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Changes in Mediterranean Coastline According to the Coastal Type and Land Cover under Climate Change: The Case of South-east Spain

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ABSTRACT

Coastline changes were analyzed considering the land cover types and the analysis of the causes that have determined these changes during the past decades. Through the overlapping of aerial photographs and GIS analysis, the results showed that the land surface increased with respect to the previous stage, gaining terrain to the sea, but this increment was caused by anthropogenic processes. In fact, without human pressure, the land surface beside the coastal line would have decreased, especially on the sandy beaches and coastal dunes. Therefore, the beaches are one of the most vulnerable ecosystems and geomorphological systems due to erosion and lack of sediment supply associated with the modified river courses (i.e. by the construction of reservoirs, concrete channeling, etc.), the inner land use changes, and the effects of global warming on the sea level. Climate change studies predict specific increases in the sea level along the coast. The aim of this work is to know if anthropic activity can reverse the effects of sea level rise and coastal erosion. In fact, it has been done for decades with measures aimed to correct impacts and favour economic activity (i.e. maintaining tourism resources) and not from the environmental issues.

Keywords: Aerial photography; Coastal changes; Coastal erosion; GIS analysis; Sea level

1. Introduction

Coastal ecosystems are a narrow space between the land and sea where living beings are especially vulnerable due to the scarce extension and the increasing human pressure over time [1-4]. The coastal environment is a complex ecosystem and geomor-

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phological system determined by land and sea processes, the weather and the anthropogenic affections, and has regressive and transgressive episodes. Some variations in the coastal area can have serious consequences for the ecosystem and especially in the biotic components [5]. Several activities alter the environment such as land reclamation from water bodies, filling and desiccation of wetlands and excessive replacement of natural surfaces with impervious materials [6-8]. Human pressures can affect coastal properties both directly and indirectly. The first one implies the human transformation and adaptation of the coast for its activities (i.e. ports and tourism resources) and the second one means that other human activities can change several characteristics like the chemical properties, the temperature and the turbidity of the water [4,9], with negative consequences for the ecosystems. Moreover, global warming can intensify coastal erosion due to the sea level rise and waves and coastal wind changes [4,10-13].

Since the middle of the XX century, the increasing population nearby the coast due to tourism and other activities, has intensified the effects on the coast and the erosion processes on beaches [12,14-16]. Such is the case of the Mediterranean coast, which is one of the most populated spaces in the world [14,17,18] and a hotspot of biodiversity [19]. The tourism development generated a great migration from rural regions to the coast [20] due to the possibility of finding new jobs. The increment in population leads to a growth in urbanized land and changes in land use and shoreline modifications. Urbanization modifies the original properties of the coast transforming it into altered or urbanized coast with ports, promenades, urban beaches, breakwaters and other infrastructures [8,10,21]. The smaller surface of the Mediterranean Sea with respect to the oceans, contributes a particular characteristic in terms of marine dynamics.

In general, two main types of coasts constitute the Spanish Mediterranean coastal environment. On the one hand, the rocky coast is close to mountainous ranges (**Figure 1**). On the other hand, sandy coasts in sedimentary basins [2,4,10,22]. In the first case, the coast is more resistant to erosion and the most common geomorphological formations in these spaces are cliffs, rocky platforms and gravel coves and beaches [2,4,22]. The rocks and cliffs are consolidated formations and the gravel coves are more dynamic, but not as much as the sandy beaches, due to the greater granulometry size of the gravel. The emerging part of the coast receives the greatest effects of the waves and coastal storms, whereas the submerged part of the coast erodes more slowly, leaving part of the rock at the same level of the sea, known as rocky platforms (**Figure 1**). In the sedimentary basins, changes in the coast are much more dynamic due to the smaller size of particles forming the beaches, especially in those formed by fine sand. In this case, the wind also acts in the environmental processes, especially by transporting the small grains of sand and dust. The most common formations found in these areas are sandy beaches, dunes and coastal lagoons [2,23].

