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Tourist Resorts and their Impact on Beach Erosion at Sotavento Beaches, Fuerteventura, Spain

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ABSTRACT

Tourism is the basic industry in Fuerteventura Island (Canary Islands, Spain), mostly due to the sunny conditions and excellent beaches. Probably the best well-known beaches are those located in the southeastern part of Jandía Peninsula, locally named Sotavento Beaches. These beaches are the largest and widest in the whole archipelago, and are up to 15 km long and 800 m wide in some points. Interest has focussed on these beaches not only from the tourism point of view, but also from a geomorphological perspective. Based on beach profile data and aerial photographs from 1963 until 1996 from the central part of these beaches, landward migration of the coastline has been identified. The width reduction of these beaches –to the point that in some areas the beach has completely disappeared- is a consequence of the reduction of sediment supply to the coast from inland sedimentary deposits. This reduction in sediment supply and consequent beach erosion is due to the development of tourism resorts and associated activities, such as road widening, sand mining and gardening along the roads.

ADDITIONALINDEXWORDS: *Aeolian sediment transport, coastline, coastal management, Canary Islands*

INTRODUCTION

Coastal tourism is one of the fastest growing areas within the world's largest industry (HALL, 2001). There are many tourism developments all around the world that have been properly designed, and where the socioeconomic outcomes have allowed the native population to reach and maintain a certain standard of living. Unfortunately there are also many projects, which have originated different kinds of damaging impacts on the coastal zone. These impacts can be grouped into: "visible" impacts, or those derived from the direct anthropogenic use of the coast; and "invisible" impacts, which normally become visible at a longer time scale, when the project has been completely implemented and is being operated.

The former group includes the physical occupation of the coast (both sea and land) by roads, buildings, marinas, harbors, etc, the increase in population (both tourists and workers) and the release of different kind of residuals (garbage, water waste, different pollutants, etc). The invisible impacts include changes in the nearshore hydrodynamics and consequently nearshore depositional patterns, decrease in biodiversity, change of water quality and increased likelihood of property losses and damage. Many examples all around the world have been reported regarding the down-drift erosion created to adjacent beaches due to the implementation of impermeable structures such as protruding jetties or detached breakwaters (FRIHY, 2001); or the sedimentation problems generated in inlets or harbors due to the poor design of an artificial beach nourishment project (XUE, 1999).

Regarding beach erosion, the causes of this problem can be found in a summary of coastal processes, where the most important ones are sediment supply, relative sea-level change, wave energy and shape and location of the beach (PILKEY and THIELER, 1992). The first of these factors is mostly due to the damming of rivers which cut off the major source of sediments for many coastal systems (GRIGGS, 1987; ADDAD and MARTINS-NETO, 2000); to seawalls that avoid the normal supply of sand from eroding bluffs or cliffs; and to the breakwaters, groins and jetties that reduce the normal longshore drift (FRIHY, 2001). Relative sea-level rise is a global problem mostly due to greenhouse effects and the subsequent melting of the Artic and Antarctic ice sheets, as well as many glaciers. Most models predict a eustatic sea-level rise of 0.5 – 2.0 meters above present sea-level by the year 2100 (WHITE, 1990). Nevertheless, this effect may be locally accelerated due to tectonics and subsidence (PENLAND and RAMSEY, 1990).

Waves energy and wave-induced currents are the predominant agents in sediment transport within the coastal zone. It is normally stated that fair-weather waves tend to move sand towards the beach, while storm waves move it offshore, generating what it has been called the bar-type profile (KING, 1972; KOMAR, 1998). Particularly in long-term analyses of shoreline change, the effect of storms should not be excluded although they seem to be temporal outliers from the average (FENSTER *et al*., 2001). Finally, the fourth factor is the shape and location of the beach. The relationships between beach morphology and wave energy have been largely analyzed (e. g. SHORT, 1978; WRIGHT and SHORT, 1984), as well as the influence of tidal range (MASSELINK and SHORT, 1993; MASSELINK and HEGGE, 1995).

This paper deals with both aspects previously considered: the effect of the development of tourism resorts on beach erosion.

Environmental and SocioEconomic Setting

The island of Fuerteventura (Canary Islands) is characterized by a nearly arid climate, due to the proximity to the Sahara desert (≈ 100 Km). In the southern part of the island is the Jandía Peninsula, where three different kinds of environment can be distinguished: the mountains, the aeolian deposits of the isthmus, and the beaches (Figure 1). The Jandía massif includes the higher mountain in the island (PICO DE LA ZARZA, 807 m), which has a great biological significance due to the presence of many endemic organisms, both animals and vegetal, some of them threatened and protected species (CRIADO, 1991).

