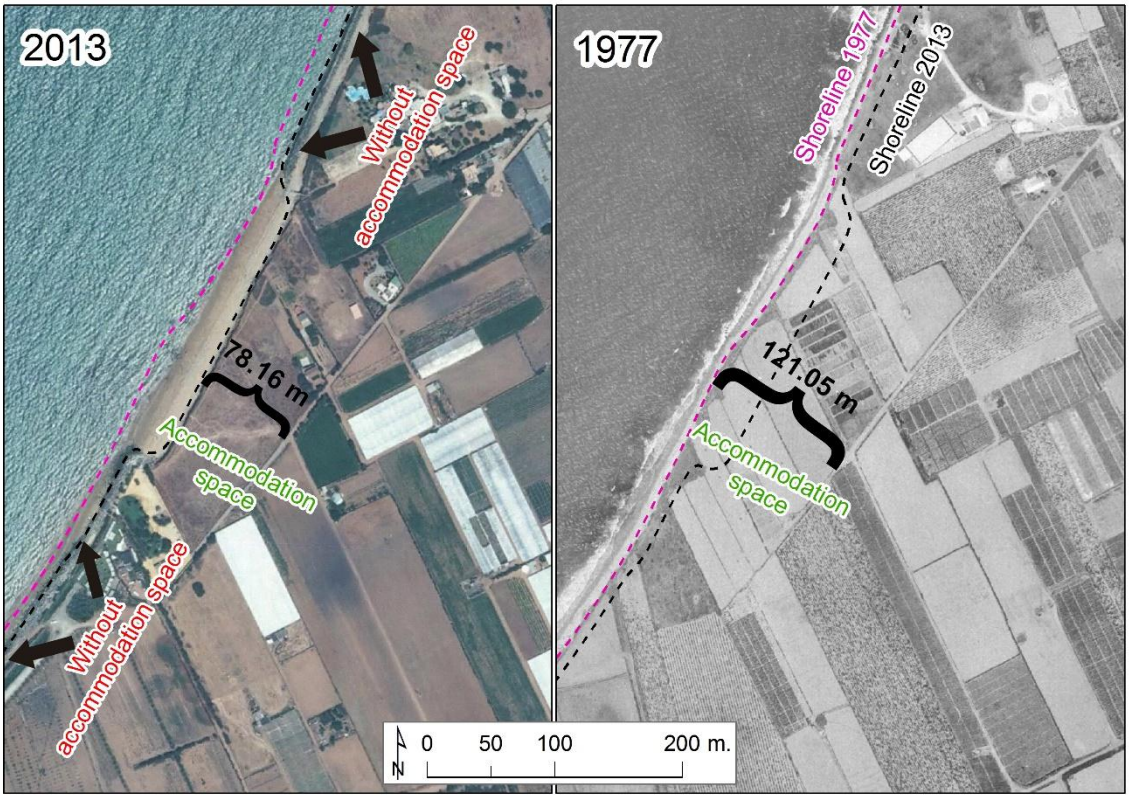

Figure 1. The right orthophoto (1977) shows the presence of extensive accommodation space for shoreline regression. The left orthophoto (2013) shows the effect of shoreline regression, which despite reducing future accommodation space allows the beach to be maintained. In the upper and lower sectors urban developments and embankments (without accommodation space) can be seen; although the shoreline is still maintained, the beach's width will be reduced until it disappears.
Source: own production.

Along with the production of environmental information on the Andalusian shoreline, information has also been gathered on the coastal urbanisation phenomenon (Villar and Ojeda, 2012; Villar, 2013), analysis of coastal vulnerability in the event of sea-level rise (Ojeda *et al.*, 2009) and different maps of flooding probability for the Andalusian coast in the event of sea-level rise (Fraile *et al.*, 2018). In order to maximise the access and dissemination of these results they were integrated into web geoviewers designed to that end (Díaz *et al.*, 2015; Álvarez *et al.*, 2017; Prieto *et al.*, 2018).

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3. Study area, materials and methods

3.1. Study area

The study area comprises all exposed beaches on the coast of Andalusia (southern Spain), a total of 620 km which represent nearly 70 % of the exposed coastal front (ECF) (see Figure 2).

Andalusia's position facing two water masses with different characteristics, as well as the distinct geological processes that have shaped its current continental and coastal morphology, have generated two disparate coasts. The presence of a broad northeast-southwest depression resulting from orogenic processes to its north (Sierra Morena) and south (Betic systems) has resulted in an Atlantic façade with smooth relief endowed with a broad and lightly sloping continental shelf. That, along with the presence of regular sedimentary sources and first-order continental drift resulted in a landscape of wide beaches and fine-grained sand, accompanied by large expanses of dunes. The scant presence of anthropic elements and substrates of rocky material (except near the Strait of Gibraltar) supply the necessary conditions for development of ample accommodation space. On the other side, the development of the Betic systems very close to the Mediterranean coastal environment has generated an abrupt landscape, characterised by a very enclosed river network, whose sudden sedimentary contributions have led to a proliferation of fluvial deposits at the mouths (deltas) and coastal flats. Together with a very short and steep continental shelf and scant longshore drift this has resulted in the appearance of very short and narrow beaches, with little dune development due to the sedimentary irregularity and larger grain-size than their Atlantic counterparts. The more widespread presence of anthropic elements and substrates of rocky material hinder the existence of large accommodation spaces.

