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NEW APPROACH FOR SORTING OUT DROWNING PROBLEM DUE TO EIGHT DETACHED BREAKWATERS ALONG RAS EL BAR RESORT- DAMIETTA, EGYPT.

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ABSTRACT

Although the eight shore-parallel detached breakwaters have succeeded to mitigate beach erosion at Ras El Bar resort, drowning of swimmers appeared as the most significant impacts resulted from constructing these structures. Statistical analysis indicates that number of drowning accidents has been severely fluctuated between 18 and 135 victims /yr, since construction of these breakwaters in 1995. Rip current formed between these detached breakwaters is more likely responsible for these dramatic accidents. To sort out the problem of drowning we should know the erosion and accretion pattern along the study area. Satellite remote sensing data is a good tool to quantify the erosion and accretion pattern than the traditional methods.

Analysis of ten scenes of landsat sensors (MSS, TM and ETM+) at unequal intervals spanning 35-year period between 1972 and 2007, was undertaken to quantify erosion and accretion pattern along the northeastern coastline of Nile Delta, from Damietta harbor to Damietta spit. Automated waterline positions were computer generated from these enhanced Landsat satellite images covering this time period. Rates of shoreline changes have been calculated from these shoreline positions at 242 locations using a Digital Shoreline Analysis System (DSAS) version 3.2 programs. To assess the impacts of coastal structures along the study annual rates of beach changes are estimated twice, prior to (1972-1990) and after protection by engineering structures (1995-2007). Rates of shoreline changes estimated from three statistical approaches of DSAS (the end point rate, the Jackknife and a weighted linear regression) are validated with those measured from field observations of beach profile survey at the same corresponding positions (Thieler et al. 2005). Comparison of shoreline rates of beach change obtained from Landsat data with that estimated from beach profiles shows that the method used is reasonably accurate with a correlation value of 0.79.

The general alongshore erosion/accretion pattern is locally disrupted by the construction of engineering structures. The erosion at the tip of the Damietta promontory is terminated due to the

construction of the 6-km seawall in 2000; originally erosion was -43 m/yr before construction of this wall. The 8-km sand spit that has been formed from the eroded zones at the promontory tip before construction of the seawall is now under erosional processes due to deficiency of sediment supply. Prior to protection of Ras El Bar resort, erosion (-10 m/yr) is spatially replaced by formation of tombolo accretion (15 m/yr) following emplacement of the detached breakwaters between 1991 and 2002 (Frihy et al. 2003).

In this study a new safety protection measure is recommended to avoid or decline the number of drowning and enjoy the beach in safety. A series of shore-parallel recycled docks fixed with an anchoring-chain system are proposed to be deployed at the safety setback line. These docks will act as a buffer line for swimmers who try to approach the rip current areas between the detached breakwaters.

INTRODUCTION

The use of Landsat satellite data with facility of spectral, synoptic and near real time data availability has helped in monitoring shoreline changes and monitoring coastal geomorphology. Coastline mapping and coastline changes are critical issues for geomorphological studies, safe navigation, coastal management, coastal protection, and coastal planning [**Addo *et al.*, (2008)**]. Now a day, coastal zones have been exposed to pressure and processes of change, including urbanization, new infrastructure, exploitation for recreation and tourism. In addition to these infringements are coastal processes such as wind, waves, tide, storm surge, relative sea level rise and land subsidence. Coastline mapping is commonly achieved through the application of different techniques and remote sensing data varies from fine to moderate spatial resolution. McFeeters 1996 used a Normalized Difference Water Index (NDWI) for detection water bodies. Waterline can also be mapped through image classification including density slice analysis [**Ryan *et al.*, (1991); Gorman *et al.*, (1998); Braud & Feng (1998); Moore (2000); Frazier & Page (2000); Pajak & Leatherman (2002); Stockdon *et al.*, (2002) and Horritt *et al.*, (2003)**]. Time series remotely sensed images with a medium spatial resolution are ideal data sources for mapping coastal land uses and monitoring their changes for a large area [**Shi *et al.*, (2001) and Bosworth *et al.*, (2003)**] used a segmentation technique for multispectral Landsat TM imagery achieved using multiresolution combined with watershed pyramids with variational region growing. [**DI *et al.*, (2003)**] investigated a novel approach for automatic extraction of shorelines from high-resolution IKONOS satellite imagery using a mean shift segmentation algorithm as a first step, and then a local refinement process. Monitoring changes in the coastline is an important task in some applications such as cartography and the environmental management of the entire coastal zone [**Dellepiane (2004); Alesheikh *et al.*, (2004) and Foody *et al.*, (2005)**] proposed a technique called a super-resolution mapping approaches applied to the soft classification. [**Lira (2006)**] proposed a new methodology to segment open water bodies based on a variant of principal component analysis. The use of satellite remote sensing data was found to be a cost effective approach to quantify the changes over large geographic regions [**Sesli *et al.*,**

(2008) and Dewidar & Frihy (2008)] used automated waterline technique for detecting pre and post beach response to engineering hard structures at the north-western part of Nile delta from Landsat satellite data.