The types of coasts regarding geological processes are closely related to seabed geomorphology. In the mountainous coast, the seabed is usually sloping and irregular, whereas, in the sedimentary coasts, the seabed is flatter, with a greater continental shelf formed by fine particle sizes [23]. In addition, the development of benthonic communities is also important. On the Mediterranean coast, *Posidonia oceanica* plays a key role in fixing the sediments and preventing turbidity of the water. Therefore, *Posidonia oceanica* is important for the quality of the beaches as well as for the marine ecosystem [2,24]. There are other relevant communities of phanerogams such as *Cymodocea nodosa*, photophilic alga, *Scylaphids algae*, and mixed zones with different species. Sediments, together with the progressive reduction of light because of greater depth, determine the benthic communities in floors or strips parallel to the coast [23].

The sandy coasts are the result of the accumulation of sediments transported by the river courses and waves-wind action. A change in the amount of the contributions of fine particles will affect the increase or decrease of sedimentary spaces in the coast [4,12,21,25-27]. Throughout recent history, river basins have undergone various processes that have

Cliffs Gravel cove

Rocky platform Sand beach

Figure 1. Common types of the coast are found in Mediterranean environments.

Source: Authors.

caused significant differences in the sediments that reach the littoral zone. Moreover, a combination of changes in land use far from the coast, i.e. changes in the forest areas, farming systems, urbanization and the creation of infrastructures for water management (reservoirs), have determined an important decrease in the amount of materials input in the coast from rivers. Due to the deficit of inputs and the increment of risk of erosion, coastline regression is noticed [27].

Natural and anthropogenic processes act on the coast. The wind is a natural element that causes changes in the emerging part of the coast, especially in the beaches and dune formations. These changes occur on the surface and are diverted by the topography and obstacles encountered. Close to the shoreline, breezes due to the difference in temperature between sea and land are found. During the day the breeze blows from the sea towards the coast while at night, it blows from land to the sea. The most intense winds occur during maritime storms and situations of high atmospheric instability. In addition to the wind, the direction and size of the waves and marine currents also influence the shape of the beaches and the coastline. In this case, sediment movements occur in the submerged part of the coast and waves and currents affect sandy beaches, gravel, pebbles and even small blocks [8,12,21,23].

Seawater temperature is a critical factor for the survival of living organisms, especially in the coastal and sea environment, where temperatures are accentuated due to the narrow sheet of water and close contact with the earth's surface [28]. Turbidity occurs more frequently near the coast. Turbidity is a factor that worsens the quality of beaches and decreases the amount of light reaching the seabed. The presence of *Posidonia oceanica* usually fixes sediments to the bottom reducing the turbidity of the beaches [2]. On the other hand, the anthropogenic discharges on the coast can produce changes in temperature and addition of nutrients modifying the biota and pollutants [29].

There are two types of tides, astronomical tides and meteorological tides. The astronomical tides are produced by the attraction effect generated by the sun and the moon, and meteorological tides are produced by the effect of atmospheric pressure [4,8,30]. In the Mediterranean Sea, the meteorological tides alter the level of the sea a few centimeters above or below, depending on the state of the atmospheric pressure, much more remarkable the effect during the maritime storms, also by the combined effect of the increase of the level of the sea and the height of the waves [8]. The stability of the sea level in the Mediterranean Sea is one of the most interesting issues to study climate change impacts in this region.

Human pressure promoted urban expansion, which is one of the main factors that has caused the most important changes on the coast. The urbanized spaces become the inner limit of the beaches, also limiting their space and their growth. What were formerly areas of dunes or diffuse or progressive limits are now maritime promenades and urbanized land [2,4,15,31-33]. Ports have increased in number and size for commercial, fishing and recreational water use. The change in land use is another factor related to the urban expansion that has occurred. The increase in population linked to the coast, increases the pressures and impacts on it, but also anthropogenic alterations far from the coast alter the coastal ecosystem (i.e. modifying river systems, the carryover and sediment deposition on the coast). The works that directly modify the coastline may be classified between hard works and soft works. The hard works are represented by the imposition of physical barriers that interrupt and modify the marine dynamics such as ports, urban constructions and breakwaters. The soft works are represented by specific changes that are less durable over time, for instance, the regeneration of beaches by adding sand extracted from the seabed.