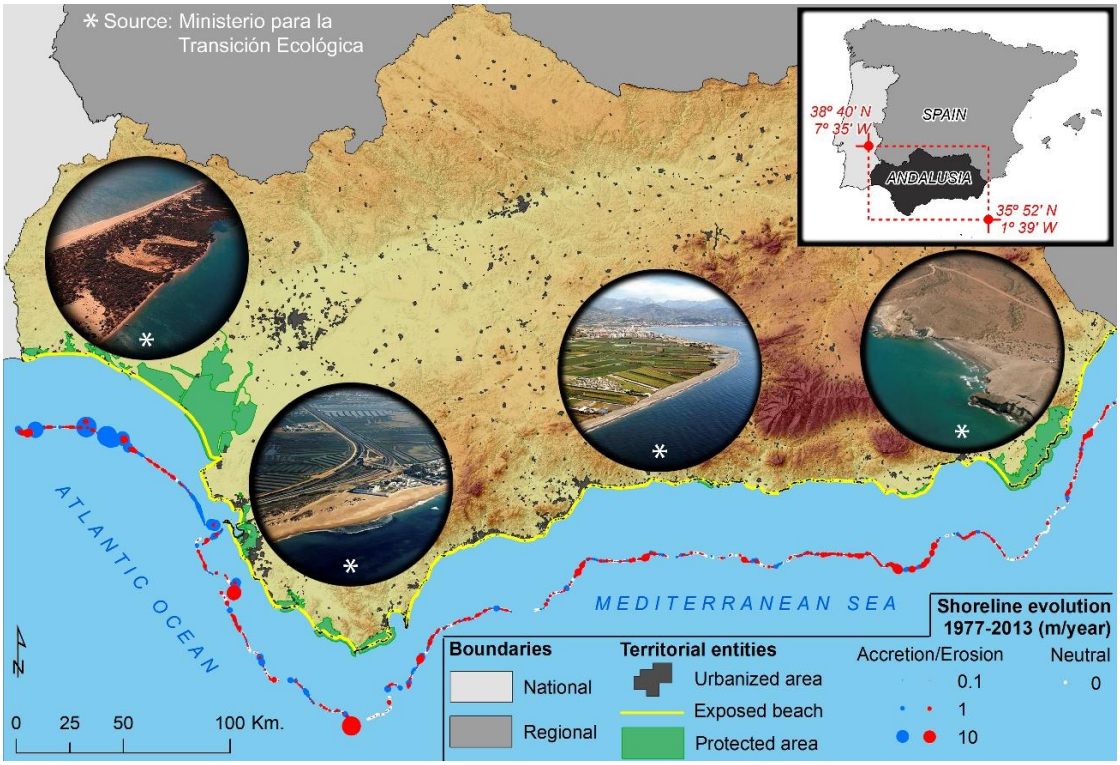

Figure 2. Study area.
Source: own production.

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The above factors, along with the human presence in the territory, distributed unequally along the Andalusian coast, have generated a very disparate evolutive behaviour at beaches during the period from 1977 to 2013 (see Figure 2). The presence of a mesotidal coast, high availability of sediments and powerful coastal drift capable of mobilizing them, give rise to generalised accumulative behaviour in some Atlantic sectors, usually associated to the existence of barrier islands and sand spits (Prieto el at., 2018).

Conversely, the Mediterranean façade, presents a microtidal coast and a low availability of sediments (Prieto el at., 2018). Thus, the beaches of the Mediterranean façade, are generally characterised by erosive behaviour only interrupted by occasional progradation of accumulative sectors, mostly corresponding to the location of anthropic elements on the coastal front (harbours, breakwaters, etc). The widespread presence of cliff sectors (and increasingly common anthropised sectors, hinders shoreline fluctuation, resulting in neutral values (stable sectors).

3.2. The data sources.

The data sources used correspond to the different orthophotos supplied by the regional government, previously used during the data model update phases and subject to strict quality controls to guarantee results of the data gathering process (Prieto *et al.*, 2018). To digitise the shorelines, orthophotos corresponding to the erosion rates study period were used (in this case, the 1977-1983 pan-chromatic digital orthophoto of Andalusia and the rigorous 2013 colour orthophoto of Andalusia); to obtain the accommodation space, the most current data source containing shoreline data was used (rigorous 2013 colour orthophoto of Andalusia).

3.3. Methodology

The methodology used to attain the planned objectives is based on accomplishment of the following clearly distinct phases:

a) Inclusion of the 'accommodation space table' in the conceptual shoreline data model;
b) Information gathering;
c) Data model implementation in PostgreSQL-PostGIS;
d) Interpretation and analysis phase;
e) Web geovisualisation of results.

All these phases will be commented on in depth in the following sections.

a) Inclusion of the 'accommodation space' table in the conceptual shoreline data model.

The shoreline information was modelled based on an entity-relationship diagram. The entities were first identified and then the relationships between them, whether alphanumeric or spatial. The cardinalities (the number of possible relationships between two records) were next established and finally, the primary and foreign keys, that uniquely identifies each record in the table and that will allow relationships between tables, were assigned.

The resulting model is spider-shaped (see Figure 3), formed by a main entity, the Shoreline Table, a geometric table containing the topologically independent digitised segments of shoreline, identified by a primary key (id_shoreline). The Shoreline Table is thematically related to the alphanumeric tables by means of a 1:M cardinality, based on the relationship between each table's primary and foreign key (see figure 3). That content, forming the original

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data model (Fernández *et al.*, 2015), has been updated in order to add new information (Figure 3[I]), concerning:

- Dune presence, including quantitative measurement of average dune width (dune information);
- Substrate characteristics (substrate information), characterising the shoreline depending on the existing substrate type behind the backshore;
- Backshore width (beach information), estimated by measuring the distance between foredune (or infrastructures in built-up environments) and high waterline (HWL);
- Update of urban areas using an urban typology (urban information) and their proximity to the ECF. This information is presented indicating urban typology and distance to backshore in metres;
- Update of the information associated to infrastructure type (infrastructure information). This information is also presented in serveral tables describing the typology of infrastructures at the ECF and the typology of infrastructures behind the backshore or foredune;
- Errors generated during the digitalisation process and associated to data sources, including potential error and mean squared error (digitisation error);
- Finally, fields associated to erosion rate calculation were added (DSAS information), among them necessary fields to run the Digital Shoreline Analysis System (DSAS) tool (Thieler *et al.*, 2009), along with others corresponding to the inclusion/exclusion of sections and type of anthropic change. This field defines the presence of infrastructure or another element or feature of the data source that impedes or hinders oscillation of the proxy. This is vital for interpreting the results.

As indicated in section 2, the information on calculation of the erosion rates for different time periods (Figure 3[II]) was also added to the shoreline data model. In this case, a unidimensional (linear) geometric table corresponding to a series of transects generated perpendicular to the shoreline was included, needed to calculate the rates by means of the DSAS tool (one for each 50 m of shore). This table (Transect) is spatially related to the Shoreline Table by means of a spatial intersection operation that enabled the information contained in the shoreline model to be assigned to each transect.

The four point entities – point (4 entities) – resulting from spatial intersections between the transects and four linear entities parallel to the shoreline, were added to the data model for semiologic treatment and web dissemination of the results. The first point entity was located at the coastline, and the rest using buffers at 450, 800 and 1150 m from the first one (see Prieto *et al.*, 2018).

The last update of the data model, a specific goal of this work, refers to the inclusion of accommodation space for the whole study scope for 2013, by including a new entity, the Accommodation Space Table (Figure 3[III]). It is a bidimensional (polygonal) geometric table referring to digitalisation of the 'accommodation space' polygon. By means of a spatial intersection operation with the transects, which have already associated all the shoreline information, its width was obtained for each transect. That allows each 'accommodation space' polygon to be classified according to its substrate type based on the substrate information table (Table 1). The type of substrate has been obtained from Map of Physiographic Units of the Andalusian Coastline (Department of Agriculture, Livestock, Fisheries and Sustainable Development, 2007).