Similar to other deltas worldwide, the Nile delta is presently subjected to shoreline changes due to a combination of natural and anthropogenic factors. These factors includes reduce in Nile delta discharge and sediment loads due to construction of dams and barrages across the Nile River, combined together with the action of wave-induced longshore currents (UNDP/UNESCO 1978). The Aswan High Dam in the Nile River reduced sediment flux into the sea by zero percent, which has induced severe erosion in the delta coast **[Frihy *et al.*, (2003)]**. This erosion mitigated by the construction of a series of coastal engineering structures at the rapidly eroding promontories. These structures include jetties, groins, seawalls and detached breakwaters. Studies of the shoreline positions and sediment budget along the coastline of the Nile delta show that the coastal areas can be divided into a series of discrete sedimentation littoral cells **[Frihy *et al.*, (1991) and Frihy & Lotfy (1994)]**. These sub-cells are part of the regional Nile littoral cells extending from Alexandria to Akko on the northern part of Haifa Bay, Israel **[Inman & Jenkins (1984)]**. Each cell contains a coherent trend of littoral transportation and sedimentation, including sources and sinks of sediment and transport paths **[Frihy *et al.*, (2003); Sestini (1976); Misdorp (1977) and Frihy (1988)]** have documented maximum erosion rates of approximately -100 m and -10 m at the Rosetta and Damietta promontories, respectively. Analyses of different remote sensing images including Landsat MSS, TM, ETM+ and Spot satellite along parts of the delta have identified areas of erosion followed by beach accretion **[Klemas & Abdel Kader (1982); Smith & Abdel Kader (1988); Bloget *et al.*, (1991); Frihy *et al.*, (1994); El Raey *et al.*, (1995); El Asmar & White (1999) and Dewidar & Frihy (2008)]**. The identified pattern has been resulted from wave-induced longshore currents. Higher rates of seabed erosion have been recorded in front of eroded Rosetta and Damietta promontories and Burullus headland **[Misdorp & Sestini (1976); Toma & Salama (1980)]**. Coastal dynamic processes **[Khafagy & Manohar (1979); Manohar (1981); Fanos (1986); El Wany *et al.*, (1988) and Nafaa *et al.*, (1991)]** and Sediment transport **[Inman & Jenkins (1984); Frihy et al., (1998); El Sayed et al., (2005) and El Banna (2007)]** have disclosed the relation between waves induced longshore currents and processes of erosion and accretion along the delta coastline. Texture and mineralogical characteristics of beach sediment versus rates of eroded and accreted stretches have been discussed by **[Frihy & Dewidar (1993); Frihy & Lotfy (1994) and Frihy *et al.*, (1998)]**.

The present work is completely different from other studies along the study area. It aimed to use automatic techniques to quantify long-term annual rate of beach changes prior to and partially after protection by using Landsat series. It includes the effect of protection works on the boundaries and sedimentation pattern of the littoral sub-cells of the delta. Also, a new safety protection line is recommended to decline the number of drowning and enjoy the beach in safety at Ras El Bar resort.

STUDY AREA

1.2 Physical settings

The study coastline from Damietta harbor to Damietta spit is about 20 km long and is linked with the Damietta river branch at Ras El Bar resort (Figure 1). The beach sands at the Nile delta coast are mainly fine sand to very fine sand grained (average median grain 0.15 mm) but at down drift areas will be coarser with grain size about 0.5mm (Sestini 1989). These beaches consist of loose quartz sand mixed with small amounts of heavy minerals and shell fragments [**Frihy & Dewidar (2003)**]. The beaches are backed by coastal flats followed by coastal dunes in some sectors. Major landuse/landcover in the study area includes, beach and coastal flats, bare soil, cultivated land, saltpan, and urban areas (Figure 1).

Wave data recorded at the Damietta promontory over 16 months between 1997 and 1999 show waves predominant from the N-W sector (81 %) with small components from the N-E (14 %) and from the S-W (5 %) quadrants. The maximum wave height observed was approximately 4.25 m with an average wave height and period of 0.50m and 6.5 s, respectively [**Frihy *et al.*, (2003)**]. The tide along the delta coast is semi-diurnal with a tidal range between 25 and 30cm. The highest water level recorded is about 80cm and the lowest level is -64 cm from the zero level (UNECO/UNDP 1978).

1.3 Protection works

Erosion along the study area has been mitigated by construction of a series of coastal structures including jetties and detached breakwaters. In 1941 and 1976, respectively, two jetties were constructed on the western and eastern side of Dameitta Nile branch to decline the deposition of drifted sediment (Figure 2). To stop severe erosion along the southern edge of the western jetty a concrete seawall was constructed in 1963. This seawall has been modified to a rubble seawall to a distance of about 1200 m westward with crest level of about 3.5 m above sea level [**Fanos *et al.*, (1995) and El Banna (2007)**]. Eight detached breakwaters were constructed between 1991 and 2002 to stop erosion along Ras El Bar resort (Figure 2A and B). These detached breakwaters were constructed at 4m water depth and about 400m from the coastline with 200m gap width and 200m length. Further west, two breakwaters were constructed in 1982 on both sides of Damietta Port to prevent deposition in the navigation channel [**Frihy *et al.*, (2003)**]. A 6-km long seawall trending E-W (Figure 1) was built onshore along the eastern side of the Nile mouth (Figures 2C), using 4-7 ton dolos (concrete blocks) similar to those at Rosetta [**El Banna (2007)**].