Coastal regenerations should be specific modifications that are made to preserve the environment, from the potential risks, with the objective of keeping the ecosystem services, the landscape and sustainable socio-economic activities. Therefore, the nature of the place will be not changed, only the factors that represent a risk should be corrected. A very common case is the recovery of beaches that have been considerably eroded by marine dynamics. But in this case, regeneration will only be considered if the poured materials are equal to the original ones. But, a gravel beach that is filled with sand is not a regeneration, but a transformation to a new state, mainly for tourism purposes.

However, part of the impacts that occur on the coasts originated in the inland regions. Rivers connect the coast with the inland regions and transport solid materials and dissolved substances in natural conditions. But, under unsustainable management due to serious modifications of the river beds, the transport of sediments is compromised.

In Spain, the coast is a place of great vulnerability as the Spanish legislation recognized (Ley 2/2013) [34]. It must be protected against all types of activities and land uses that may be harmful to the coastal and marine ecosystems. In order to avoid that, it is important the delimitation of the Terrestrial Maritime Public Domain (TMPD) and its regulation [35]. In addition, other elements that determine the land uses are the land planning strategies through the urban planning of each municipality, and the protected coastal areas, as those included in the European Natura 2000 Network. The current law incorporates into the TMPD the concept of the shore of the sea, which is any space that may be flooded naturally by the effect of tides and waves, including rivers as far as the effects of the sea arrive. This law focuses on the sustainability of the activities that occur on the coast through their concessions and, for the first time, a strategic plan for the adaptation to the effects of climate change was established [4].

Considering the effects of climate change on the coast (article 2a), but especially protection and sustainable use are the main demands of the latest Spanish Coastal Law (Ley 2/2013) [34]. This is carried out through the Strategy of Adaptation to Climate Change on the Spanish Coast [4]. In order to determine the effects that may occur, it is necessary to know the characteristics of each coastal area. From the studies carried out, it has been concluded that the effects of climate change will be different in each coastal space. There are, for example, areas with a high risk of erosion and sea level rise, and others that are more stable and their effects will occur over a longer period of time. In areas with astronomical tides, the effects of climate change and rising sea levels will occur in a shorter period of time and with greater intensity than in the Mediterranean Sea [11]. The effects of climate change are not reduced only to the rise in sea level. In the long term, there may be changes in currents, marine dynamics, winds and tides, accentuating the erosion of beaches and more vulnerable areas [11].

This work analyzed the evolution of the southeast coast of Spain, associated with the period when the tourism model and Spanish economy has been developed. This work shows the contrast between the expected reduction of coastal area opposite the increment associated with human pressure. The changes in the shoreline and the surface are directly related to the land use management. Types of the coast and land cover were studied and analyzed in order to determine if changes detected are due to natural processes or anthropogenic actions. Finally, as it is a study of coastal changes over time, attention should be paid to the possible expected effects of climate change, the increment of sea level with a possible reduction of a coastal land surface.

2. Methodology

2.1 Study area

The area selected for this study is located on the Mediterranean southeast coast of Spain. It covers from Cape of Palos (37°37.95'N, 0°41.44'W) to the south and Cape of La Nao (38°44.77'N, 0°13.92'E) to the north and it is represented in **Figure 2**. This area has been selected for its stability, since there is an almost absence of the effects from tides and the sea level in general has few oscillations. In addition, the city of Alicante, which is within the range of the study area, is the reference of the sea level in Spain (marks the point 0 meters above the sea level). The study area is heterogeneous and represents different types of coast and land uses. It is therefore a good example of a Mediterranean coastal environment. This is also one of the most affected areas by the urban expansion and development of tourism for the last 60 years in the Mediterranean basin.