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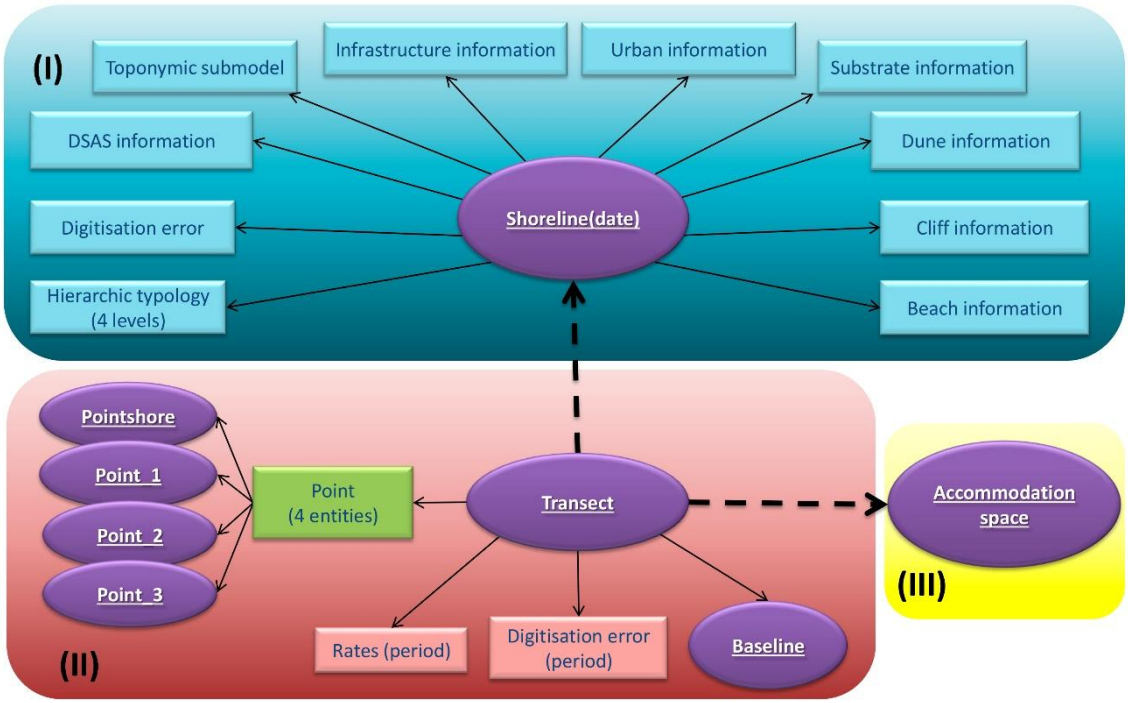

Figure 3. Data model. Continuous line shows an alphanumeric relation and dashed line an spatial one.
Source: own production.

Table 1. Substrate characterising the 'accommodation space' table.

Substrate	Vulnerability
Sedimentary formations associated to foredunes	- ↓ +
Sedimentary formations associated to aeolian dunes	
Detritic substrate associated to deltas, floodplains and coastal plains	
Brittle rocky substrate	

Source: own production.

b) Information gathering

Once the conceptual model was designed, the accommodation space was digitised for the entire Andalusian coast (Figure 4). The photo-interpretation and digitalisation of accommodation space for Andalusia's beaches was done using the ArcGis 10.3 proprietary software in an ESRI spatial database environment (geodatabases), enabling control of the final quality of the geometric (topological analysis) and thematic (use of domains) component.

The digitalisation process was done at detailed scale from the shoreline toward the interior. The proxy used is backshore/foredune boundary, which respectively establishes the boundary between the high (dry) beach and associated coastal dune or with the cliff base or direct contact with infrastructure. Many authors consider it to be the most stable long-term criterion, as it is marked by the maximum level reached by the sheet of water during exceptional weather and/or astronomical events (Ojeda, 2000; Del Río, 2007), and is isolated from the

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disruptive effects of continual changes of the transversal profile due to its immediate response to tides and waves (Ojeda, 2015).

The limit established for the accommodation space in this paper has been 1 km towards the inland, as long as an anthropic element does not exist. In this case, the limit would be the anthropic element itself.

Figure 4. Photo-interpretation and digitisation of accommodation space based on the backshore/foredune proxy of the 2013 shoreline.
Source: own production.

The reference system of coordinates used for the whole process, per current legislation (Royal Decree 1071/2007), is the European Terrestrial Reference System 1989 (ETRS89), projected in UTM for the 30 N zone.

c) Data model implementation in PostgreSQL-PostGIS

Once the data model was designed and the accommodation space digitised for 2013, it was implemented in the shoreline/erosion rates database managed by the PostgreSQL 10.2/PostGIS 2.3 open-code spatial database management system. All the information was thus entered in it and prepared for use by physically assigning the primary and foreign keys of the different tables and by building spatial and thematic indexes to facilitate exploitation of the information as well as web visualisation.

d) Interpretation and analysis phase

After the model was implemented in the database management system, in this phase the work focused on designing different queries in the Structure Query Language so the main results could be obtained.

The queries were basically meant to pool information about the 2013 accommodation space polygon with information from the shoreline model. To achieve that, a spatial intersection of the accommodation space polygon was undertaken with the transects, which now has the information referring to shoreline (Figure 5).

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Figure 5. Intersection of transects with the accommodation space polygon.
Source: own production.

e) Web geovisualisation of results

In this paper, once the main results were calculated, they were published as OGC (Open Geospatial Consortium) services. Next, using the research group's experience generating web viewers (Díaz *et al.*, 2015; Ojeda *et al.*, 2015b, Álvarez *et al.*, 2017, Camarillo *et al.*, 2014; Camarillo *et al.*, 2018), it was decided that these services should be published in a prototype GIS-AND-COAST web geoviewer (Prieto *et al.*, 2018) designed to facilitate access to that information by the general public and by researchers and planners who work with such information.

4. Description and analysis of results

Table 2 and Figure 6 show the percentage of Andalusian beaches that have accommodation space and classify them by type. In general, around 60 % of Andalusian beaches have accommodation space, although in many cases it is very narrow (5-10 m).

Analysis per the different coasts shows that the highest percentages of beaches with accommodation space in Andalusia are located on the Atlantic façade (85 %) and are also wider (around 74 % of them measure more than 100 metres). This is mainly due to the absence of anthropisation and the presence of large protected natural spaces (Doñana Natural Park, Odiel Marsh Nature Area, Asperillo Cliffs Natural Monument, Breña Natural Park and Barbate Marshes, etc). The substrate types of those places are fundamentally associated to sedimentary formations (foredunes 80 %, aeolian dunes 11 %) and brittle rocky substrate (7 %), formations typical of zones with abundant sedimentary inputs.

Conversely, on the Mediterranean façade only 42 % of the beaches have accommodation spaces, of which 20 % are no more than 25 metres wide; only 48 % measure

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more than 100 metres. This is due to the presence of rocky cliffs and fundamentally to the high degree of anthropic occupation of different sedimentary formations, notably in the case of Málaga and Granada provinces, which present the lowest percentages of beaches with accommodation space (30 % and 36 %, respectively). As for substrate type, around 52 % comprise foredune formations and 39 % detritic substrate.

The accommodation spaces on this façade are thus mainly associated to zones where foredunes have been preserved (Artola Dunes Nature Area, Cabo de Gata Natural Park, among others), fluvial deposits (courses with occasional contributions – deltas), fluvial/colluvial deposits in coastal plains (bay of Marbella) and other sandy formations (Campo de Dalías).

