Socio Economic Impacts of the Guadiana jetty

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Abstract: *The importance of beaches to the tourism industry and the need to protect such resources is not only vital to the economy of nations but for many localities and regions. Coastal erosion is the major reason of disappearance of beaches. As a result, it requires application of a series of engineering techniques. Therefore, hard and soft engineering solutions are used for the shore protection and utilization through recreational purposes. The Guadiana shore protection jetty Protugal and Spain border represents a good example of such a problem. After the jetty was constructed, the west of the river mouth, experienced a continuous trend of accretion, while the down drift sectors were subjected to severe erosion. This jetty is a source of environmental problems and creates long term economic impacts in positive and negative ways to the surrounding coast-line. The present study showed that, the Portuguese side has gained more economic and social benefits, and conversely, the Spanish side has lost their economic income and land due to the jetty construction.*

Keywords: *Guadiana, jetty, erosion, economic impact.*

1. INTRODUCTION

Beaches are scarce resources stretching between the coast and the land. However, 95% of the world beaches are eroding due to human activities and moving dynamics (Pranzini & Rossi, 1995). Beach erosion is a common and expected event. Natural shoreline erosion is not a threat to the coast or to the beach. Erosion and longshore sediment transport are, in fact, an integral part of long term coastal evolution and an important aspect of the dynamic system. Coastal erosion does not necessarily mean the beach is disappearing; it is simply changing its location. The sandy beach exists in a balance between sand supply, beach shape, wave energy and sea-level rise. Most construction on or near the shoreline, changes this balance and reduces the natural flexibility of the beach.

The engineering structures are constructed to protect properties, increase accessibility to transport and improve the economy. These structures cause indirect long term impacts on coastline. A jetty is a coastal engineering structures extending from a shore into a body of water and is usually constructed for several purposes. One of the main reasons is to stabilize one or both sides of the inlet from shifting its position. Jetties also prevent large volumes of sediment from filling in the inlet by permitting its continued navigation (Davis and FitzGerald, 2004; Schwartz, 2005).

Downstream erosion of jetty usually results in need of extend structures to protect greater lengths of the shoreline (Phillips & Jones, 2006). Therefore, alternative soft engineering techniques are used conjunction with natural coastal processes. These included the construction of submerged jetties that reduced the effective offshore depth, and consequently reduced the wave power and erosion of the beach (Aminti et al., 2002). The Beach nourishment method is another soft engineering solution. The new, wider beach, serves shore protection from the impacts of storms and increases recreational benefits with new tourism related opportunities (Benassai et al., 2001).

In addition, the SPICOSA project is mainly focused on the support and implementation of a framework for sustainable development in the area of Coastal Zone Management within the European regions (SPICOSA, 2009). Further, SPICOSA considers the need for better integration of scientific knowledge in the implementation of local developmental policies, while balance of ecological, economic and social considerations at an appropriate level (SPICOSA, 2009). Therefore, under this project, different types of case studies were selected throughout the European directive. The Guadiana Estuary is one of the Study Site Applications (SSA) used to describe the System Approach Framework (SAF). To develop adaptable SAF within the Guadiana estuary, the policy issues were identified. River discharge reduction due to dams, coastal erosion on the Spanish beaches, sediment infilling of tidal creeks and channels on salt marshes and substitution of fine sediment stock with sand intrusion over tidal plans are some of the issues which need to be discussed under the SPICOSA project. Therefore, studies on the behaviour of sediment along the Guadiana coast and effects to social, economic and ecological aspects are of great importance in the development of SSA.