The Spanish Mediterranean coastal climate is generally Csa according to the Köppen-Geiger classification in this area. It is a temperate climate with

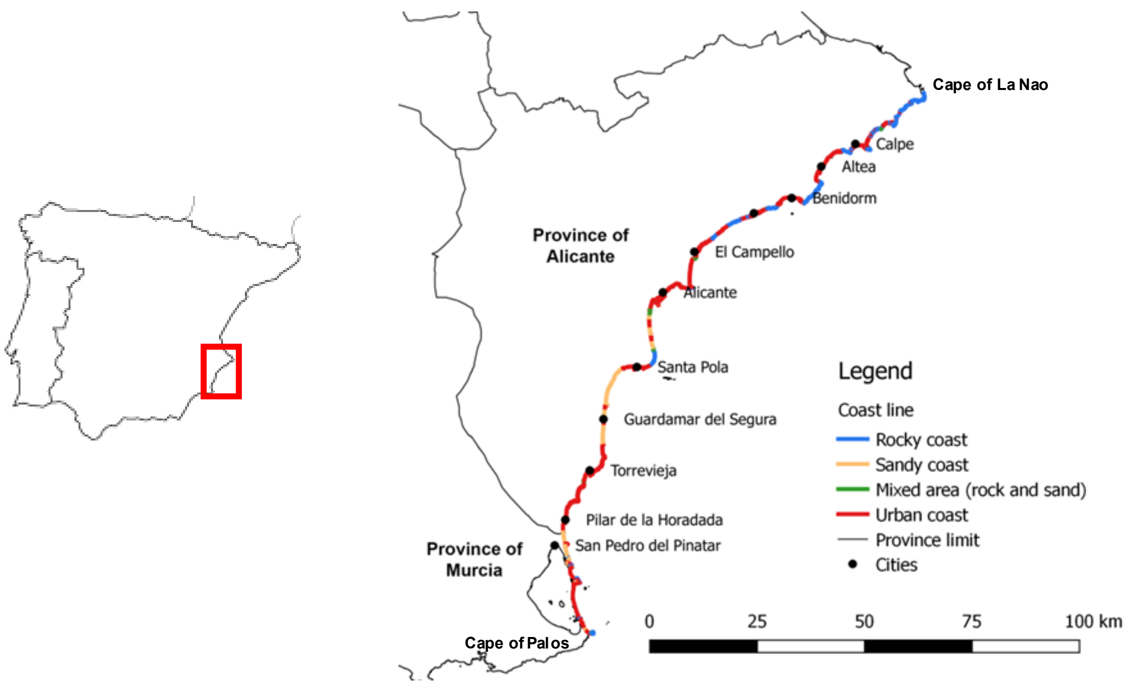

Figure 2. Study area with the different types of coast present in the area.

Source: Own elaboration.

warm summer and winter softened by the effect of the proximity of the sea. The temperatures are mainly equinoctial, being especially arid in the summer months. In the southeast of Iberian Peninsula, the Mediterranean climate has more marked aridity, and in several cases, the climate becomes BSh in the Köppen-Geiger classification, known as mid-latitude steppe and desert climate [36].

2.2 Aerial photography

Changes in the coastline can be determined by photo interpretation of aerial images. On the one hand, aerial images from the period 1956-1957 taken in a flight called *American Flight* were used, *American Flight B* series from the IGN (open source: National Geographic Institute, Army Map Service (USA), 1956-1957. [Vuelo americano Serie B] [fotografías aéreas]. 1:33.000. Madrid: Centro Cartográfico y Fotográfico del Ejército del Aire). On the other hand, the recent orthophotos belonging to the years 2014 (province of Alicante) and 2016 (province of Murcia), have been obtained from the PNOA (open source: National Plan of Aerial Orthophotography, PNOA 2014-2016 CC BY 4.0 www.scne.es). Both were used to determine the coastline and to study land cover changes in this research. The methodology employed was similar to the one used in the works of Cremades et al. [37] and Pagán [8,15,38], since they used aerial photography to establish comparisons of the coastal line. The difference is that those works focused on sandy beaches, while our objective is to obtain data on changes in all the types of coasts, covers and land use under the expected effects of climate change or anthropic changes.