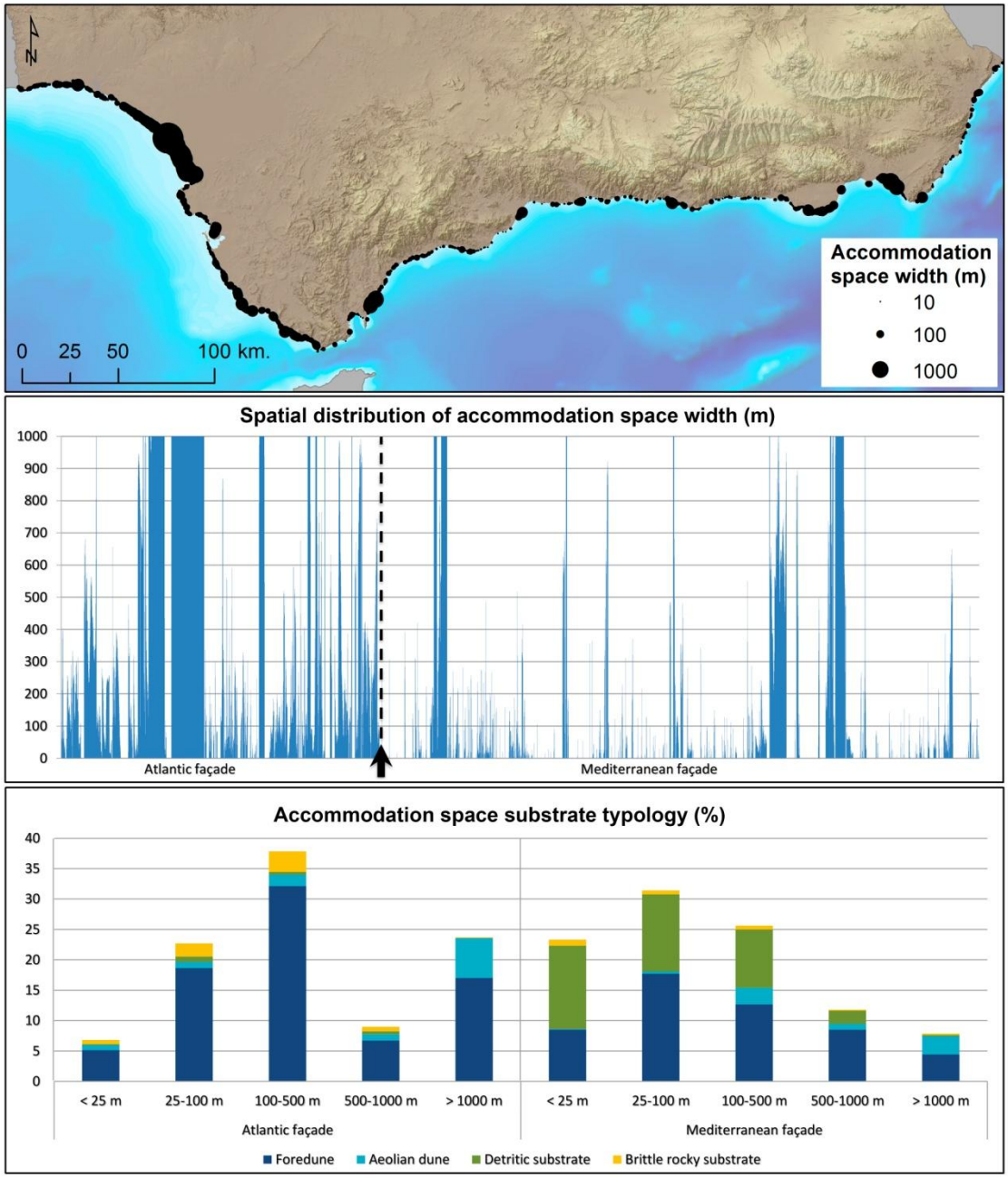

Figure 6. Spatial distribution, width and typology of accommodation space by façade.
Source: own production.

Prieto Campos,A., Díaz Cuevas, P., Ojeda Zújar, J. (2019): "'Accommodation space' at beaches in Andalusia: calculations derived from the 2013 shoreline data model and the use of spatial databases", GeoFocus (Artículos), nº 23, p. 97-117. ISSN: 1578-5157 http://dx.doi.org/10.21138/GF.628

		Shoreline length (m)				Transect percentage				
	Width (m)	**Foredune**	**Aeolian dune**	**Detritic substrate**	**Rocky substrate**	**Foredune**	**Aeolian dune**	**Detritic substrate**	**Rocky substrate**	**TOTAL**
Atlantic façade	**< 25**	9000	1100	100	1400	4.4	0.5	0	0.7	**5.6**
	25-100	35050	1450	1750	4600	17.1	0.7	0.9	2.3	**21**
	100-500	73050	4100	750	6700	35.7	2	0.3	3.3	**41.3**
	500-1000	15700	3650	650	1500	7.7	1.8	0.3	0.7	**10.5**
	>1000	32050	12250	50	0	15.6	6	0	0	**21.6**
	TOTAL	**164850**	**22550**	**3300**	**14200**	**80.5**	**11.0**	**1.5**	**7**	**100**
Mediterranean façade	**< 25**	10050	100	17550	1750	6.7	0.1	11.8	1.3	**19.9**
	25-100	27250	650	19300	1050	18.2	0.4	12.8	0.7	**32.1**
	100-500	16950	3700	14950	950	11.4	2.5	10.1	0.6	**24.6**
	500-1000	6400	1750	3500	400	4.3	1.2	2.3	0.4	**8.2**
	>1000	15850	4950	1950	0	10.6	3.3	1.3	0	**15.2**
	TOTAL	**76500**	**11150**	**57250**	**4150**	**51.2**	**7.5**	**38.3**	**3**	**100**

Table 2. Length and percentage of accommodation space by substrate typology.
Source: own production.

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Analysis by province (Figure 7) consolidates the data obtained for each coast. It can thus be seen that most beaches in the Atlantic provinces have accommodation space, which is also generally wider. Huelva province stands out in this case, as nearly all its beaches (94 %) have such space and in almost half of them it is more than a kilometre wide, where the sandy formations of Abalario and Doñana play a fundamental role. The beaches of Cádiz are more variable due to the presence of cliff formations in the province's southern sector (Campo de Gibraltar). Three quarters of the province's beaches thus have accommodation space. In this case, beaches with mean widths of between 100 and 500 m (42 %) and less (39 %) stand out, concentrated in the marsh areas of the Bay of Cádiz (Los Toruños, Camposoto and Sancti Petri) and a few southern sectors (El Palmar, Zahara, Bolonia, Los Lances and Sotogrande). The substrate typology is mostly sandy, associated to both active formations from the standpoint of coastal dynamics (foredunes) and inactive formations (aeolian dunes). In this regard, all the accommodation space of Huelva province and 81 % of that of Cádiz province pertain to this type.