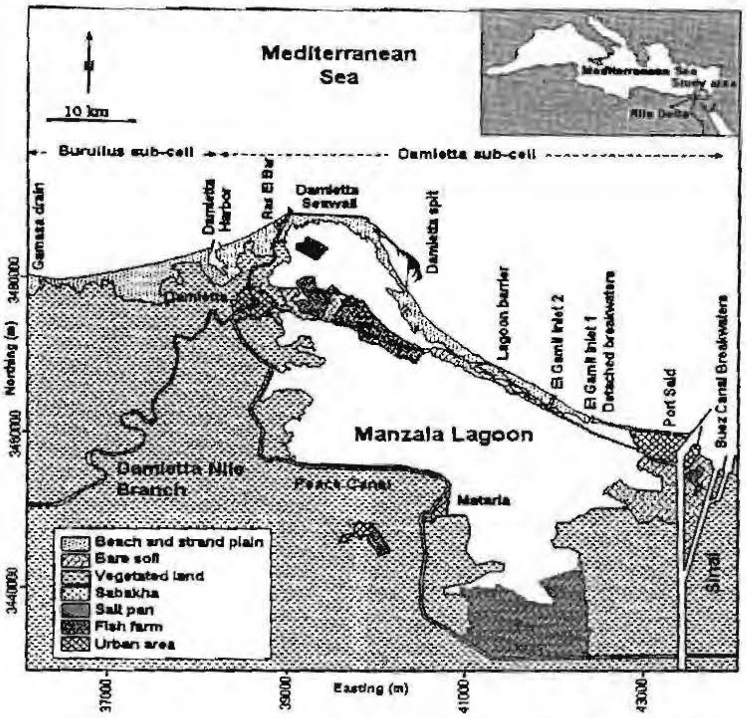

Fig. (1): Showing major geomorphologic units identified from the ETM+ 2007 and field observations along north eastern part of Nile delta coast

1.4 Drowning problem:

Beach erosion undoubtedly poses a significant threat to recreation and tourism and consequently the economy of many localities and regions. Hard structures often have environmentally and aesthetically undesirable effects such as loss of the recreational beach and threaten human safety. Hard structures tend to benefit the owners of property improvements because it protects houses, villas, businesses. However, stabilization may diminish the beacb amenities sought by visitors. These coastal structures are successed to stop beach erosion but ignore the human being effect. Local tourists who visit Ras El Bar resort searching for recreation may be disappointed for the impact of rip current created by detached break waters in this area. Rip currents and gyres inside the shadow area of Ras El Bar breakwaters including the gap areas have seriously affected swimmers. Currents measured (up to 55 cm/s) drag swimmers downward to the bottom, causing drowning. As seen in Figure 3 number of drowning accidents has noticeably increased since the construction of breakwater system. Number of victims during the last two decades averaged 66 victims. These estimates are based on data consulted from the city council of the Damietta governorate.

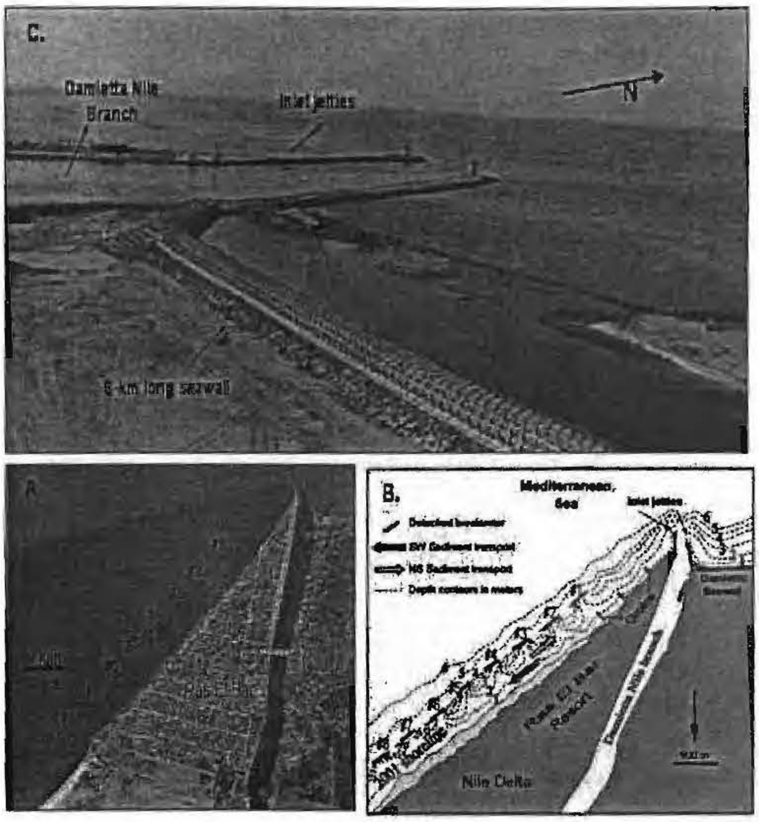

Fig. (2): Protection works at the study area: (A) Eight detached breakwaters fronting Ras El Bar resort, (B) Bathymetry map (water depth contour are in meters below sea level) and coastal structures along of Ras El Bar resort, and (C) photograph showing the inlet jetties at the Damietta River mouth and the 6-km long seawall built east of the river mouth.