The economic impacts of the Guadiana jetty is related with erosion and land accretion beside the jetty along the beach. The behavior of the land area is well documented before and after jetty construction (e.g. Gonzalez et al., 2001a; 2001b). However, the area of sand accumulated after the construction of a jetty is poorly understood and assessment have been inconclusive. Thus studying the accumulated area of sand gives an idea of the amount of sand accreted within a year (yearly behavior) and can be identify the specific locations of sand accumulation. At the same time, the SPICOSA project aims to discuss the sediment starvation of the Guadiana estuary in theoretical and practical ways. Although the Spanish side of Isla Canela beach is highly eroded due to long shore sediment transport (Dias et al., 2004), the accreted sand area in Portuguese side is an asset to Portugal for economic development. However the long term economic impact of Guadiana jetty due to erosion in Spain Isla Canela beach and accreted sand in Portugal are poorly documented. Therefore, it is important to identify the relationships between the cost of erosion and the cost of accretion in the Guadiana jetty. Thus, primary objective of present research was to assess the long term economic impacts due to jetty construction.

Furthermore, this study provides a precise case study for the economic impacts of hard and soft engineering coastal structures. In the evaluation of the economic impacts of the Guadiana jetty, tourist and property values were considered as main criteria. In here, natural intervention of storms, sea level increases and coastal floods were not considered to describe the economic impacts. Understanding of spatial distribution of pressures that cause erosion along given coastline will useful to identify locations that need mitigating measures for erosion control. Moreover, it is important to understand the present situation, tourist attractions and land use types of the neighboring coastlines of Guadiana jetty for successful future development plans.

2. STUDY AREA

The Guadiana River is a trans-boundary river where the national border of Portugal and Spain runs the last 200 km of the river course. The Guadiana estuary mouth alters sand migration paths across the main estuarine channel and inhibits the obstruction of (international) shipping ways. Therefore, the jetty was built in 1972-1974 (Dias, 1988) in the Guadiana estuary to protect the channel entrance. This jetty belongs to Portugal which is 2040 m in length (Gonzalez et al., 2001). The geographical coordinates on the Portuguese margin of the jetty are 37º10’ N and 7º24’E (SPICOSA, 2009). Further, there is a 300 m long groyne in Portuguese side, 1.7 km west (Figure 1) of the jetty to prevent a quick infilling of the adjacent western border of the jetty (Dias, 1988). The Portuguese side of the adjacent coastline comprises two administrative divisions, namely, Monte Gordo and Vila Real de Santo Antonio. The coastal stretch in the Spanish side is a part of Ayamonte municipality which is involves two administrative boundaries, called, Isla Canela and Isla del Moral. Figure 1 shows the satellite image of the area (Year 2000) and administrative boundaries (Municipal) of both countries. In addition, the administrative map shows the main urbanized areas belongs to both countries.

The Guadiana river mouth beach is sandy, which is typical of wave dominated environments. The mouth of the Guadiana estuary is a highly dynamic area, with considerable movement of sediments and associated morphological changes (Morales, 1997; Gonzalez et al., 2001: Lobo et al., 2004). The Guadiana estuary has a semidiurnal mesotidal system, with a mean tidal range of 2.0 m, ranging between maximum values of 3.8 m and a minimum of 0.5 m (Instituto Hidrogra´fico, 1998). The wave regime is characterized by waves of low to medium energy, including both Atlantic swell waves and local sea waves (Morales, 1997; Morales et al., 2006).

Figure 1 Boundary of the Study Area

The offshore coastal wave regime is primarily dominated from west and south west (approximately 50% of occurrences) and south east waves have a significant influence on the beach (with 25% of occurrences) (Costa, 1994; Gonzalez et al., 2001). Therefore, the net annual littoral drift is from west to east (Gonzalez et al., 2001; Morales et al., 2006). Furthermore, due to the jetty, there are modified sediment dynamics within the delta and as a result, there have been considerable changes in its morphology (Morales, 1997). The delta front is made up of several barrier islands such as Isla Canela and Isla del Moral. Also transverse growth of the Monte Gordo Beach spit has occurred on the Portuguese side. The Monte Gordo beach is located along the Portugal coast. However, at present the Guadiana River basin has been under growing pressure from anthropogenic activities such as tourism, agriculture, industry, dam construction and urban pressure (Morales et al., 2006). The Alqueva dam which built in 2002, along the Guadiana River is a risk to the downstream ecosystems, mainly to the estuary and adjacent coastal areas (Morais, 2008). Similarly, the Spanish coast of the Guadiana River mouth has anthropogenic influences due to the tourism industries such as the Isla Canela Tourist Resort and Isla del Moral Tourist Resort village. All of these activities are main considerations in addressing the long term economic impacts of Guadiana jetty.