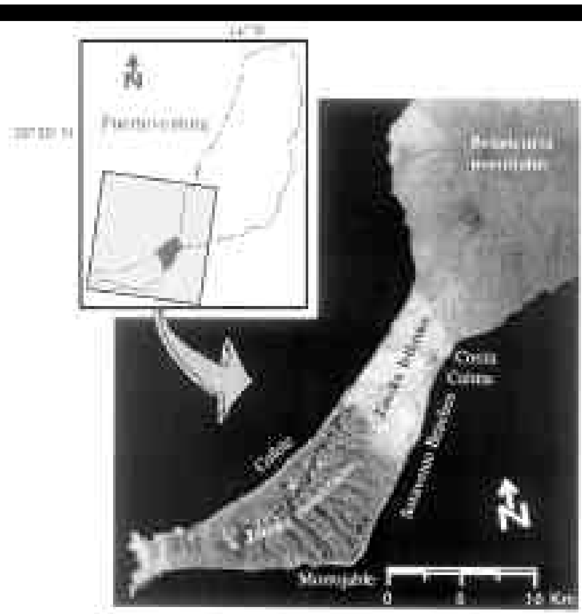

Figure 1. Location map of the Sotavento Beaches, showing the location of the two tourism resorts at the area: Costa Calma and Morrojable.

The isthmus is the widest aeolian sedimentary environment in the Canary Islands and one of the most relevant sites to study the paleoclimatic evolution of the Canaries (ZAZO *et al*., 1993; MECO *et al*., 1997). Apart from this interest, this area has been considered from many different points of view: the landscape evolution of the area was analyzed by ALCÁNTARA-CARRIÓ *et al*. (1996), the characteristics of the sediments by ALONSO *et al*. (1998) and the aeolian dynamics by ALCÁNTARA-CARRIÓ (1999). This is an area of very low relief (average height is 130 m above sea level) located between two mountainous areas: Betancuria and Jandía massifs in the NE and SW respectively. For this reason northerly winds flow through this area with higher velocities than adjacent areas. Most of the surface in the isthmus is composed of loose sediments, particularly medium and fine sands with nearly 88% carbonate content (ALCÁNTARA-CARRIÓ and ALONSO, 2001).

The third significant environment in the Jandía Peninsula is the beaches, which can be found around most of the coast. In the eastern side of the peninsula are located the Sotavento beaches, which constitute the largest beach system in the Canary Islands, extending along more than 15 km along the coast. The system is composed of several beaches of different length and width, separated by small cliffs. This beaches are extremely important for two main reasons: one is for the geomorphologic significance of a sand bar which extends for 3 km at approximately 400 m from the cliffs, which is the only geomorphologic feature of this type in the Canaries. Between the cliff and the bar there is a lagoon mostly composed of muddy sand, which becomes covered during high tides. Water flows in and out through small ephemeral openings created due to wave action, and behave in the same way as inlets in barrier islands. Some times during spring tides water also flows over some sectors of the bar. The second reason is that these beaches are the main resource used by millions of tourists that visit the island during the whole year, and obviously, the erosion of these beaches could force the tourists to move to another destination, with catastrophic effects on the local economy.

HALL (2001) refers to the four "s" of tourism: sun, sand, surf and sex. This is the kind of tourism that exists in Fuerteventura and that has become the base of present economy in the island. This activity has generated a strong modification of the coastal and inland landscape of Fuerteventura to the point that, according to NORDSTROM (1994), should be better named a cultural landscape rather than a natural landscape.

Traditional human uses of Fuerteventura were goat and other livestock farming, fisheries and agriculture. These uses only permitted low levels of economic activity. Tourism is now the most important industry in the island, with nearly 70% of the total population depending directly or indirectly on this activity.

Three seaside tourist resorts are located in the island, and two of them are in Jandía Peninsula: Costa Calma, located at the northern limit of Sotavento Beaches, and Morrojable at the southern limit of the island. Development of hotels and apartments in these resorts began in the 1970s, but it was during the 1990s when the building activity become more intense, and it still continues at present. Los Gorriones Hotel located in the Sotavento beaches was built in 1969-70 and is the oldest one in Jandía Peninsula.