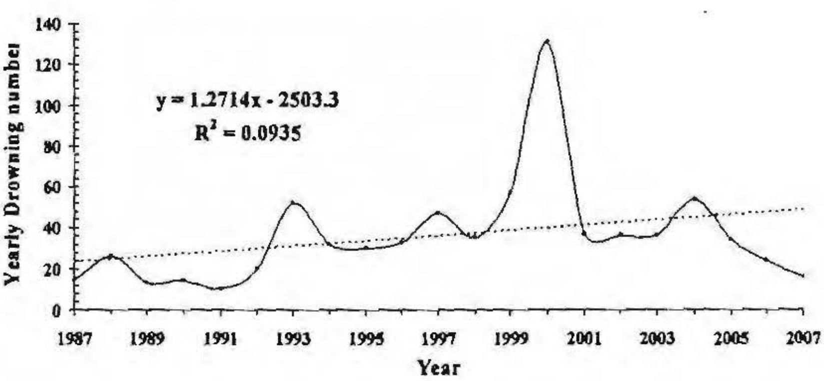

Fig. (3): Yearly rate of drowning (Average 66 victims/year) in the bathing water zones recorded at Ras El Bar resort beach. (Data provided by City council of Damietta governorate).

1.5 City Council perspective on drowning management:

The problem of drowning in Ras El Bar resort resulted from the constructed eight detached breakwaters. This problem which rose by media pressure is a matter of concern by decision makers in the Damietta governorate. As a result, decision makers have assigned a team work for rescue operation at Ras El Bar resort. In view of early management, the rescue team has created a safety protection line behind the detached breakwaters. The safety line was practically implemented by inserting a group of steel bars of about 6m high into the seabed, four meter submerged and the remaining two meter are emerged above sea surface. This safety protection line has been repeatedly constructed with no successes using different materials connecting between the steel bars, these materials includes1)-Plastic and silk wires,2)-Fiber wires and karuna,3)-Bone wires,4)-Stainless steel wires, 5)-Iron Chains and 6)-Nylon net.

In addition, a number of metal towers have been high-elevated along the shore for watching swimmers before reaching unsafe deep water between the protection line and the breakwaters. More recently, two marine motorcycles are being used to support the rescue operation.

MATERIALS AND METHODS

In this study, a series of image data are acquired at unequal intervals between 1972 and 2007, i.e., covering a time span of 35 years (Table 1). This series includes ten shorelines: 1972, 1973, 1984, 1990, 1995, 1998, 2000, 2003, 2005, and 2007. The images have been acquired almost in summer season in good quality, with no effective clouds or sensor defects such as striping. The study area is encountered in the TM and ETM+ scene (Path / Row 176/38), while it is (Path / Row 190/38 and 191/38) for the MSS. All image scenes are subjected to image processing using Erdas Imagine software version 8.4 **[Erdas (1999)]**. In this study, two techniques are used to estimate rate of shoreline retreat. The first technique corresponds to the formation of automated shoreline positions and the second one is for estimated rate of shoreline change based on a time series of Landsat satellite data applying Digital Shoreline Analysis System (DSAS) software. The processing techniques will be cited in the following two sections. In the third section scientific vision for sorting out drowning problem will be handled in details.

Table (1): Acquired dates, sensor type and spatial resolution of remote sensing data used in this study.

Serial #	Acquired date	Sensor type	Spatial resolution (meters)
1	31/08/1972	MSS	57.00
2	03/01/1973	MSS	57.00
3	20/09/1984	TM	28.50
4	04/08/1990	TM	28.50
5	11/04/1995	TM	28.50
6	07/06/1998	TM	28.50
7	11/11/2000	ETM+	14.25
8	24/08/2003	ETM+	14.25
9	18/06/2005	ETM+	14.25
10	04/03/2007	ETM+	14.25

Mapping shoreline position

The obtained data were geometrically rectified to the Universal Transverse Mercator (UTM) map projection system; zone 36 north, using 35 ground control points evenly distributed within the 2007 Landsat-7 ETM+ scene. The image rectification accuracy is < 0.5 pixel. Other dates of satellite images scenes are registered to the rectified image of date 2007. The image registrations accuracy is < 0.4 pixel between each date and image date 2007. In this study, all Landsat image data were atmospherically corrected by using 6S model [**Vermote** ***et al*****, (1997)**].

To extract shoreline position image threshold was formed to band 4 (0.8-1.1μm) for MSS or band 7 (2.0-2.35μm) for TM/ETM+ (shortwave infrared) in each date to form binary image or image mask (zero value for water and one value for land). The selections of these bands depend on the strong capability of water to absorb the incident energy. So the water appears black in color in these bands and sharp edge has been detected between water and land. Binary images are used as input layers in unsupervised classification Module to form complete separation between land class and water class, and remove effect of suspended materials due to longshore sediment transport. Horizontal and vertical Sobel filters [**Erdas (1999)**] were used to each unsupervised classified image of each date to enhance edge detection. Some editing to remove small objects and fill holes is formed for each filtered image in each date. The filtered images for each date are converted to vector layers by using Raster to Vector