2.3 GIS analysis

The software QGIS 3.16 (Hannover) was used for processing the aerial images obtained through the WMS server (World Map Service) of PNOA and IGN (National Geographic Institute). The first step was to trace the coastline of both periods (1956-1957 and 2014-2016). Both coastlines were disposed of under the same coordinated system, orthogonally projected and adjusted (resampling) [39].

By means of the superposition of both coastlines (overlapping), a series of polygons was obtained marking zones where the coast did not fit in both periods (coastal changes). These zones may be due to the increase or decrease of the coastal surface with respect to the previous situation. In **Figure 3**, an example of coastal changes is given to understand the methodology followed in this work. The data obtained (surface changes) were incorporated into the database together with the type of land cover (land use considering anthropic areas) of each zone.

In this work, knowing the regional environment and historical changes, it is interesting to consider the nature of these changes. In the ports and coastal infrastructures, the changes are always considered artificial (man-made). On the beaches, however, they may have an artificial origin (replenishment, regeneration, etc.) or a natural origin (wind, ma-

Figure 3. Coastline changes between 1956 (left) and 2014 (right) in Torrevieja (Alicante, Spain). In red colour the loss of coastal area and in yellow is the gain of the coastal area.

rine dynamics, erosion, etc.). In most cases, there is some anthropic influence but only intentional human changes on the coast, due to artificial works, regenerations and other alterations, will be considered artificial processes. Most of the changes produced in these areas will be considered natural changes during this period.

The coast was classified into four categories, according to the characteristics of the coast presented in the study area: The sandy coast, the rocky coast, the mixed rock-sand coast and the urban coast.

The Corine Land Cover classification system was used for land cover types (Copernicus Programme) [40], adding a space of special interest for the analysis of changes in sea level, which was the rocky platforms. The rocky platforms are flat spaces that are close to the sea due to the erosive effect of the waves on the cliffs and coastal rocks. The rise in sea level would facilitate the regression in part or totally of the rocky platform space. The land cover classification used to describe the polygons are presented in **Table 1**.

3. Results

3.1 Coastal types

The types of coasts were classified following the four categories established (**Table 1**) and the coastal line length obtained for each one is presented in **Table 2** for both periods analyzed. These results from PNOA 2014-2016 indicate that more than half of the coastline (close to 65%) was urbanized. The 35% would be considered as natural formations although not exempt from several anthropic influences (i.e. disperse occupation, access to beaches, etc.). 23% is a rocky coast and 11% is a sandy or sedimentary coast. In general, a reduction of all the categories except urbanized coastline was detected from 1956-1957 to 2014-2016.

After the superposition of both coastlines, from the middle of the XX century to the recent aerial photography, polygons, where changes occurred (modification of coastal line), were determined and

Table 1. Characteristics used to describe polygonal space units.

Land cover	Process type	Change type	Coast type
Beaches	Artificial	Increase	Rocky coast
Breakwaters	Natural	Decrease	Sandy coast
Cliffs			Mixed rock-sand coast
Port areas			Urban coast
Promenades			
Rocky platform			
Sparsely vegetated areas			
Urban areas			
Water courses			

Table 2. Coastal perimeter related to the types of the coast.

	American flight 1956-1957		PNOA 2014-2016	
Coastal type	Lenght (km)	%	Lenght (km)	%
Rocky coast	164.68	63.01%	67.71	22.8%
Sandy coast	38.26	14.64%	31.33	10.6%
Mixed rock-sand coast	20.41	7.81%	5.86	2%
Urban coast	38.01	14.54%	191.8	64.6%
Total	261.36	100%	296.7	100%

were associated with several natural or human processes.

The results presented in **Table 3**, show the changes (increase or decrease) and the process associated with these changes, classified as artificial or natural changes. In the table, we consider the total increase or decrease due to the sum of artificial and natural changes.

Changes in the surface due to the displacement of the coastline affected all the types of coast considered in this work, increasing or decreasing the area due to the changes in the coastline.

