

IMPACT OF THE URBANIZATION ON COASTAL DUNE: CASE OF KHARROUBA, WEST OF ALGERIA

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Abstract

Despite the coming into force of the Algerian Littoral Law 02/2002, which aimed the protection of the coast and a sustainable use of its resources, construction projects have been authorized on brittle unstable lithology. Relating to this, Kharrouba experienced a tremendous change during the period 2004-2012 due to a massive urbanization. Accordingly, expert's reports concerning the sustainability of construction projects as required by the Law 01-03-2003, were not sufficient. In this work, we analyzed the morphological coastal transformation of Kharrouba between 1989 and 2016 with particular interest in the decline of the dune due to a strong urban growth. For this purpose, a topographic map and Google Earth Pro pictures were used and processed in a geographical information system (SIG). The results of the diachronic analysis and the evolution of the coastal dune showed that the dune surface increased 23.82 % between 1989 and 2004; a period marked by a low construction activity. On the other hand, the surface of the dune regressed 59.67% during the period 2004-2012 that

coincided with a major flat construction for the local population and secondary for the tourism. In addition to the environmental impact, the degradation of the dune led to more erosion, sediment balance disturbance of the beach, and coastal risk susceptibility. Moreover, the study area already experienced two landslides between 2012 and 2014 with negative socioeconomic consequences. A sustainable development of the coastal zone in Kharrouba and the province of Mostaganem should consider the environment and its protection as inevitable conditions for long-term economic activities. Therefore, the stakeholder of this region should comply with the existing laws regarding the preservation of the dune and the respect of the legally fixed distance between the coastline and a planned construction project.

Keywords: Algeria. Coast. Dune. Impact. Urbanization. SIG.

1. Introduction

Coastal areas present a complex geomorphology, which is constituted by rocky and sandy features. According to Kim et al. (2009) and Martínez et al. (2013) marine and atmospheric forces influence the morphology of the beach and the fore dune. The littoral dune, being the extreme seaward edge of all terrestrial existence, plays a key role in the protection of the near land against the storm (Jenks, 2014; Muller et al., 2016); it is as well a reserve of sediment for the beach nourishment.

Coastal dune around the world undergoes many morphological changes as a consequence of anthropogenic pressure. Many authors report that sand

loss, construction of harbors for commercial purposes and touristic infrastructure seem to be the most important disturbing factors (Williams et al., 2001; Scarelli et al., 2017; Duffy et al., 2018;), which led to the decline of coastal dunes (Paskoff, 1994; Ghodbani, 2005).

In Algeria, 2/3 of the population is concentrated at the coast, which represents 5% of the country area (Bouroumi, 2014). From the seventies, this country knew a significant built-up development, especially in Algiers, Oran and Annaba cities, where the sandy coastal features have been transformed massively by the construction. Consequently, the Algerian legislation introduced the Littoral Law 02/2002 aiming to protect and to assess the

coast as a natural resource (Ghodhani and Berrahi-Midoun, 2013; Taibi, 2016).

The present study is focused on Mostaganem, located in the north-western of Algeria. Due to the urbanization, tourism activities, and an excessive sand extraction for the construction, this area experienced a beach regression and disturbance in its sediment budget. The monitoring of the dune changes is an important task in order to understand the evolution of the coastal zone, its management, the loss of biodiversity and hazard assessment (Andrews et al., 2002; Falcucci et al., 2007).

This work aims to identify, and to quantify morphological changes of the coastal features in Kharrouba between 1987 and 2016. For this task, the applied methodology is based on the integration of geographical techniques such as the integration of historical cartographic documents treated and analyzed in a geographic information system (GIS). Last one is a powerful tool used as a monitoring of the spatiotemporal

evolution of land use/land cover, landslide hazard assessment (Abdikan et al., 2016).

2. Material and Methods

2.1. Study area

This study was focused on the coast of Kharrouba, an agglomeration located in the province of Mostaganem, in the northwest of Algeria (Fig. 1). Accordingly, its morphology comprised cliffs, beaches, and extended dune that represents a significant landscape feature. Geologically, Kharrouba showed two distinct formations, Upper Cretaceous rocky cliffs in the northeast and quaternary sandy beaches, dune and alluvium in the southwest. The coastal area is built by mobile dune close to the beach and consolidated dune (Paleo dune) in the supra littoral zone.