3. METHODS AND DATA ANALYSIS

This study focused mainly to find economic impacts. Evolution of the area of the Guadiana Estuary mouth was studied mainly by using the available aerial photographs and field investigations. However, in order to apply the selected method, the study area was divided into two different parts: namely the Portuguese side and Spanish side. To describe the economic impacts, Portuguese and Spanish margins were used. The Guadiana jetty, western side of the study area was in between the Portuguese jetty and groyne structure, eastern side study of the area was in between Punta de la Espada to end of Isla del Moral beach.

The available projected aerial photographs (which were done for the Megasig project) were used for this research. All the aerial photographs were scanned and were geo-referenced by using a series of geographic tie points. The projection Datum was Intern_1924_Transverse_Mercator_Megasig. The available aerial photographs are: 1977, 1980, 1985, 1986, 1991, 1994, 1996, 1998, 2002 and 2005. The scale of the photographs varies between 1:8000, and 1:30000. Study area boundaries were demarcated by inspecting the coverage of available aerial photographs.

Areas were drawn using ArcVeiw GIS 3.3 software and ArcVeiw GIS 9.1 software. A series of geomorphologic elements were identified and mapped on all photographs. The criteria for distinction of the areas were drawn by shape, shade of grey (or colour when available) texture and context. The selected boundary of the study area was equal in all aerial photographs. Every map should represent the same geographical boundary when describing the morphological variation. According to this, areas were sketched to all the available aerial photographs. The areas that were drawn on the Portuguese and Spanish side were used to describe the land area change and to evaluate the economic impacts. Furthermore, the area was found in km^2 by using the ArcVeiw GIS 3.3 software.

Moreover, key morphologic and anthropogenic elements were identified during field visits. The aim of the field visit is to explain the present situation and to inspect the economic impacts due to the jetty construction along the Spanish and Portuguese study area. In Spain coast socio-economic changes and locations of beach erosion were inspected from Punta de la Espada to the end of Isla del Moral jetty. On the Portuguese coast field investigation was carried out from the jetty to the groyne structure to inspect sedimentation and the impact of tourists to the beach. Photographs were taken, while walking along the coastline to describe the important features of the coastline. Major economic developments that occurred during the past years in the study area were identified during the field investigations evaluated the economic impacts of these developments. Evaluation of economic impact was limited to the "physical carrying capacity," which is the number of individuals a beach can physically accommodate. Also, to calculate the economic impacts, cost of the sand on each side was valued by using the cost of sand nourishment and volume of eroded and accreted sand. Furthermore, the impacts to the tourism's income were calculated by valuing the land area and required land area per tourist.

4. RESULTS AND DISCUSSION

During the field visits, it was identified that the beach section between Punta de la Espada and Isla Canela was subjected to severe erosion (Figure 2). It was clearly found that severe erosion had occurred in the Guadiana river mouth.