The tendency on the rocky coast was to decrease although its erosion is slow. The sum of the increases and decreases of coastal space is negative, around –15.05 ha in the study area.

The sandy coast represents 10.6% (2014-2016) of the coastline, but it is one of the areas where the majority of changes occur. Decrements dominate increments, especially due to erosion and lack of sediment input from rivers. The changes of artificial origin are not very representative since the classification of sandy coastline refers to dunes and non-urban beaches, where there is no presence of infrastructures or anthropic modifications. The total change on the sandy coast is negative, with a reduction of the area of –18.86 ha (**Table 3**).

Mixed rock-sand spaces are places with the presence of sand, rocks and materials of varied granulometry, they are transition zones between sandy and rocky coasts. These represent only 2% (2014-2016) of the coastline in the study area. In these spaces, decreases dominate increases and all change processes have been considered as natural processes, with –4.06 ha (**Table 3**).

The urban coast reaches 65% of the coastline in the study area in 2014-2016. It is formed by the coastline of urban fabrics, urban beaches, promenades, ports, docks and any infrastructure that has been built on the coast. In urban coasts, unlike the rest of the typologies, the growth is dominant process. Changes due to artificial processes on the urban coastline have resulted in considerable surface growth, especially represented by the construction and expansion of ports. The global change in the urban coast is an increment of 212.78 ha in the entire study area (**Table 3** and **Figure 4**).

Table 3. Type of changes (artificial and natural) associated to the types of coast (sandy, rocky, mixed rock-sand and urban coast).

Change type	Process	Surface (ha)	Rocky coast (ha)	Sandy coast (ha)	Mixed rock-sand (ha)	Urban coast (ha)
Increase	Artificial	316.41	0	25.31	0.26	290.84
Increase	Natural	29.53	3.10	18.28	1.12	7.03
Decrease	Artificial	–22.34	–0.04	–0.21	–0.01	–22.07
Decrease	Natural	–148.78	–18.12	–62.23	–5.43	–63.01
Total increase		345.94	3.10	43.59	1.38	297.87
Total decrease		–171.12	–18.16	–62.44	–5.44	–85.08
Artificial changes		294.07	–0.04	25.09	0.25	268.77
Natural changes		–119.25	–15.01	–43.95	–4.31	–55.98
Total change		174.82	–15.05	–18.86	–4.06	212.78

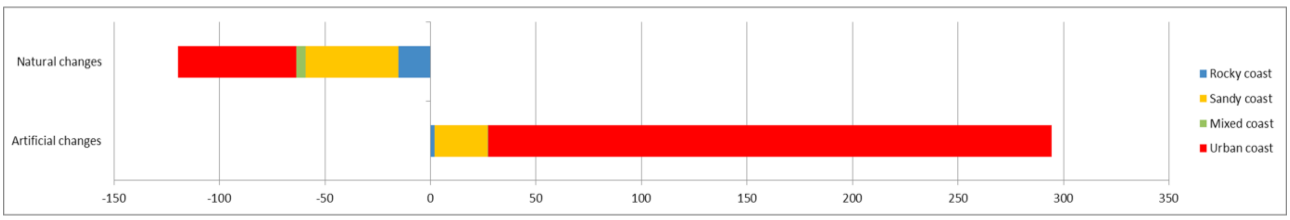

Figure 4. Natural and artificial surface changes in the coast regarding the type of coast.

3.2 Land cover changes

The land cover has been divided into nine categories, eight of from the Corine Land Cover [39], and another added by its importance that corresponds to the coastal rocky platform. The rocky platform, being aligned with sea level, would be an indicator of possible changes in sea level. The changes in the different land cover types between the period 1956-1957 and 2014-2016 are shown in **Table 4**.

Beaches are highly dynamic spaces whose materials are eroded and easily transported. On the beaches, erosion dominates over growth despite the anthropic actions carried out for their protection (regeneration, filling, etc.). The total changes in beaches, considering artificial and natural processes, is negative, with –33.93 ha in the study area (**Table 4** and **Figure 5**).