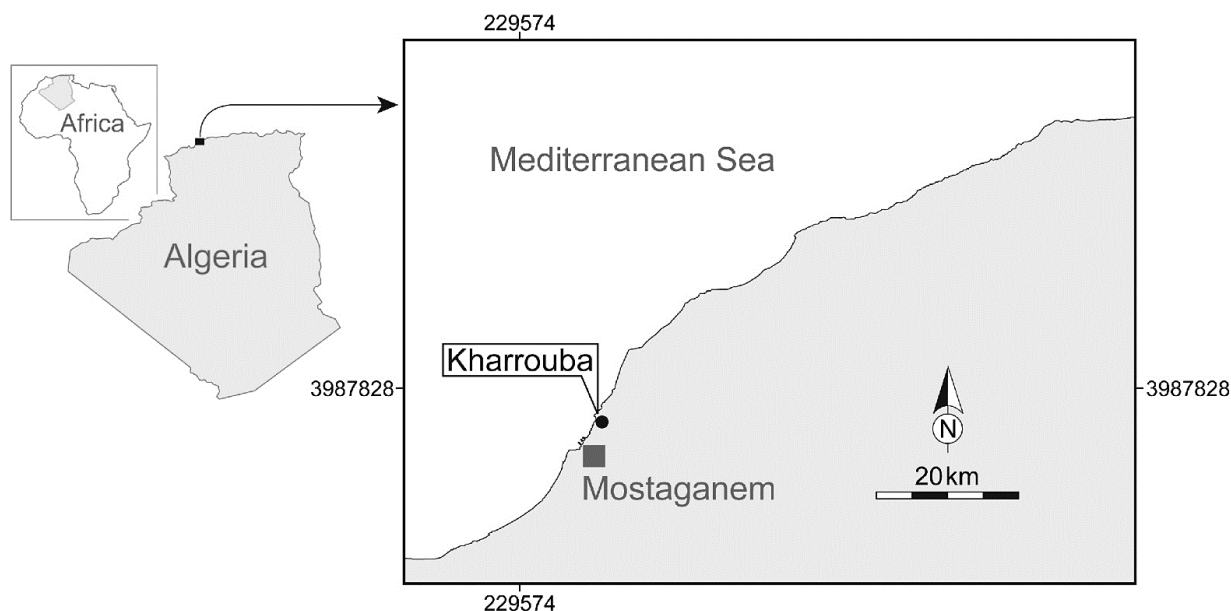


Fig. 1. Geographical setting of the study area.

2.2. Methodology

Different data and methods as historical maps, aerial photographs, satellite data processing, unmanned aerial vehicle (UAV), airborne Photogrammetry, GPS, DGPS and field survey are useful tools to identify different transformations that occurred in the coastal area (Faye Ibrahima et al., 2008; Cohen et al., 2018). Kaliraj et al. (2017) used remote sensing and GIS techniques in order to monitor the different changes in the coast of Kanyakumari/India. Chaibi et al. (2013) identified changes in the littoral of El Djadida (Morocco) by means of aerial photography. Antso et al. (2013) used topographic map and field works to identify different pressures at coastal zones in Estonia. The present study

aimed to identify and to quantify the evolution of the coastal dune of Kharrouba using Geographical Information system techniques (GIS). Generally, coastal dune changes frequently its shape because it is vulnerable to wind, wave and storms (Andrews et al., 2002). For this reason, we based on the vegetal cover as an indicator in order to delineate the coastal dune morphology and limit.