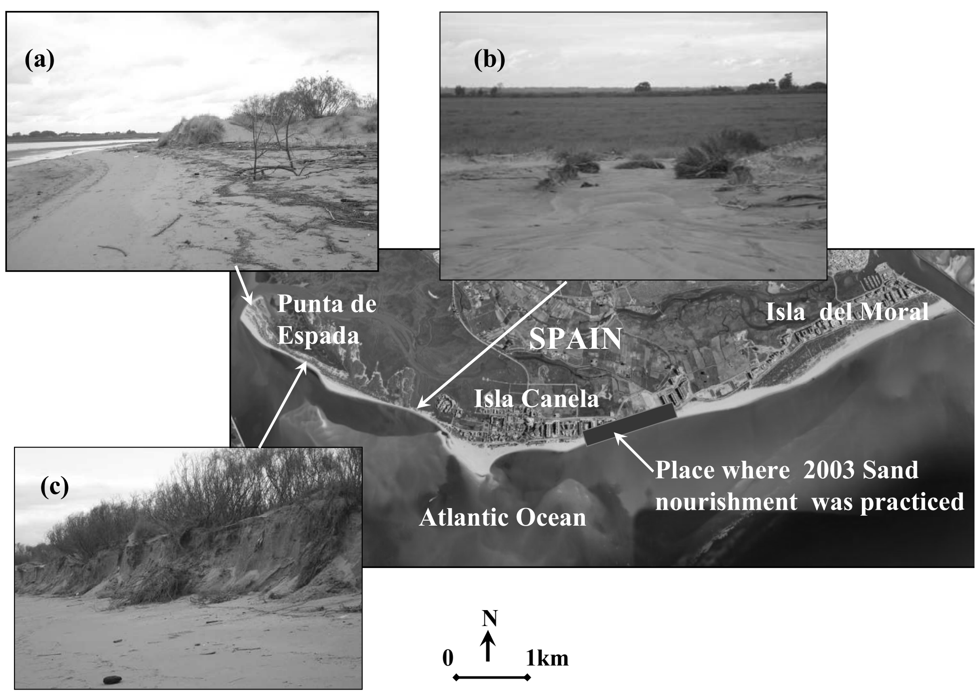

Figure 2 Observed eroded places in Spanish Margin during the field investigation

Also, at the end of the Isla Canela beach, this erosion is severe. Because the jetty is placed perpendicularly to the shoreline and that traps sand on the updrift side by extending out into the water and interrupting the littoral drift, this causes deposition of sand. However, after the water column loses its suspended sand load, its velocity increases. As a result, this causes it to trap around the jetty and pull more sand away from the down-drift side, resulting in downdrift beach erosion. Therefore, with high velocity, waves erode downdrift of the Spanish beach and carried more sediment away from the beach. The end of Isla Canela beach directly contact to the longshore current paths. Consequently, high velocity longshore currents bring more sand away from the Isla Canela beach and caused severe erosion.

In 2003, sand nourishment took place along the Spanish side which is shown in Figure 2. For the artificial nourishment 414 000 m^3 of sand was used with a cost of 2.5 Million Euros (Institute of Hydrographic, Spain). This took place at the end of Isla Canela tourist village. By analyzing the 2005 aerial photographs, it can be clearly identified that, the place, where sand nourishment was practiced is widen. Consequently, it can be said that five years after sand nourishment, beach become wider. On the other hand, the Western end of artificial sand nourished area now (year 2010) has a much wider beach section as found in field visits.

Further, from field investigations it was found that new sediment spits developed in front of the Spanish coast as shown in Figure 3. Also, inlets are sinks of sediment in which ebb and flood shoals are formed. These ebb and flood shoals are supplied predominately by longshore sediment transport. Thus, the construction of a jetty at an inlet will alter the tidal currents; disturb the longshore transport and cause formation of new ebb and flood shoals. Therefore, the jetty construction at an existing inlet will confine the ebb-tidal current and push the ebb shoal offshore from its original location. Also, part of the longshore littoral drifts pass to sea and deposit in the bottom. This ebb shoals migrates onshore and give the appearance of accretion by longshore transport on the down-drift side of the inlet. This will be continuing until the disappearance of the previous portion of the ebb shoal and removing the sand source. The down-drift and, possibly, up-drift beaches will then begin to erode. However, these sediment pathways for natural bypassing depend on wave conditions particularly between typical seas (Militello and Kraus, 2003). However, the Guadiana jetty is long relative to surf zone, therefore, pushing the ebb shoal to outside the active littoral zone.