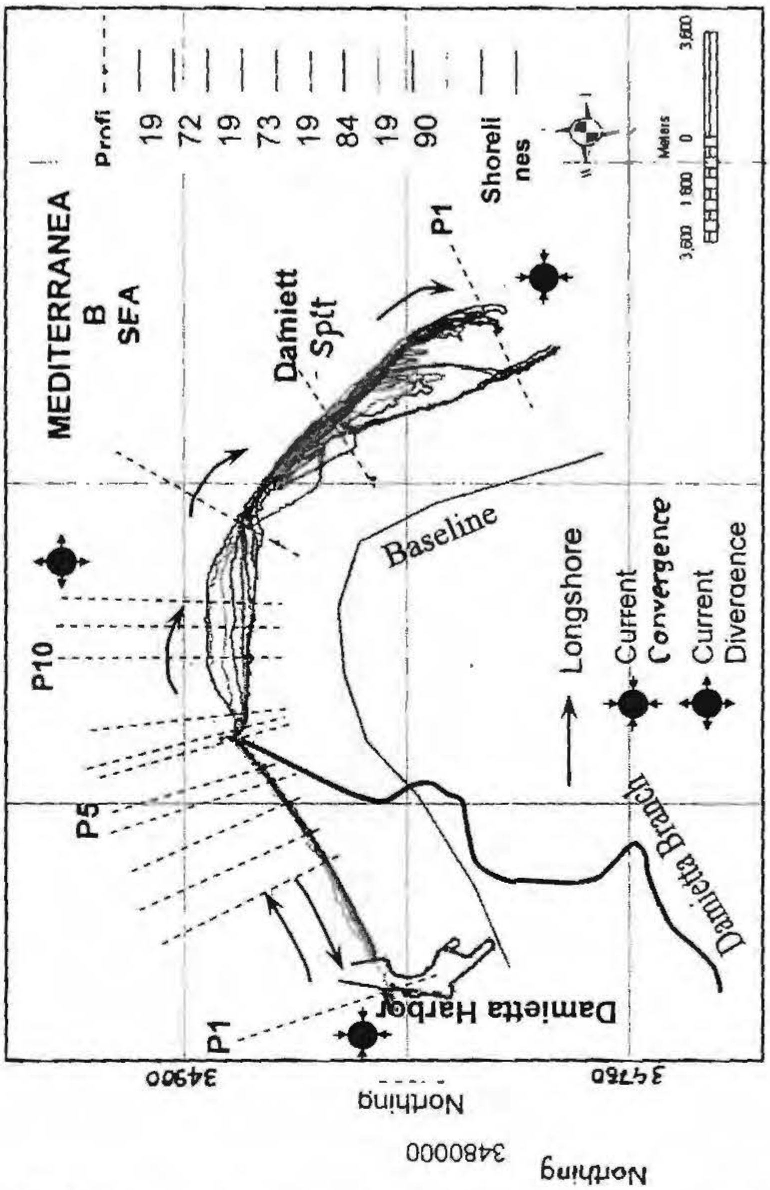

Fig. (4): Superimposed shoreline positions alongshore the study area that is extracted from the 10 landsat images. Solid lines are the 242 cross-shore transects generated to intersect the superimposed vectors and the backshore baseline. Dashed lines (labeled P1 to P15) indicate positions of profiles at which rate of shoreline changes have been calculated from ground survey **[Frihy & Komar (1993)]**.

module. The generated vector maps (Arc Coverage) for the yielded ten shoreline positions are processed in geographic information system called ARCGIS software version 9.0 **[ESRI (2004)]**. All shoreline features were then merged within a single line on the attribute table, which enabled the multiple shoreline files to be appended together into a single shapefile (Figure 4) in order to calculate shoreline change rate with the Digital Shoreline Analysis System (DSAS).

2.2 Landsat shoreline analysis

In the present study a Digital Shoreline Analysis System (DSAS) version 3.2 programs developed by Thieler et al. 2005 is used to calculate rate of shoreline changes. This system requires user data to meet specific field requirements. In this study the examined time series of multiple shoreline positions are prepared for these requirements. Based on our setting, DSAS program generates 242 transects that are oriented perpendicular to the baseline at a 100 m spacing alongshore **Fig. (4)**. These transects span the entire study coastline from Damietta harbor to Damietta Spit (~20 km length). To assess the spatial and temporal migration trend of shoreline positions a hypothetical baseline was created from east to west parallel to the present-day coastline geometry with a position of approximately 4 km distance behind. The measured distance between the fixed baseline point and the shoreline positions generated by the program provides a reliable record monitoring the changes of shoreline positions over the 35 years time frame of the generated vectors.

The generated cross-shore transects together with the extracted 10 shoreline vectors are graphically depicted in **fig. (4)**. The data measured from each profile are then used to estimate the mean annual rate of shoreline change (meter per year) employing linear regression techniques. To assess impacts of coastal structures on the beach morphology the shoreline positions are divided into two groups. The first group (1972-1990) is designated to calculate rates of shoreline retreat before protecting the coastline and the second one (1995-2007) after construction. In this study shoreline retreats were estimated by using three different statistical approaches. The End Point Rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements at each transect. The Jackknife Rate (JKR) method is implemented as an iterative linear regression that calculates a linear regression fit to shoreline data points with all possible combinations of shoreline points, leaving out one point in each iteration. The Weighted Line Regression (WLR) emphasis on data points where the shoreline position accuracy is lower on certain year **[Thieler *et al*, (2005)]**. The resulted rates of shoreline changes (erosion or accretion) estimated at each transects are plotted alongshore of the study coastline in **fig. (5)** and **fig.(6)**.