For this task, we used a 1/25000-scaled topographic map and images extracted from Google Earth Pro related to the periods 2004, 2012 and 2016. Cartographic data have been geometrically corrected and digitized; the area of the affected coastal features has been calculated using a GIS. Furthermore, the evolution of the dune and the consequences of the urbanization have been analyzed and mapped. In order to characterize the different surveyed

dunes and its vegetal cover, we used the Corine Land Cover nomenclature, which is a computerized inventory to describe a land cover at a scale of 1/100000 and using 44 classes (Bossard et al., 2000; Feranec et al., 2007; Samaali, 2011). This nomenclature is structured in 3 levels regarding the resolution and this study goal (Acosta et al., 2005). The landslide event occurred in 2012 in Kharrouba has been analyzed using the report provided by the Directory of public works located in Mostaganem (DPW, 2012).

3. Results

The cartographic and GIS data on the spatiotemporal evolution of the coastal dune in Kharrouba let distinguish

changes in the Paleo dune and the recent dune during the period 1989-2004, and drastic transformation between 2004 and 2012 (Fig. 2). The high demand on residential habitations for the local population led to massive construction among the dune or close to it twelve years long (2004-2016, Fig. 3). Consequently, the coastal environment experienced a considerable transformation, impacting the natural features formed by the recent dune and the consolidated dune (Paleo dune, Fig. 4). Whereas, the changes related to the built-up development occurred between 1989 and 2004 are minor than those registered in the period 2004-2012. The lost or gain resulting from the changes of the features is given in comparison to the total area of Kharrouba (Tables 1-3).