The beaches of the Mediterranean provinces behave in a manner contrary to their Atlantic counterparts, due to the greater presence of rocky sectors close to the coast and highly anthropised sectors (Figure 7). Standing out are the beaches of Málaga province, of which only a third have accommodation space, followed by the beaches of Granada (40 %) and Almería (50 %). The accommodation space's width is very much less due to the scant setback margin owing to the closeness of rocky sectors and the increasingly extensive anthropic presence on the coastal front. In this case, 70 % of the accommodation space of Málaga's beaches is mostly less than 100 m; that width is only higher in a few natural sectors (Artola Dunes and mouths of the Guadalhorce and Vélez Rivers). The widths of accommodation space in Granada province are nearly identical to those in Málaga, with 64 % of them under 100 m and greater widths only at the mouth of the province's main waterway (Guadalfeo River), where it can measure more than a kilometre. Almería's accommodation space is slightly different, owing to the presence of low-elevation sectors close to the Gulf of Almería (Campo de Dalías and Las Amoladeras), which enable inland development of large adjustment spaces. Nearly half of the province's accommodation space is nevertheless less than 100 m wide. Sandy substrate continues to prevail in the provinces of Málaga (54 %) and Almería (68 %), with increasing importance of detritic substrate (43 % and 32 %, respectively) due to the notable presence of formations of fluvial/colluvial origin throughout this coast; it is the dominant substrate in Granada province (98 %).

Finally, Figure 8 shows the visualisation of the accommodation space polygon and of the substrate type integrated through production of OGC services in the GIS and COAST viewer (https://www.nacional_2.gis-and-coast.org/). Their inclusion enables simultaneous viewing of other information produced by the group, such as the polygons for flood danger owing to sea-level rise due to climate change or erosion rates. The accommodation space's relationship to these elements will be subject to study by the authors in the future.

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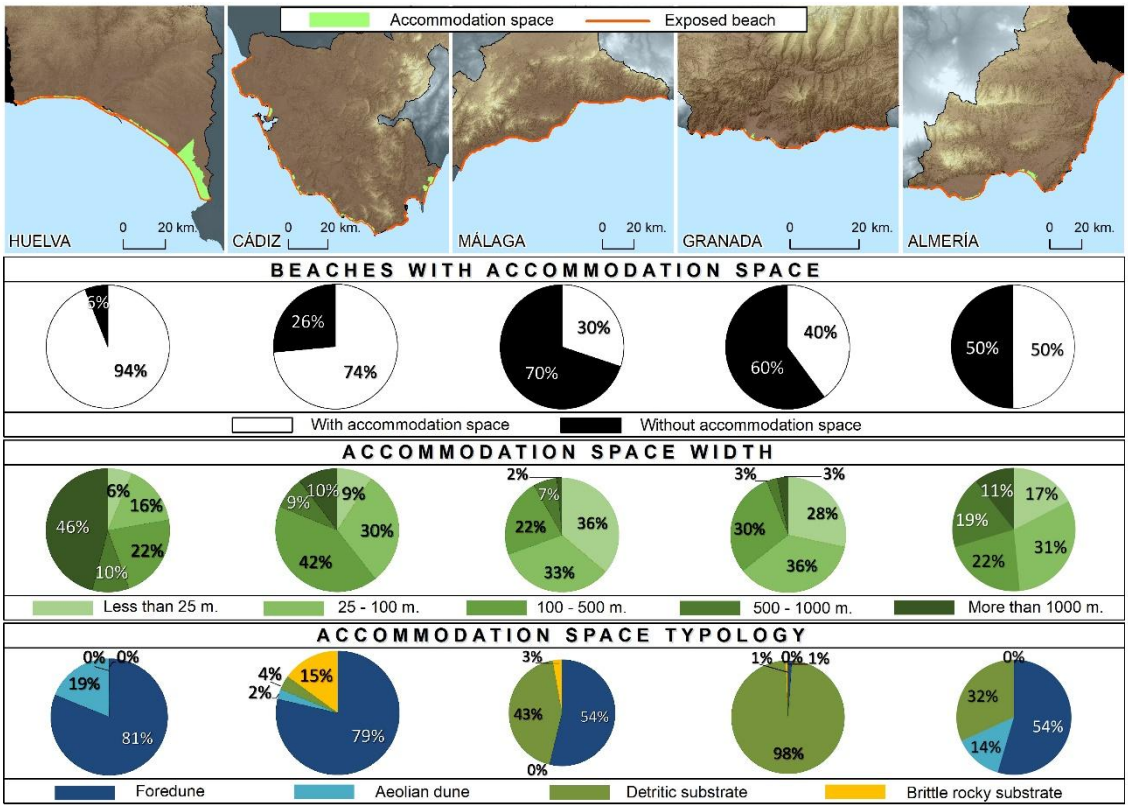

Figure 7. Presence, width and substrate typology of accommodation space by province.
Source: own production.

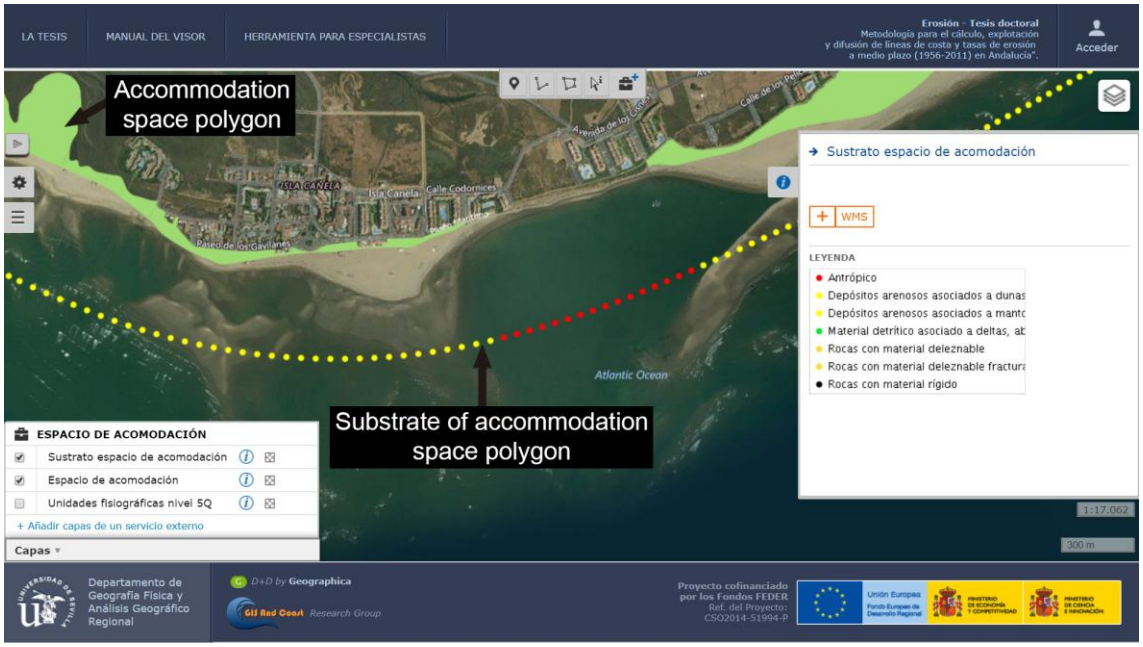

Figure 8. Accommodation space polygon and substrate typology in the GIS and COAST web geoviewer.
Source: own production.