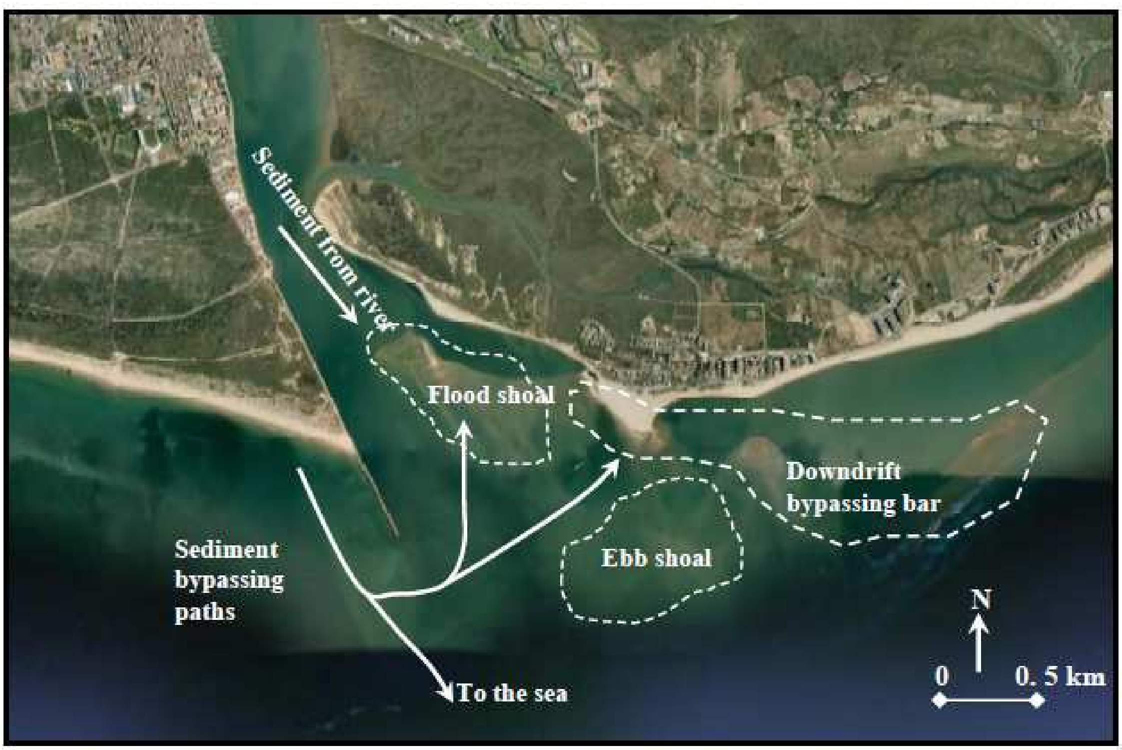

Figure 3 Sediment behaviour of Guadiana river mouth

Therefore, these new ebb shoal bars or O Brill bank is migrating to the Spanish downdrift side. Finally, at present it can be seen that the new sand spits occur in the eastern estuary margin. Further, ebb shoals and particularly flood shoals offer a good source of material for the beach nourishment (Militello and Kraus, 2001).

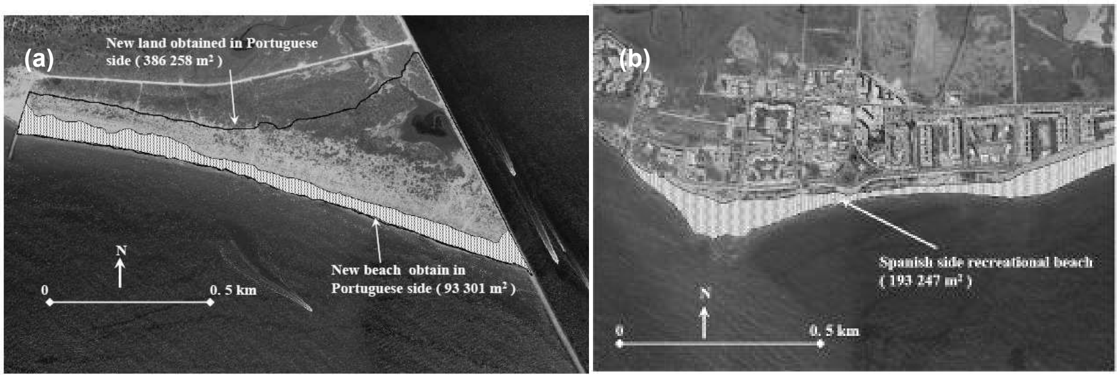

Figure 4 Area use for the beach recreational activities in year 2005
(a) Portuguese Beach, (b) Spanish Beach