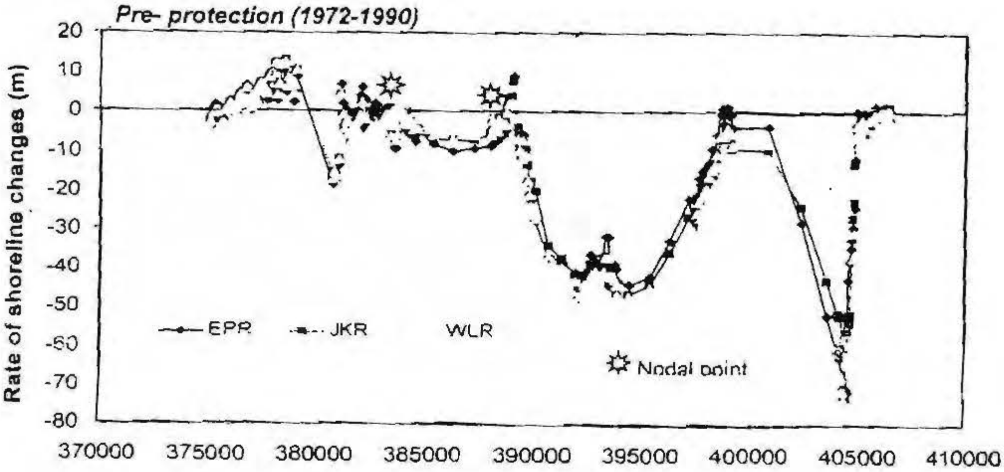

Fig. (5): Pre- alongshore annual rates of shoreline changes at 15 profiles determined from analysis of imagery data (this study). EPR = End Point Rate, JKR = Jackknife Rate, WLR = Weighted Line Regression. Positive and negative values, respectively, indicate accretion and erosion rates.

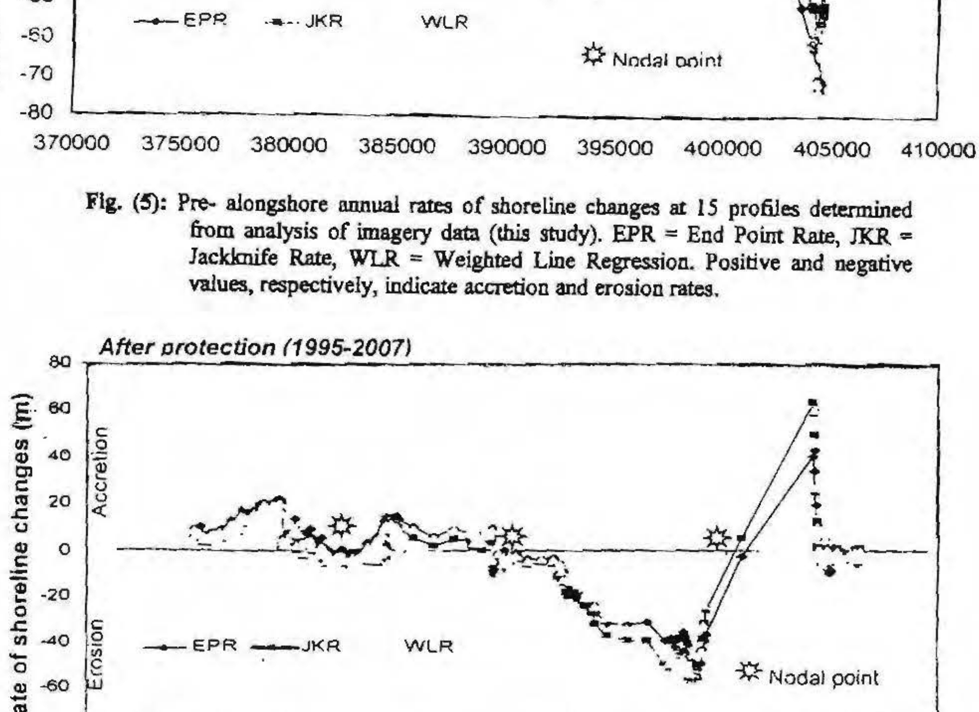

Fig.(6): Post- alongshore annual rates of shoreline changes at 15 profiles determined from analysis of imagery data (this study). EPR = End Point Rate, JKR = Jackknife Rate, WLR = Weighted Line Regression. Positive and negative values, respectively, indicate accretion and erosion rates.

2.3 Scientific vision for sorting out drowning problem:

To overcome drowning problem public sector (stakeholders) who are using this resort should be involved to solve the problem. These stakeholders are swimmers, casino owners, rescue men's, salesmen's, and city council decision makers. Unfortunately, all materials used in building the safety protection line have been stolen due to irresponsibility of unqualified people (personal communication with the rescue team). Therefore, our approach is divided into two steps. Step one is how to increase the knowledge and awareness of the stakeholders about this problem. The second step is to select an appropriate safety measure rely on scientific bases.

2.3.1 Public awareness:

To encourage publics to save the selected measure, their knowledge should be enhanced through different ways. These ways includes producing leaflets, put marks along the shore, and distribute CD or DVD to the visitors, as well as multimedia tools to show the dangerous of rip currents and swimming behind the safety protection line. Also, we can use the cinema screen at Casinos and coffee shops at Ras El Bar beach for announcement about this safe measure. In addition we can penalty swimmers who ignore the notes and legislations.

2.3.2 Scientific approach

Based on repeated field survey, and field observation carried along Ras El Bar beach. The shoreline was surveyed by Global positioning System (Garmin Summit Etrex) with accuracy ± 3m. The water depth measured by using portable sounder (Speed tech instruments) with accuracy ± 25cm. Water depth was measured behind detached breakwaters by the help of rescue team work. Bathymetry map was produced to judge the situation of safety protection line. Also, to put our vision on the type of materials used in constructing the safety protection line.