Breakwaters are works carried out on the coast to protect a space or land use from the damage that waves can cause. They are located next to urban beaches, promenades and ports, but they are also used to protect communication routes or urbanized areas. Breakwaters are man-made features and therefore their increase can only be artificial, however in many cases their construction can favor the accumulation and retention of sediments. The total change of the surface of the breakwater cover is an increase of 3.12 ha with respect to the situation in 1956-1957 in the study area (**Table 4** and **Figure 5**).

The cliff changes, in this case, were mainly due to natural processes associated with the erosion resulting in –6.19 ha (**Table 4** and **Figure 4**). Opposite to this, the ports are the spaces that have provided the greatest increases in coastal space in the study area. Changes are due to artificial processes, both increases and decreases. The increment of the port areas was 197.17 ha in the study area, mainly due to the expansion of the port of Alicante (**Table 4** and **Figure 5**).

The promenades, which are artificial works, apparently maintain the surface, without significative changes as a small reduction is detected (–0.08 ha). However, the effects on rocky platforms have been higher with –10.26 ha (**Table 4** and **Figure 5**). The loss of the rocky platform would be an indicator of sea level rise, however, other effects associated with the geological movements of rising or falling off the coastline could act and it is difficult to determine the origin of the effect in such a short period of time.

On the coastline, some spaces that do not respond to the specific characteristics of others, formed by areas of land with unconsolidated materials that in many cases are the result of discharges of rubble and clearings that were anthropically deposited on the coast and in many cases covered by vegetation were assigned to a cover type defined as sparsely vegetated areas. These spaces tend to grow due to the fact that in most cases their origin is artificial. There was an increase of 30.24 ha in the entire study area (**Table 4**, **Figure 4**).

The urbanized spaces have an increase of 1.94 ha. The watercourses surface losses predominate and in most cases due to artificial processes, with a reduction of –7.19 ha (**Table 4**, **Figure 5**).

Table 4. Type of changes (artificial and natural) associated with land cover in the coastal area.

Change type	Process	Surface (ha)	A	B	C	D	E	F	G	H	I
Increase	Artificial	316.41	69.58	6.92	0.21	200.02	0.46	0.29	36.31	1.94	0.68
Increase	Natural	29.53	23.89	0.05	1.51	0.02	0	0.59	0.87	0	2.60
Decrease	Artificial	–22.34	–9.12	–2.32	0	–2.79	0	–0.16	0	0	–7.95
Decrease	Natural	–148.78	–118.28	–1.52	–7.91	–0.07	–0.55	–10.79	–7.14	0	–2.53
Total increase		345.94	93.47	6.97	1.72	200.04	0.46	0.88	37.18	1.94	3.28
Total decrease		–171.12	–127.40	–3.85	–7.91	–2.86	–0.55	–10.95	–7.14	0.00	–10.47
Artificial changes		294.07	60.46	4.59	0.21	197.23	0.46	0.12	36.31	1.94	–7.27
Natural changes		–119.25	–94.39	–1.48	–6.40	–0.05	–0.55	–10.19	–6.27	0	0.07
Total changes		174.82	–33.93	3.12	–6.19	197.17	–0.08	–10.26	30.24	1.94	–7.19

A: Beaches / B: Breakwaters / C: Cliffs / D: Port areas / E: Promenades / F: Rocky Platform G: Sparsely vegetated areas / H: Urban areas / I: water courses.