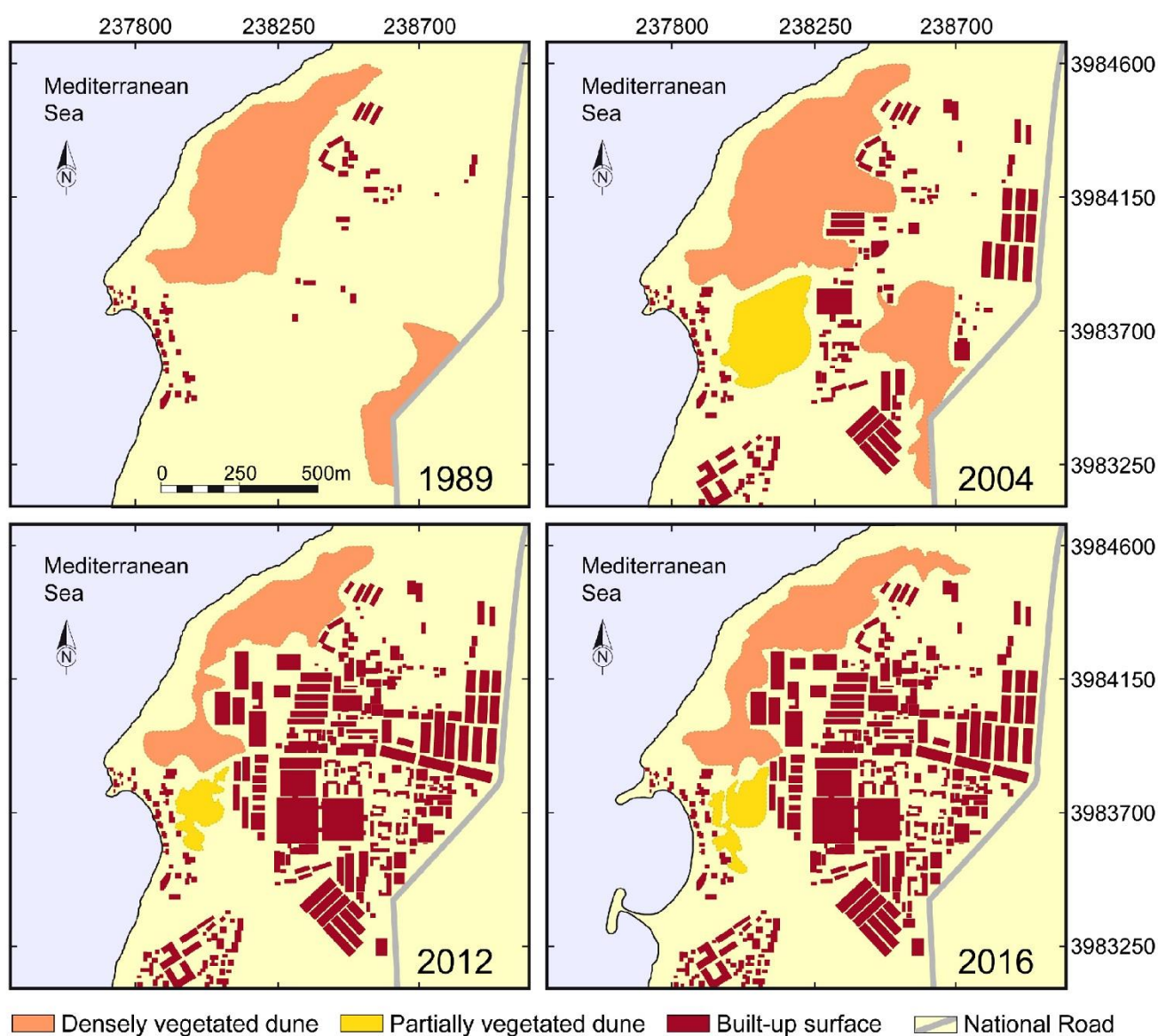


Fig. 2. Land cover changes in the coast of Kharrouba during the period 1989-2016.

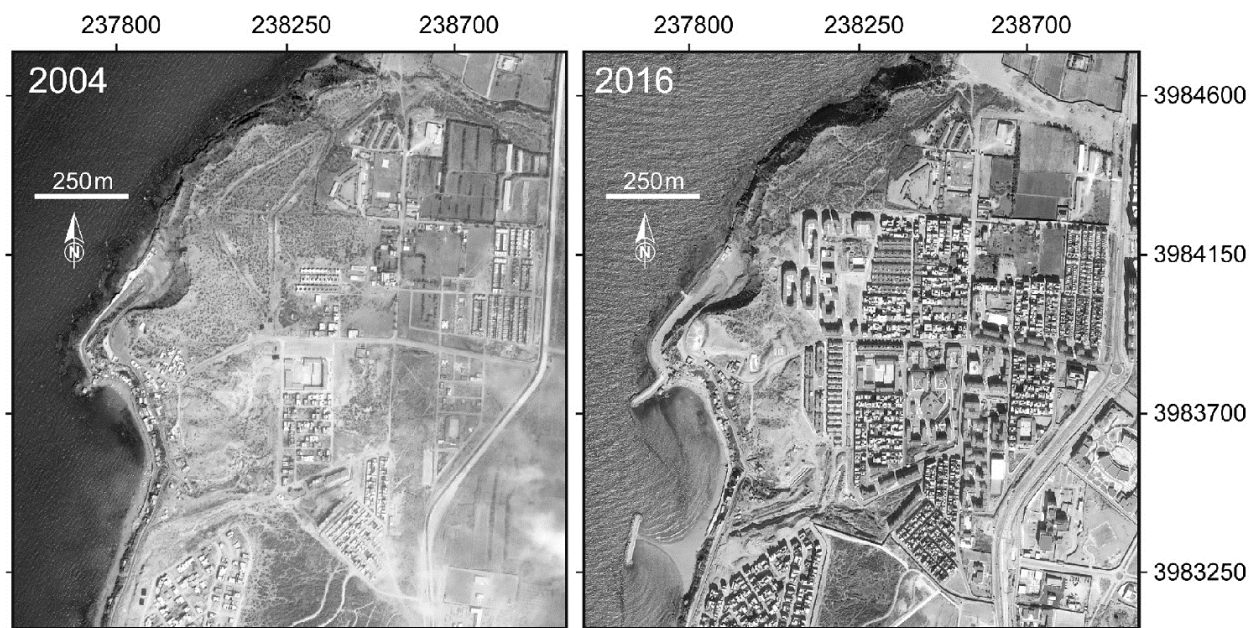


Fig. 3. Land cover changes in Kharrouba during the period 2004-2016 (Google Earth 2018).