After analysing the aerial photographs, it was identified that, the western estuary margin has an accreted sand area of 386 258 m^2 after the construction of the jetty between 1977 and 2005. Out of that new land area, a portion of 93 301 m^2 belongs to the Portuguese beach (Figure 4(a)). This new beach can be used for tourism purposes. At presen,t without proper facilities, this new beach is being used for the tourism industry. On the other hand, loss of land in the Spanish side due to the erosion from 1977 to 2005 (boundary is Punta de la Espada to End of Isla Canela beach) is 245 462 m^2. However, 193 247 m^2 area is used for beach recreational purposes in front of the Isla Canela beach in year 2005 (Figure 4(a)). For recreational purpose, one tourist needs 10 m^2 of surface area without overcrowding the beach (Da Silva et al., 2007). Therefore, as a result of accretion, 9 330 tourists can use the Portuguese beach and because of erosion, the Spanish beach loss 24 546 tourists.

Table 1 Tourist economic income gain in Spanish and Portuguese sectors

(Negative value represents the loss of income)

Study Site Location	Recreational beach Land Area (m^2)	Required land area per tourist (m^2/person)	Number of Tourists	Tourist Income (Euro/Person)	Total income (Euro in millions)
Portuguese	93 301	10	9 330	500	4.6
Spanish	193 247	10	19 325	500	- 9.6

Furthermore, it was estimated that approximately 500 Euros income can be gained from each person (Institute of Tourism Spain 2001 statistics). According to the Table 1, it can be seen that the Portuguese economy gains nearly 4.6 million Euros and the Spanish the economy loses 9.6 million Euros within a year. One can clearly identified that nearly double of the Portuguese income is loss by the Spanish government due to the beach erosion. Tourism income directly and indirectly impacts economic growth, jobs, and foreign exchange. The Portuguese's economy has ability to utilize a totally new beach area for tourism purposes. On the other hand, the Spanish economy lost 9.6 million of income including direct and indirect jobs, foreign exchange, hotels, property, services and goods.

5. CONCLUSION

Addressing economic and social impacts of Guadiana's river mouth is a vital issue at present, due to the long term impacts experienced by both bordering countries of Portugal and Spain. According to the present research, it was found that the Portuguese gained new income due to the jetty construction while at the same time the Spanish economy lost double that of the Portuguese side's income. Therefore, protecting the Spanish recreational beaches from further erosion is a highly important aspect to the Spanish economy. On the other hand, according to the above results, total area of Spanish beach increases after sand nourishment. Hence, as a solution for future erosion, sand nourishment can be applied on the Spanish eroded beach especially end of the Isla Canela beach. The Spanish side's newly obtained ebb shoal sand volume is a significant economic gain. Sediments in ebb shoal sand are same sizes that are present in Spanish beach. Thus, sand in ebb shoal can be used for the sand nourishment on the Spanish beach. This will reduce the cost of sand transport for the sand nourishment project and reduce the erosion. Even though, sand nourishment is a costly process, in the long term nourished land area contributes to a reduction in the effects of the Spanish economy due to beach erosion. Thus management of sediment deprivation and related coastal erosion problems along the Guadiana jetties should provide long term benefits to Spain and Portugal. Moreover, the SPICOSA project is currently seeking to identify the present situation and involve in finding a long term coastal zone management system and alternative implementation. Thus, present research is part of the SPICOSA project, which has been primarily focused to address the economic impacts and the processes of sedimentary behavior after the construction of Guadiana jetty.

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