Prieto Campos,A., Díaz Cuevas, P., Ojeda Zújar, J. (2019): "'Accommodation space' at beaches in Andalusia: calculations derived from the 2013 shoreline data model and the use of spatial databases", GeoFocus (Sección), nº 23, p. 97-117. ISSN: 1578-5157 http://dx.doi.org/10.21138/GF.628

5. Discussion and assessment of findings

The research group on Coastal Management and Territorial Information Technologies of the University of Seville has been specialising in the design and application of strategies to produce, use and disseminate information about the shoreline of Andalusia. These strategies are mainly based on spatial modelling and the respective implementation in relational spatial databases managed by PostgreSQL/PostGIS. This has enabled the shoreline data model, originally designed by the group for a specific purpose, to be subject to various updates, leading to the generation of coastal indicators, some of them calculated for the first time for the entire Andalusian coast, such as the case of erosion rates. One of those updates is presented in this paper – the inclusion of 'accommodation space', a relative concept understood to mean the availability of free space (absence of anthropic constructions) with any sedimentary substrate that allows migration of the coastal system toward the interior in the event of coastal regression.

This work constitutes the first experience on the Andalusian coast of measuring accommodation space for the totality and diversity of its beaches, on both the Atlantic and Mediterranean façades. It may therefore serve as a reference for other more detailed analyses.

In general, the results obtained enable affirmation that about 40 % of Andalusian beaches do not have accommodation space and would be unable to establish a natural response to erosion or flooding phenomena, with maintenance of their natural form compromised. Conversely, around 60 % of Andalusian beaches, 354 km of shoreline, are endowed with accommodation space, enabling shoreline fluctuation and hence a certain response of the beach to the aforementioned phenomena. Some 70 % of those spaces are foredunes, the category which would allow maintenance of the maximum substrate quality at those beaches. However, these results are aggravated on the Mediterranean façade, where only 76 km of beaches have foredune-type accommodation space, of which 37 km are less 100 m wide.

By provinces, the good position of Huelva province stands out. Not only are 94 % of its beaches endowed with accommodation space, nearly half of them (46 %) are more than 1000 m wide and most are also composed of substrates associated to foreunes, which would allow the substrate's quality to be guaranteed. They are therefore the beaches on Andalusia's coast most resilient to impacts stemming from erosion phenomena. The case of the beaches in Málaga province is the opposite, as only 30 % present accommodation space, which in 36 % of them measures less than 25 m. In this province, the beaches are the most vulnerable and least resilient on the Andalusian coast; they are also subject to high anthropic pressure because they support much of the region's tourist activity – the municipalities of Málaga's Costa del Sol by themselves account for 31 % of regulated tourist occupancy places in the littoral of Andalusia (Institute of Statistics and Cartography of Andalusia, 2018). Thus, 7 from the 10 Andalusian municipalities with the highest number of regulated tourist occupancy places**,** are situated in Costa del Sol (Table 3). It is extremely important to recognise that the beaches with less ability to respond to erosion/flooding phenomena are those with the highest tourist burden.

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Table 3. Andalusian municipalities with the highest number of regulated tourist occupancy places. In grey, municipalities of Málaga´s Costa del Sol.

Classification order	Municipality	Regulated tourist occupancy places	Total regional percentage (%)
1	Marbella	28126	5.6
2	Torremolinos	21766	4.3
3	Sevilla	21174	4.2
4	Benalmádena	19166	3.8
5	Roquetas de Mar	17915	3.6
6	Granada	17013	3.4
7	Fuengirola	15093	3
8	Málaga	14862	3
9	Mijas	13230	2.6
10	Estepona	13138	2.6

Source: Institute of Statistics and Cartography of Andalusia, 2018

Despite configuring these important preliminary results, a number of considerations must be borne in mind:

- As occurs with the interpretation of erosion rates, although the most effective and real calculation is the one that enables three-dimensional analysis (m^3), surface calculations and linear distances have historically been used more, owing to the lack of three-dimensional data (Prieto, 2017). This nuance is crucial, given that, per Ojeda (2015), a 2 m regression on a 3 m high coastal dune causes erosion of 6 m^3, while the same regression on a 1 m high dune only causes erosion of 2 m^3. It is therefore necessary to note that caution that must be taken when interpreting the results. The authors proposes for the future the to characterization of this space on the basis of the sedimentary volume it encompasses, calculated with a LIDAR DEM, only recently available for the coast of Andalusia.
- The spatial modelling of information and the use of spatial relational database management systems allowed the research group to make progress on strategies for producing detailed information on the Andalusian coast, very important for planning and management. Moreover, the structure of the relational databases used means the information can be easily linked, enabling new indicators to be built and new data relationships explored. Hence, for example, this methodology has allowed accommodation space to be compared with the corresponding information on beaches derived from the shoreline, so that the percentage of beaches with accommodation space on the Andalusian coast can be ascertained, as well as information corresponding to dunes derived from shoreline, enabling calculation of the percentage of dune formations within the accommodation space. It would also allow it to be compared with erosion rates, thereby evaluating the behaviour of beaches endowed with accommodation space;
- The large amount of information gathered (shoreline for 2013 digitised at a very detailed scale of 1: 2500, transects and accomodation space for the entire Andalusian coast) means the most ideal way to assimilate the results should be via geovisualisation to make use of its integrative capacity and instantaneous reading. Although the instrument traditionally used was thematic mapping, at present, and given the volume of information and its scale, a more flexible interactive instrument with direct internet access was indispensable. Altogether, this led to consider the use of a web geoviewer fed by interoperable services according to Open Geospatial Consortium (OGC)

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standards, along with intense work to select the appropriate semiology with a view to resolving that problem and ensuring its dissemination and public access.

Finally, this paper manifests the need to establish measures which guarantee protection of existing accommodation spaces. The role protected natural spaces have played in protecting such spaces in some sectors of the Andausian coast is notable, contrary to the role of urbanisation and pressure from tourism and other anthropic uses that prevent the development or maintenance of the accommodation space, which have led to the destruction of many of them.

6. Conclusions

The inclusion of accommodation space in the shoreline data mode is fundamental for assessing the coastal front's vulnerability with respect to its behaviour in the medium/long term. This variable, aggregated for each topologically independent section of coastline, is essential for understanding the current dynamics and future evolution of Andalusia's beaches. Indeed, although 3D analysis is the method that allows the most reliable characterization of the phenomenon, the lack of availability of historical three-dimensional data sources (the LiDAR is only available for very specific sections and for current dates), avoids a retrospective analysis of the phenomenon and, therefore, has opted in this paper for a one-dimensional (linear) analysis to detect changes in the evolution of exposed beaches.