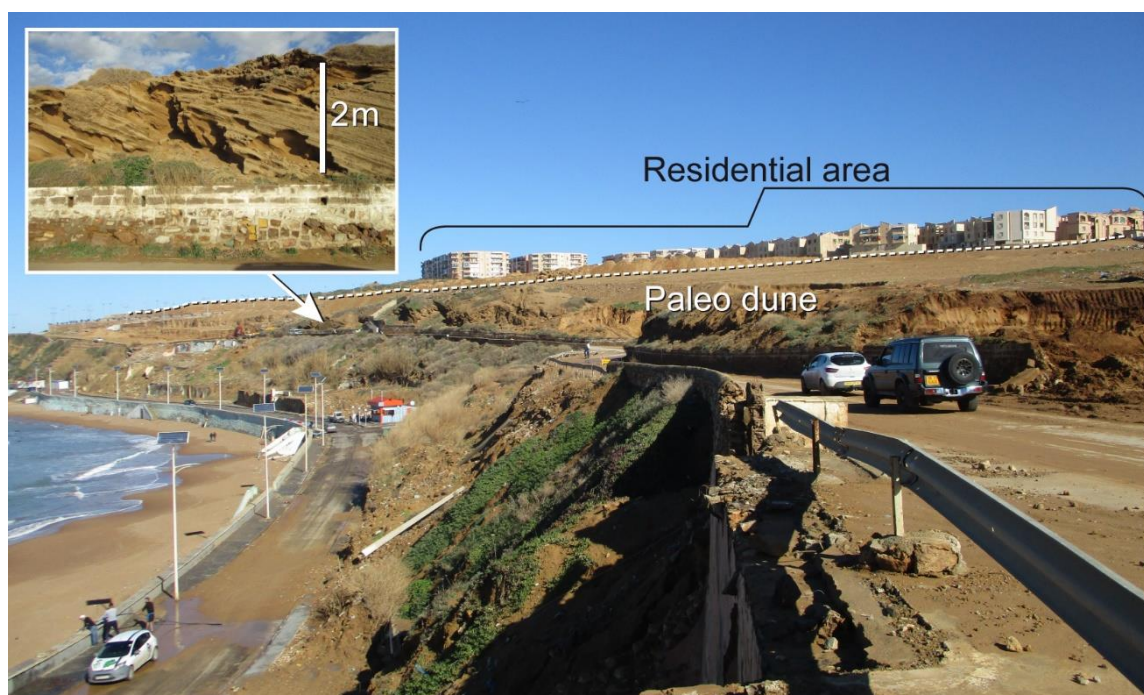


Fig. 4. Kharrouba is formed mainly by Paleo dune (NE-oriented photograph).

3.1. Period 1989 - 2004

The field survey showed that the sandy coast of Kharrouba is mainly occupied by recent dunes. Accordingly, this class presented a sporadic vegetal cover, which contributed to its identification.

Historically, the morphological situation in 1989 of the dunes had not been reported on the available topographic

maps at that time. As an alternative, we used, a corresponding image extracted from Google Earth Pro.

During the period 1989-2004, the coast of Kharrouba enrolled a change in favor to the growth of densely vegetated dune. This feature represented 16 % of the total area in 1989 and went up to 23.8 % in 2004. The drastic change was registered in the built-up area, which increased 71.3 % between 1989 and 2004 (Table 1).

3.2. Period 2004-2012

During the period 2004-2012, the coast of Kharrouba experienced a crucial transformation that led to the urbanization of 32 % of the total area as a response to the high demand for residential flats, stores and tourism structures. The coastal patterns underwent a significant alteration in this period despite the existing Littoral Law 02/2002, which aimed to protect the coastal natural resources.

In 2004, the surface loss of the densely vegetated dune was 60 % in ratio to the total study area. In the same period, partially vegetated dune suffered as well the construction activities; this class decreased about 67.4 % of the total area (Fig. 5). Consequently, the built-up area increased 216.9 % compared to its initial surface (Table 2).

3.3. Period 2012-2016

This period showed an irrelevant transformation because 2.2 % of the total area of Kharrouba experienced changes. Accordingly, densely vegetated dunes increased 8.6 %; partially vegetated dune registered a gain of 23.9 %, and the built-up area 4.7 % (Table 3); both classes of dune increased together 32.5 % in ratio to the initial dune area. According to the field surveys, the situation of Kharrouba reflected the application of the

Littoral Law 02/2002 and the awareness of the local authorities regarding the environmental impact of the urbanization on the society.