Sediment Dynamics

Previous studies in the area concluded that the source area of the sediments is located inshore in the Upper Pleistocene and Holocene sedimentary deposits covering the present surface of the Jandía Isthmus (MECO, 1981; FERNÁNDEZ, 1990; ALCÁNTARA-CARRIÓ *et al*., 2000a, 2000b). These deposits are continuously eroded by trade winds, which flow from April until September at relatively high velocities, with a daily average of 11 m/s and constant direction from the north. The rest of the year exhibits greater variability both in direction and intensity.

As a result of the arid and windy climate, as well as the grain size and compositional properties of the sediments, overlying material is blown south until it reaches the Sotavento Beaches. Using sand traps ALCÁNTARA-CARRIÓ and ALONSO (2002) concluded that there are two main aeolian paths through which the aeolian flux reaches the coast. One is located in the center of the isthmus and the other one in the southward limit. Once aeolian sand is on the beach, sediments are moved southwards by the predominant southerly longshore drift (COPEIRO, 1995), feeding the whole beach system. Sediments accumulate in the Morrojable area (Figure 1), and probably leave the littoral zone due to the narrow platform in this sector.

Field Techniques and Methods

Different techniques were used to account for the erosion along the beach and the shoreline movement, following Gorman *et al*. (1998). Beach profiles were surveyed every season over a two year period at different locations along Sotavento Beaches. Surveys were carried out by means of an electronic total station (ETS) whose error is below 1 cm in both vertical and horizontal planes. This error is much lower than two other vertical errors in the beach profiles: the error induced by the small irregularities on the beach surface due to footsteps, which has been estimated at 10 cm, and the error that arises through different depths of penetration of the surveying rod. Although the rod holder always tried to minimize this error, it can be estimated up to a maximum of 8 cm. At each profile, the ETS was always placed at the same location by means of a bench mark located in the upper foreshore or on top of the cliff.

Vertical aerial photographs from the central sector of the beach where also used to estimate the shoreline migration rates.

RESULTS

Total computations of beach erosion and shoreline movement, including beach profile data, aerial photography and other data will be found in ALONSO *et al*., (in preparation). Preliminary results from the data set show a clear landward displacement of the sand bar. Figure 2 shows one of the beach profiles, where it can be seen that altitudinal changes in the lagoon are smaller than 15 cm between all the surveys, while the bar crest changes nearly 1 m in height and 60 m in horizontal displacement. It is important to note also the location of the tidal channel, which shifted landwards 62 m in only two years.

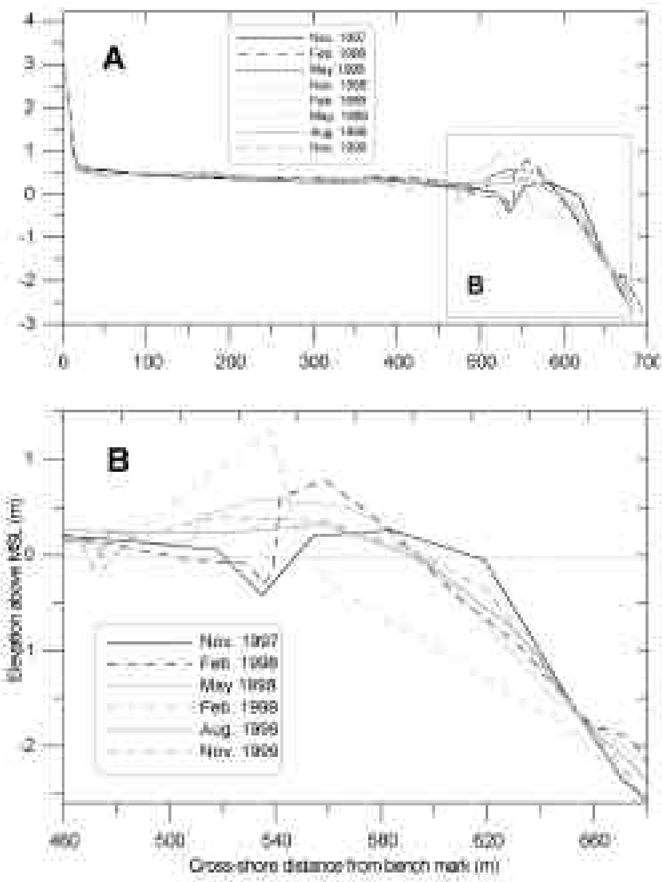

Figure 2. Evolution of beach profile 9, whose position is shown in Figure 4. A) Whole profile, where the lagoon and bar can be well distinguished. B) Enlarged area of the bar section .