From the tourism standpoint both the sedimentary viability of the beaches in the medium/long term and its quality are extremely important, whereby it is imperative to study the substrate on which both the beaches and their accommodation space develop.

According to the results, the Atlantic-facing coast is characterised by extensive accommodation spaces with mostly sandy substrate (associated to dune formations), which guarantees optimal quality of sedimentary material for its beaches. The mostly accumulative behaviour of these areas attests to the strong resilience capacity of the Atlantic beaches with respect to erosive processes.

The high level of anthropisation and nearness of steep terrain endow the Mediterranean façade with beaches that have scant accommodation space, corresponding to a high percentage of detritic substrate (deltas) as wells as sedimentary quality below that of the Atlantic environment. The erosive process present on most of the coastal front, along with the characteristics described above, mean the Mediterranean beaches have little capacity to adjust to shoreline fluctuations, with a consequent high level of vulnerability to erosive processes.

Finally, the spatial modelling and the model's implementation in a spatial database managed by PostgreSQL/PostGIS enables the gathering of detailed information, besides implying an improvement in the management and storage of information through use of that database management system's analytic capabilities. It also facilitates use of the data and the design and production of indicators by means of simple SQL sentences, updatable and replicable in other study contexts. Also, the indexing functions, both spatial and thematic, streamline not only information management and use but also facilitate dissemination of results on the internet for any user by means of web geoviewers.

Finally, the authors intend to address the evolution of accommodation space on other reference dates, in order to establish the relationship between accommodation space and erosion rates.

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References

Álvarez, J.I., Ojeda, J., Díaz, P., Prieto, A., Pérez, J.P. (2017): "Difusión web de tasas de erosión en las playas de Andalucía: geovisores web para la exploración de datos", *Geotemas*, 17, pp.147-150.

Barragán, J.M. (2004): *Las áreas litorales de España: del análisis geográfico a la gestión integrada*. Barcelona, Ariel.

Barragán, J.M., Chica, J.A., Pérez, M.L. (2008): "Iniciativa andaluza (España) para la gestión integrada de zonas costeras (GIZC)", *Revista de Geografía Norte Grande*, 41, pp. 5-22.

Camarillo, J.M., Álvarez, J.M., Limones, N., Pita, M.F. (2014): "Globalclimatemonitor.org: una herramienta de acceso a datos climáticos globales", *Geofocus* (Recursos), 14, pp. 1-6.

Camarillo, J.M., Álvarez, J.M., Limones, N., Pita, M.F., Aguilar, M. (2018): "The global climate monitor system: from climate data-handling to knowledge dissemination", *International Journal of Digital Earth*, pp. 1-21.

Choowong, M.; Phantuwongraj, S.; Charoentitirat, T.; Chutakositkanon, V.; Yumuang. S., Charusiri, P. (2009): "Beach recovery after 2004 Indian Ocean tsunami from Phang-nga, Thailand". *Geomorphology*, 104, 3-4, 134-142.

Cendrero, A., Sánchez-Arcilla, A. y Zaxo, C., Bajadí, T., dabrio, C., Goy, J.L., Jiménez, J.A., Mösso, A., Rivas, V. (2005): "Impactos sobre las zonas costeras", en Moreno (Coord.): *Evaluación preliminar de los impactos en España por Efefecto del Cambio Climático. Central de Publicaciones*, Secretaría General Técnica. Ministerio para la Transición Ecológica, pp. 469-524.

De Andrés, M., Barragán, J.M. (2016): "Desarrollo Urbano en el Litoral a Escala Mundial. Método de Estudio para su Cuantificación", *Revista de Estudios Andaluces,* 33, 1 , pp. 64-83.

Del Río, L. (2007): *Riesgos de erosión eostera en el litoral Atlántico gaditano*. Ph.D. Thesis, University of Cádiz, Puerto Real, Spain.

Department of Agriculture, Livestock, Fisheries and Sustainable Development (2007). Map of Physiographic Units of the Andalusian Coastline. Junta de Andalucía.

Department of Tourism and Sports (2016a): *Balance del año turístico en Andalucía.* Department of Tourism and Sports, Seville, Spain. [accessed on 06/11/2018]. Available online: http://www.juntadeandalucia.es/turismoydeporte/publicaciones/estadisticas/bata_2016.pdf

Department of Tourism and Sports (2016b): *Turismo en el Litoral de Andalucía.* Department of Tourism and Sports, Seville, Spain. [accessed on 06/11/2018]. Available online: https://www.turismoandaluz.com/estadisticas/sites/default/files/litoral_2016.pdf

Díaz, P., Prieto, A., Fernández, M., Ojeda, J. (2012): "La línea de costa como base para la generación de indicadores de estado y de seguimiento ambiental: modelo de datos y conceptos de líneas de costa en el litoral de Andalucía", en *Las Tecnologías de la Información Geográfica en el contexto del cambio global*. *XV Congreso Nacional de Tecnologías de la Información Geográfica*. Madrid, pp. 29-38.

Díaz, P., Prieto, A., Ojeda, J. (2013): "Modelo de datos de línea de costa como soporte para la caracterización y cálculo de indicadores en la zona de transición costera: la costa andaluza", en *Espacios insulares y de frontera. Una visión geográfica*. Palma de Mallorca, pp. 361–369.

Prieto Campos,A., Díaz Cuevas, P., Ojeda Zújar, J. (2019): "'Accommodation space' at beaches in Andalusia: calculations derived from the 2013 shoreline data model and the use of spatial databases", GeoFocus (Sección), nº 23, p. 97-117. ISSN: 1578-5157 http://dx.doi.org/10.21138/GF.628

Díaz, P., Ojeda, J., Álvarez, J.I., Prieto, A. (2014): "Sensibilidad de las playas en función de la accesibilidad de los potenciales usuarios turísticos (plazas regladas) en la costa andaluza y los procesos de erosión", en *XVI Congreso Nacional de Tecnologías de la Información Geográfica*. Alicante, pp. 954-966

Díaz, P., Ojeda, J., Pérez, J.P., Álvarez, J.I. (2015): "Diseño y funcionalidades de un visor web para la participación pública en los procesos de planificación y gestión costera", *Geotemas*, 15, pp. 105-109.

Díaz, P., Prieto, A., Ojeda, J., Álvarez, J.I. (2017): "Tasas de erosión en playas con dunas costeras en el litoral de Andalucía. Primeros datos globales", en *Naturaleza y Cambio Global. XXV Congreso de la Asociación Geógrafos Españoles*, Madrid, pp. 86-96.

Fernández, M., Díaz, P., Ojeda, J., Prieto, A., Sánchez, N. (2015): "Multipurpose line for mapping coastal information using a data model: the Andalusian coast (Spain)", *Journal of Coastal Conservation*, 19-4. pp. 1-14.