Based on the discussions with the publics and decision makers at different levels in the study area we suggest building a safety protection setback line from recycled docks. The portable docks are valuable in many ways: you can move them from impending storms, and move them from season to season. Also, these materials are friendly to the environment (Figure 7). These portable docks have been wide use in many applications such as connect shore with the ship, walking for tourist people, and park the ship and boat. The shape of these portable docks can varies from cylinder, rectangular or any shape you like it. The color of docks can be chosen based on their objectives. In this study we recommend use these portable docks as safe line to protect the swimmers to go through deep water. Also, we recommended the yellow color to be clearly visible at night. An example of this dock model is suggested to be placed along the protection safety line (Figure 7).

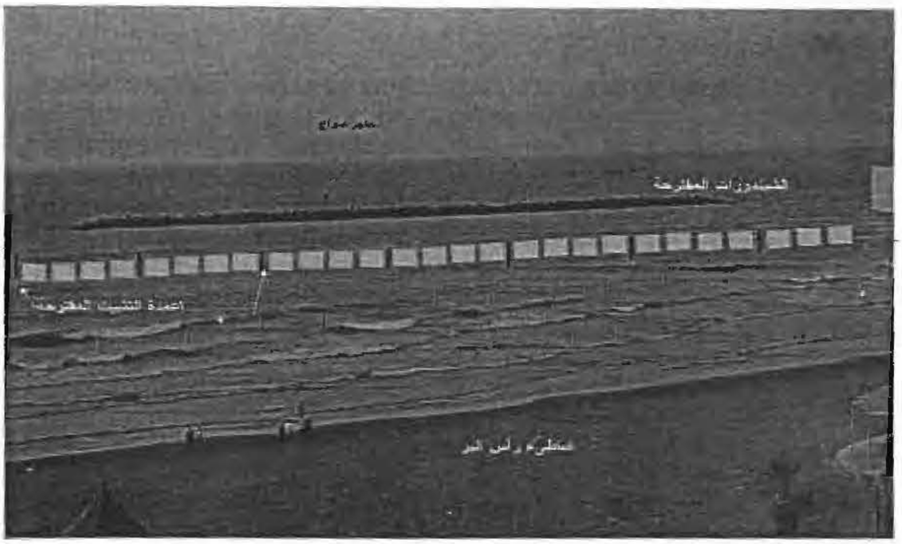

Fig. (7): The safety protection line constructed by rescue team work at Ras El Bar Resort beach.

RESULTS AND DISCUSSION

The superimposed annual rates of erosion and accretion calculated from landsat series using the three different statistical techniques reveal a good correspondence between them (Figure 5&6). To validate results yielded from the analysis of imagery processing, we consulted rate of shoreline changes calculated from ground survey measured before protection between 1972 and 1990 (Table 2). These rates which were derived from beach profiles measured at 15 points (P1 to P15, Figure 4) are the only available data in the region, although they mainly cover the pre-protection interval (1972-1990). As can be noted in Table 2, results derived from both land survey and satellite imagery at profiles P1 to P15 show good similarity in erosion and accretion pattern but with increase or decrease in rate values in some profiles. Reliability of results is statistically evaluated by correlating rates of shoreline changes obtained from the two approaches (Table 2). The best fit regression line between ground survey measurements and rates of shoreline retreat derived from satellite images show highly significant correlation coefficient of value 0.79.

Pre- and post alongshore rate of changes show many reversals between erosion and accretion along the length of the study area (Figure 5 and 6). This also is accompanied by a considerable variability in shoreline changes in terms of erosion and accretion. This alongshore pattern of shoreline changes and rates is found to be consistence with the wave refraction orthogonals (wave energy) modeled by **[Quelennec & Manohar (1977)]** for the refraction of waves arriving from the NNW. Results of this model indicate areas of convergence orthogonals of high wave energy at Damietta promontory (source area with current divergence) followed by areas of divergence orthogonals of low wave energy along saddle and embayment of this promontory (sink area with current convergence) including Gamasa embayment and Lake Manzala barrier. As can be seen in figure 4 a major transport reversal occurs in front of the Damietta promontory, creating a divergent longshore sediment transport to both the west and southeast away from the month. This transport divergence is induced from the effect of high energy waves as indicated by the convergence of the wave orthogonals [**Quelennec & Manohar (1977)**].

Starting from the west, sand derived from continued erosion of the central part of the delta is accumulated within Gamasa embayment including Damietta Harbor area (see figure 1 for location). Gamasa embayment represents a part of Burullus sub-cell. This sub-cell is one of four sub-cells defined along the delta by [**Frihy *et al.*, (1991)**]. The blocking of sediment flow to the east has induced beach erosion (-5 m/yr) east of the harbor breakwater and accretion on the up-drift side (10 m/yr). Generally, this erosion continued alongshore for a distance of ~9.0 km eastward and gradually followed by a relatively lower rate of -2.0 to -5.0 m/yr. This in turn is followed by a higher erosion rate -10m/yr at Ras El Bar beach (Figure. 5). Using satellite images El Asmar and White 2002, reported shoreline erosion along the eastern breakwater of the Damietta harbor resulted in 80 m of landward shoreline recession between 1984 and 1993, with an average shoreline retreat of 8.9 m/yr.