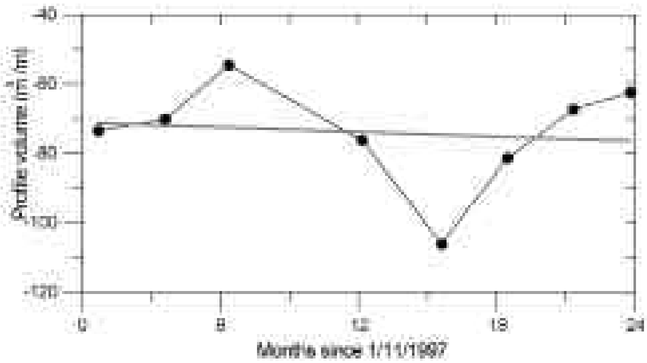

Figure 3. Time series of sand volume per meter of longshore distance at profile 9, including the linear fit of the data.

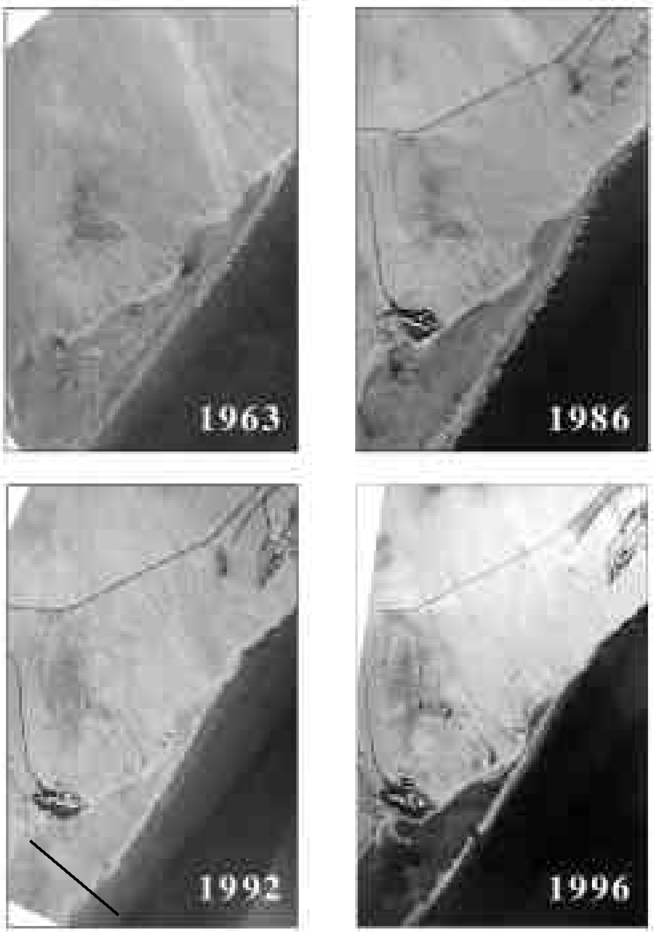

Figure 4. Aerial photographs of the central zone of Sotavento Beach, covering the period 1963-1996. Los Gorriones Hotel is shown in the lower left corner of the photographs, and Costa Calma resorts at the upper right. The line close to the hotel in 1992 photograph represents profile 9, shown in Figure 2.

In addition to morphological changes in beach profiles, the total sand volume per meter was calculated to provide an indicator of net erosion or accretion. To minimize errors collected during the survey across the lagoon, only the bar area shown in Figure 2B was considered. Results in this particular profile (Figure 3) show significant differences between different surveys. The range in bar volume from the highest volume condition (May 1988) to the lowest one (February 1999) is 52 m^3/m, which is comparable to values obtained by DAIL *et al*. (2000) for the whole shoreface of a smaller beach. No seasonal pattern has been found, and the slightly negative slope of the linear fit (Figure 3) denotes net erosion during the study period.

Regarding aerial photographs, Figure 4 shows four stages in the evolution of the central part of the isthmus between 1963 and 1996. Even though these photographs have not been corrected to avoid distortions due to differences in scale and tilting the huge difference between them is clear, not only regarding the development of tourism resorts and roads, but especially regarding the bar displacement.