Fernández, R. (2006): *El tsunami urbanizador español y mundial*. Barcelona,Virus.

Fraile, P., Álvarez, J.I., Ojeda, J. (2018): " Cartografía de la probabilidad de inundación del litoral andaluz a finales del siglo XXI ante la subida del nivel del mar", *Cuadernos Geográficos*, 57, 2, pp. 6-26.

Frieyro, J.E., Ojeda, J., Giménez de Azcárate, F., Cáceres, F.,Moreira, J.M. (2010): "Desarrollo del Sistema de Información sobre el Litoral y el Medio Marino de la Red de Información Ambiental de Andalucía (REDIAM)", en Ojeda, J., Pita, M. F. y Vallejo, I. (Eds.), *Tecnologías de la Información Geográfica: La Información Geográfica al servicio de los ciudadanos. XIV Congreso Nacional de Tecnologías de la Información Geográfica*, Sevilla, pp. 97–107.

IECA Institute of Statistics and Cartography of Andalusia (2017): "*Encuesta de ocupación hotelera"*. [accessed on 01/11/2018]. Available online: https://www.juntadeandalucia.es/institutodeestadisticaycartografia/eoh/index-eoh.htm

Jiménez, J.A., Valdemoro, H., Sanchez-Arcilla, A., Nicholls, R.J. (2017); "Impacts of sea-level rise-induced erosion on the Catalan coast", *Regional Enviromental Change*, 17, pp. 593-603.

Ojeda, J. (2000): "Métodos para el cálculo de la erosión costera. Revisión, tendencias y propuestas". Boletín de la Asociación de Geógrafos Españoles, 30, pp. 103-119.

Ojeda, J. (2015): "Los procesos erosivos de las playas en la nueva "Ley de Costas". Reflexiones desde la geomorfología litoral", en J. Rodríguez y M.C. Núñez (Eds.), Litoral de Andalucía. Norma y naturaleza. Universidad de Huelva, pp. 13-39.

Ojeda, J., Álvarez, J.I., Martín, D., Fraile, P. (2009): "El uso de las TIG para el cálculo del índice de vulnerabilidad costera (CVI) ante una potencial subida del nivel del mar en la costa andaluza (España)", *GeoFocus*, 9, pp. 83-100.

Ojeda, J., Fernández, M., Prieto, A., Pérez, J.P., Vallejo, I. (2010): "Levantamiento de líneas de costa a escalas de detalle para el litoral de Andalucía: criterios, modelo de datos y explotación", en Ojeda, J., Pita, M. F. y Vallejo, I. (Eds.), *Tecnologías de la Información Geográfica: La Información Geográfica al servicio de los ciudadanos. XIV Congreso Nacional de Tecnologías de la Información Geográfica*, Sevilla, pp. 324-336.

Ojeda, J., Prieto, A., Díaz, P., Vallejo, I. (2015a): "Los procesos erosivos de las playas en la nueva Ley de Costas de 2013: Ejemplos en sectores del litoral andaluz", *Geotemas*, 15, pp. 53-57.

Prieto Campos,A., Díaz Cuevas, P., Ojeda Zújar, J. (2019): "'Accommodation space' at beaches in Andalusia: calculations derived from the 2013 shoreline data model and the use of spatial databases", GeoFocus (Sección), nº 23, p. 97-117. ISSN: 1578-5157 http://dx.doi.org/10.21138/GF.628

Ojeda, J., Díaz, P., Álvarez, J. I., Pérez, J. P., Prieto, A. (2015b). "Geoportales y geovisores web: Un nuevo entorno colaborativo para la producción, acceso y difusión de la información geográfica", en de la Riva, J., Ibarra, P., Montorio, R., Rodrigues, M. (Eds.), *Análisis espacial y representación geográfica: innovación y aplicación. XXIV Congreso de la Asociación de Geógrafos Españoles*, Zaragoza, pp. 777–786.

Prieto, A. (2017): *Metodología para el cálculo, explotación y difusión de líneas de costa y tasas de erosión a medio-largo plazo (1956-2011) en Andalucía*. Ph.D. Thesis. University of Seville, Seville, Spain.

Prieto, A., Díaz, P., Ojeda, J., Álvarez, J.I. (2017): "Tasas de erosión en las playas de Andalucía: el efecto de infraestructuras costeras longitudinales y urbanización", *Geotemas*, 17, pp. 243-246.

Prieto, A., Díaz, P., Fernández, M., Ojeda, J. (2018): "Methodology for Improving the Analysis, Interpretation, and Geo-Visualisation of Erosion Rates in Coastal Beaches—Andalusia, Southern Spain", *Geoscienses*, 8, 335.

Psuty, P., Silveira, T.M. (2010): "Global climate change: an opportunity for coastal dunes??". *Journal of Coastal Conservation*, 14, 153-160.

Royal Decree 1071/2007. 27 July 2007. Regulates the Geodetic System of Official Reference in Spain.

Seisdedos, J., Mulas, J., González de Vallejo, L. I., Rodríguez Franco, J. A., Gracia, F. J., Del Río, L., Garrote, J. (2013): "Estudio y cartografía de los peligros naturales costeros de la región de Murcia", *Boletín Geológico y Minero*, 124, 3, pp. 505-520.

Servera, J. , Rodríguez-Perea, A. (2009): "Development and setting of the Alcudia Bay beach–dune system (Mallorca, Spain)", *Geomorphology*, 110, 172-181.

Suanez, S.; Cariolet, J.M.; Cancouët, R.; Ardhuin, F.; Delacourt, C. (2012): "Dune recovery after storm erosion on a high-energy beach: Vougot Beach, Brittany (France)". *Geomorphology*, 139-140, 16-33.

Thieler, E.R.; Himmelstoss, E.A.; Zichichi, J.L.; Ergun, A. (2009): "*Digital Shoreline Analysis System (DSAS) Version 4.0—An ArcGIS Extension for Calculating Shoreline Change"*, Serial Number 2008-1278. Reston, VA, USA, U.S. Geological Survey. [accessed on 03/09/2018]. Available online: https://pubs.er.usgs.gov/publication/ofr20081278

Vera, J.F., Rodríguez I. (2010): "Tourism strategies for the renovation of mature coastal destinations in Spain", *WIT Transactions on Ecology and the Environment*, 139, pp. 21-33.

Villar, A. (2013): "La mercantilización del paisaje litoral del mediterráneo andaluz: El caso paradigmático de la Costa del Sol y los campos de golf", *Revista de Estudios Regionales*, 96, pp. 215-242.

Villar, A., Ojeda, J, (2012) "El desarrollo de una base de datos espacial sobre el proceso de urbanización en el litoral de Andalucía: Indicadores del colapso inmobiliario (2004-2007-2009)", en Martínez Vega J. y Martín Isabel, P. (eds.) *Tecnologías de la Información Geográfica en el contexto de Cambio Global*. *XV Congreso Nacional de Tecnologías de la Información Geográfica*, Madrid, 427-492.