4. Discussion

4.1. Morphologic changes caused by the urbanization

The morphologic and environmental changes occurred in Kharrouba as a result of an intense urbanization forced by a rapid growing population are not an isolated case.

Accordingly, Ghodbani (2009) reported a comparable issue that occurred in mean coastal cities of Algeria as a consequence of the permanent growing population. Bouroumi (2014), Cheruto et al. (2016) and Li et al. (2017) connected the land cover change in coastal areas with the population growth, tourism, and industrial development. According to the National Statistics Office (2010), Mostaganem town, including the coast of Kharrouba registered a rapid population growth between 1998 and 2008. The tourism activities also registered an increase of the visitant number that reached 11 million in the summer 2012 (Taibi, 2016).

Tab. 1. Coastal features change during the period 1989-2004. Legend: 1 Surface of densely vegetated dune; 2 Surface of partially vegetated dune; 3 Artificial surfaces.

	1989 (m ²)	2004 (m ²)	Affected area (m ²)	Affected area (%)
DVD₁	296 043	366 565	70 522	23.8
PDV₂	-	75 834	-	-
AR₃	18 042	146 757	128 715	71.34

Tab. 2. Coastal features change during the period 2004-2012. Legend: 1 Surface of densely vegetated dune; 2 Surface of partially vegetated dune; 3 Artificial surfaces.

	2004 (m ²)	2012 (m ²)	Affected area (m ²)	Affected area (%)
DVD₁	366 565	147 830	-218 735	-59.7
PDV₂	75 834	24 746	-51 088	-67.4
AR₃	146 757	465 098	318 341	216.9

Tab. 3. Coastal features change during the period 2012-2016. Legend: 1 Surface of densely vegetated dune; 2 Surface of partially vegetated dune; 3 Artificial surfaces.

	2012 (m ²)	2016 (m ²)	Affected area (m ²)	Affected area (%)
DVD₁	147 830	160 529	12 699	8.6
PDV₂	24 746	30 671	5 925	23.9
AR₃	465 098	486 916	21 818	4.7

Compared with other regions of the Mediterranean context, the actual situation of the Province of Mostaganem reflects the socioeconomic development (Alonso et al, 2002; Megherbi, 2015; Ghodbani et al.,

2016; Taibi, 2016). The Algerian Ministry of Land-use Planning, Tourism, and Handicraft (2015) mentioned that the available host accommodation in 2014 could satisfy the demand of 11000 tourists whereas the

Province of Mostaganem registered in the same year 10 million visitors during the summer. Consequently, the inadequacy between tourism demand and offer would probably lead the decision maker to build more host structure close to the shore, that would mean a progressive dune destruction in favor to the urbanization (Paskoff, 1994; Scarelli et al., 2017; Kim et al., 2017). In this period (2012-2016), two breakwaters have been constructed with the aim to protect the beach of Sidi Medjdoub, the most popular bathing site of Kharrouba, against the marine erosion; according to Rizzi et al. (2015), such a protection presented a weak resilience against storms and rainfalls.

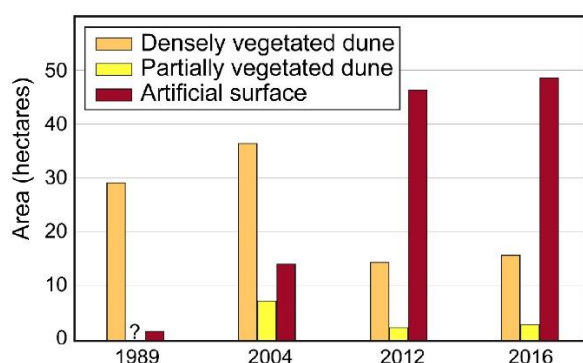


Fig. 5. Pattern evolution registered during the period 1989-2016 (Kharrouba).