DISCUSSION

There are different activities and land uses that interfere with the natural aeolian flux. Probably the most widespread is the development of tourism resorts, since these are impermeable structures that completely stop the sand transport through them. A secondary activity is the building and development of roads, which also potentially has a great influence in the aeolian sediment dynamics.

Roads are linear structures which cross the territory. In this particular study case, the main road that connects Morrojable with the rest of the island pass through the whole isthmus. In some areas sand overpasses the road, so that the sedimentary flux can reach the beaches, but in some other areas the road is 1-2 m above the surface, and in these cases it represents a very large obstacle for the sediment transport (Figure 5).

Figure 5. The road is an obstacle to sand transport although in same places sand overpasses it. Sediment transport is from right to left.

Landscape evolution is also influenced by the creation of many sand extracting areas all around the island, and particularly at the Jandía Isthmus (Alcántara-Carrió *et al.*, 1996). This activity is very closely related to the development of resorts, since sand is the basic raw material for construction. The more intense the extractive activity, the lower the amount of available sediment to be blown.

Analysis of 1996 aerial photographs (Figure 4) shows a different land use at Costa Calma resorts, which consists of planting of forest-like gardens along the roads. This gardens, designed to enhance the landscape decelerate the wind velocity and consequently, interrupt the aeolian sand transport across the isthmus from the inland arid zones towards the coast.

The result of all these activities is a considerable decrease in sedimentary inputs to the coast. It is reasonable to assume that previously to the development of any building, road, sand extraction and planting, the beaches were in sedimentary equilibrium (photograph of 1963 in Figure 4). Since the longshore drift has not been interrupted, it means that outputs have not changed and, therefore, the sedimentary budget shows a deficit.

This sedimentary deficit has resulted in the landward displacement of the longshore bar, which migrated landwards and southwards, to the point that in some areas the beach has completely disappeared (Figure 4). One of the most evident zones where this migration is taking place is a small beach located in between Los Gorriones Hotel and Costa Calma resort named La Barca beach. This is the area where the bar begins at present, though in 1963 it was more than 500 m northwards. Figure 6 shows two different images of this beach taken from a similar position in February 1998 and February 2001. The landward migration of the bar can be observed over this three year period. An example of erosion is shown in Figure 7, which shows the severe retreat of the shoreline due to the beach and dune erosion in this area.

Figure 6. Pictures of La Barca beach, taken in February 1998 and February 2001. Apart from differences in tidal height, note that the bar that extends parallel to the shoreline has migrated landwards.

Figure 7. Beach and dune erosion at the northern margin of La Barca beach adjacent to a rock headland.

The landward migration of the tidal channel shown in Figure 2, can only be explained from the perspective of the onshore displacement of the bar, which is due to the general erosive situation at the Sotavento Beaches.

RECOMMENDATIONS

Four main causes of the decrease in sediment supply to the beaches are identified: building of tourism resorts, roads, extracting activities and gardening on the roadsides. All them are the consequence of deficient spatial planning, since the resorts, extractions and gardens could be planned in areas where the aeolian flux is negligible, and a different design of the roads could improve the natural sand by-passing. Several other authors have also reached similar conclusions in different parts of the world (Cravidao and Cunha, 1996; Lizarraga-Arciniega *et al*., 2001). To prevent beach erosion appropriate management of the coastal area should be carried out. Managers should consider the point of view of both the local and regional administrations, but also those who know how the natural system works.

Unfortunately this is not the case in Fuerteventura, since in the particular case of Sotavento beaches, the local government has recently approved a new tourism resort consisting of 2,500 new beds at La Barca beach, just in the area where a small amount of sediments still reaches the beach. By the time the resort has been completed, the beach may have disappeared.

CONCLUSIONS

Using data from beach profiles and aerial photographs, it has been shown that Sotavento Beaches, located at the southern part of the island of Fuerteventura, are suffering severe erosion. This erosion is a consequence of the reduction of sediment supply to the coast from the sedimentary inland deposits located in the inner part of the Jandía Isthmus, and the predominant reason is the development of tourism resorts and associated activities, such as road widening, sand mining and gardening along the roads.

Tourism is the basic industry in the island, and the kind of tourists are those who like sunshine and beaches. The erosion at Sotavento Beaches, the largest and widest ones in the whole archipelago could endanger the tourism industry, to the point that tour operators may eventually refuse to send tourists to the resorts if the beaches have disappeared.

LITERATURE CITED

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