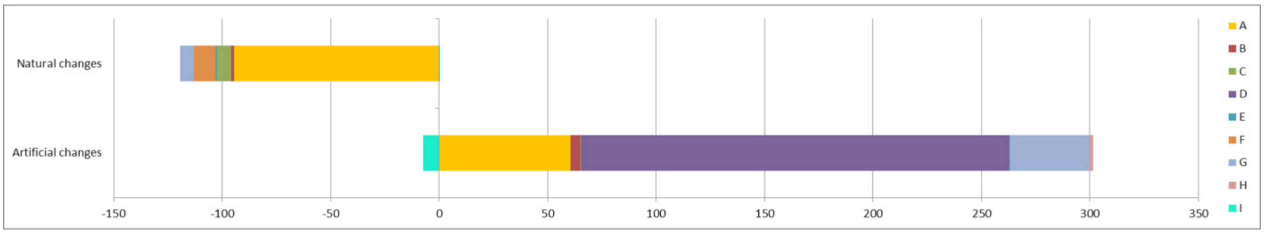

Figure 5. Natural and artificial surface changes in the coast associated with land cover: A-Beaches, B-Breakwaters, C-Cliffs, D-Ports, E-Promenades, F-Rocky Platform, G-Sparsely vegetated areas, H-Urban areas, I-water courses.

Regardless of the type of coastline or land cover, there has been a total increase of the surface estimated at 345.95 ha and the total decrease has been 171.12 ha. Therefore, the balance of land changes in the study area is positive, gaining 174.83 ha. The causes that have produced these changes, increasing the coastal surface, are artificial processes (constructions, regenerations, etc.), while natural processes (winds, waves, currents, sediment deposits, etc.) tend to produce decreases (**Tables 3 and 4**).

Between 1956-1957 and recent years (2014-2016), the coastal surface has grown and it seems a paradox considering the expected effects derived from climate change [41], the surface of the coast has maintained and/or increased. A more detailed analysis is necessary to understand what is happening on the coast and the responsibility of artificial human activities in this increment. There is a great difference between the geomorphological factors affecting the coast, and those derived from the high degree of anthropization and urbanization that at least, are the drivers of the processes that have caused a change or displacement of the coastline.

Although it is not the objective of this work, the administration needs to re-think the strategies that should be followed to reduce the expected climate change impact on the coast, considering not only the increment of anthropic works but facilitating the natural processes that can help to maintain the coastline within the rest of actions that should be applied to mitigate climate change.

5. Conclusions

Nowadays, the most natural environments (cliffs, gravel coves and rocky platforms) of the study area represent only 35.4% of the coast and have suffered changes (–39.19 ha) since the middle of the XX century. The urbanized coast, which represents more than half of the coastline of the study area (64.6%), is a space in which the trend is to increase the area gained to the sea due to anthropization of the coastal area (211 ha). Urban and other anthropic land uses such as ports, promenades and breakwaters, have been increased, which implies the growth of the coastal area and the coastal perimeter). Finally, it is important to notice that the coastal area has increased and especially in previously anthropized areas. In the spaces where the coastline was artificially altered, the coastal area has increased, but, in the areas where natural processes predominate, a progressive loss was noticed.

Beaches are one of the most important land covers because of tourism activities. Beaches can be both natural and urban spaces and there is a great interest in their conservation. However, despite the actions of regeneration and protection of the beaches, the final trend was the loss of surface (–33.93 ha).

The effects of climate change on sea level must be very carefully analyzed, because other geological processes can affect, not only the rising of sea level. Therefore, a slight rise in sea level would be intuited in rocky platforms, although it cannot be confirmed.

The trend over recent years shows an increment in the urbanized coastal area. This behavior is strongly related to the economic activity. Non-urban spaces tend to have a certain regression. In this work, it has been observed how humans are able to adapt and transform the coast, but special attention must be paid to the beaches as they are very fragile and dynamic places with a high environmental, social and economic value.

Author Contributions

Conceptualization (PML, JNP). Methodology (PML). Software (PML). Validation (PML, JNP). Formal analysis (PML, JNP). Investigation (PML). Resources (PML). Data curation (PML). Writing-original draft preparation (PML, JNP). Writing-review and editing (JNP). Visualization (PML, JNP) Supervision (JNP).

Conflicts of Interest

There is no conflict of interest.

Data Availability Statement

Data supporting the research are freely available from IGN (open source: National Geographic Institute) and the PNOA (open source: National Plan of Aerial Orthophotography, PNOA 2014-2016 CC BY 4.0 www.scne.es).

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