The experience of the Spanish Mediterranean coast showed the impact caused by an intense urbanization close to the coastline that led to beach erosion and dune system regression. Garcia-Lozano et al. (2018) studied the historical transformation occurred in the coastal dune in Catalonia during the period 1890 to 1960. In this sense, the results evidenced the dunes disappearance or the advanced regression of those that remain today; 60% of the dunes disappeared and 30% of them retreated in size. In this context, the region of Barcelona was the most affected zone because 80% of the beaches lost their dunes. Furthermore, Girona and Tarragona enrolled, respectively, a loss of 60% and 40% of their dunes; nowadays, 10 % of this feature remained pristine on the littoral of Catalonia. In the Northeast of the Italian Mediterranean Sea, Malavasi et al. (2013) focused their study on the evolution of the Landscape formed by coastal dunes and noted that 44% of the littoral morphology changed during the period 1954-1984 due to agriculture, afforestation and urbanization. However, Molise experienced a lower change (26%) between 1984 and 2006. Long-term surveys highlighted the impact due to the transformation of a vulnerable feature such as dune and beach; different socioeconomic activities carried out close to the shoreline led to the alteration, and in extreme situations, to the definitive disappearance of the coastal dune. The Ministry of Land-use Planning,

Tourism, and Handicraft created in the province of Mostaganem 16 tourist extension zones with the aim to develop seaside tourism activities; Kharrouba, being a coastal zone, will irremediably undergo this ruling. The construction of the necessary host accommodation to satisfy the tourism demand will continue to alter the dunes and to increase the landslide hazard.

4.2. Coastal erosion and risk susceptibility in strong urbanized areas

In order to improve the socioeconomic situation, the construction of host structures for the seaside tourism was the most valuable activity in different Mediterranean countries and this contributed to the disturbance of the coastal dune (Taibi, 2014; Comor et al., 2007; Toubes et al. 2017); accordingly, the coast of Kharrouba experienced the same issue. Consequently, the monitoring of the coastal evolution is a primordial tool for the stakeholder by making decisions on territory planning (Carboni et al., 2009). The anthropic alteration of the dune could change the balance of the sediment budget and lead to beach erosion. Since the eastern part of Kharrouba is strongly urbanized, the sediment transfer between the beach and the dune could not occur, and consequently increased the erosion process that affected the stability of the steep coastal slope; in January 2012, a landslide occurred producing socio-economic damages (Fig. 6), and two years later, another landslide has been registered in the same place producing the road subsidence (Fig. 7). These repetitive events showed obviously the vulnerability of the coast of Kharrouba in terms of static stability. Consequently, extreme weather conditions could generate in future other landslides combined with subsidence, especially the erosive action of the water flow within the sediment layer.

5. Conclusion

The use of a geographic information system (GIS) to monitor the morphological changes in the study area was a powerful tool that provided an evaluation of the natural surface lost during the period 1989-2016. In 27 years, the dune surface of Kharrouba retreated 39% due to an intense urbanization. Accordingly, it was necessary to satisfy the high demand on residential structures for the local population, however, it was the wrong decision to build among the dune owing to its vulnerability.

Despite the Algerian law, 01-03-2003 that regards the environmental feasibility of projects supposed to be carried out in a natural site or close to it, build-up activities happened and impacted the sandy coast. The same issue occurred in reference to the Algerian Littoral Law 02-2002 that aimed to protect the coastal zone against any activity with environmental damage. With respect to this, the

terrain reality demonstrated that the control of the construction feasibility was unreliable in the province of Mostaganem. In addition to the environmental impact, the intense urbanization realized in Kharrouba on vulnerable terrain led to ground instability that produced landslides and road subsidence in 2012 and 2014; these repetitive events showed how difficult is to ensure the construction durability on the dune.



Fig. 6. Landslide in Kharrouba occurred in 2012 (DPW, 2012, NE-oriented photograph).



Fig. 7. Subsidence of the road produced by landslide (photograph taken on 17th April 2014).

The acquired study data can serve the stakeholder and the decision makers to handle adequately in terms of territory management, and rational use of the coastal resources. The development of the coast of Kharrouba should consider the (paleo) dune vulnerability to secure long-term economic activities and population safety.

In future, it is recommended to program the construction beyond the 300 m distance from the coastline as stipulated by the Algerian Littoral Law 02/2002.

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