Between 1991 and 2002, a series of eight detached breakwaters were constructed along the coastline of Ras El Bar beach (Figure 2B). Prior to the construction of these breakwaters at Ras El Bar Resort, erosion rates between -5.35 to -10.26 m/yr are estimated using the present approach (Figure 5). These results are closely comparable with those values obtained by [**White & El Asmar (1999)**], during the period 1984 to 1990. Following construction of the breakwaters, accretion has become the dominant process with the formation of tombolos on the leeward side of the structures. This accretion is occurring at a maximum rate of 15 m/yr and has partially filled the shadow area between the coastline and the breakwaters. As expected, local erosion is observed farther down coast of these breakwaters at breakwater #8; being approximately 5m/yr (see Figure 2B for location). This adverse local erosion has resulted from the interruption of the reversal westward sediment transport by the breakwaters and tombolo formation, thus increasing sand starvation of down coast beach. The smaller portion of waves coming from the N and NE is responsible for generation of the reversed longshore currents toward the west at Ras El Bar and thus inducing such local changes. Results of rate of beach changes obtained in this study are found to be consisted with that calculated from profile data by [**El Banna & Frihy (2008)**]. The accretionary tombolo formed in the lee side of these breakwaters has abruptly altered the rate of local erosion in this area before protection. This local erosion averaged 3 m/yr prior to the building of the breakwaters in 1970-1990.

Further east, prior to protection (1972-1990), highest rate of erosion is centered on the Damietta Promontory (-42.1 m/yr) as waves and longshore currents transport sand away from the Damietta headland (Figure 5). Generally, eroded sand from the tip of Damietta promontory moves toward the east to replenish the down drift accretionary spit at about 6-km from Damietta river branch. The configuration of this spit suggests that it was formed by the easterly movement of sediment, induced by the net longshore current to the east. It was formed approximately between 1955 and 1972, although its source has now been depleted [**Frihy & Lawrence (2004)**]. This spit has been previously discussed by [**Manohar (1981); Klemas & Abdel Kader (1982); Frihy**

(1988) and Smith & Abdel Kader (1988)]. In comparison, the estimated massive erosion at the outer margin of the Damietta promontory before protection (-42.1 m/yr) is relatively higher than that measured from beach profile survey (-5.6 m/yr) by **[Frihy & Komar (1993)]**. This could be attributed to the fact that our analysis is based on a longer term period than that of **[Frihy & Komar (1993)]**. In contrast, the western flank at Ras El Bar has experienced much less change (-5.35 to -10.26 m/yr) and this can be attributed to the early protection of this sector in 1941 (Figure 5).

Further east, three nodal points are positioned between Damietta spit and west of Suez Canal breakwater due to the alternating pattern of erosion and accretion along this area. Beach immediately down coast of this spit exhibited erosion between -5.1 and -10.16 m/yr due to sediment starvation at its down drift side (Figure 6). In contrast the beach accretion (15.14 m/yr) east of El Gamil inlet #2 is caused by the interruption of the prevailing eastward sediment transport by the tombolos formed in the lee side of the constructed 5 detached breakwaters and thus inducing local morphologic changes (Figure 6).

As the longshore sand transport is almost unidirectional easterly, up drift accretion has taken place at Port Said beach to the west of Suez Canal breakwater (8 m/yr). Previous studies have confirmed that Port Said beach essentially acts as a sediment sink for sand coming from the erosion of adjacent western shores including Damietta promontory. The N-W waves transport sediment in a uniformly east direction along this lake barrier due to the acute angle of wave attack versus shoreline orientation. This transport process is also accompanied with a westerly seasonal reversals induced from the NNE waves, but the net transport is to the east. We expect that sediment producing to Port Said beach will gradually deceasing as a result of the extensive engineering structures built including the 6-km long Damietta seawall and the shore-parallel breakwater system built at El Gamil beach which have trapped much of sediments moving to the east by the easterly longshore current.

Table (2): Annual rates of shoreline changes determined from ground survey (Frihy and Komar 1993), and estimated from analysis of imagery data (this study). EPR = End Point Rate, JKR = Jackknife Rate, WLR = Weighted Line Regression. Positive and negative values, respectively, indicate accretion and erosion. Locations of the examined profiles are shown in Figure 4.

Profile No.	Easting (UTM)	Northing (UTM)	Annual rate of shoreline change (m/yr)			
			From ground Survey	Calculated from DSAS program		
				EPR	JKR	WLR
P1	382762.1	3484184	1.2	1.96	-1.24	-1.09
P2	387019.2	3486278	0.3	-0.56	-1.21	-1.18
P3	387937.8	3486786	-0.1	-0.28	-0.23	1.76
P4	388812.6	3487380	-0.2	-5.35	-5.31	-4.32
P5	389493.4	3487997	-0.6	-10.26	-7.2	-6.98
P6	389861.9	3488301	3.2	3.52	2.43	1.89
P7	390255.5	3488801	2.1	0.34	0.48	1.49
P8	390255.5	3488801	0.7	-9.53	-11.71	-12.71
P9	390540.1	3488317	-10.4	-22.64	-19.08	-23.82
P10	394318.9	3488005	-5.1	-36.5	-38.95	-42.55
P11	396760.7	3485497	-4.8	-38.9	-43.84	-42.93
P12	403946.0	3478118	-5.6	-42.1	-44.22	-44.72
P13	396760.7	3485497	1	0.7	-6.51	-6.33
P14	403946.0	3478118	3.5	1.5	0.22	-0.73
P15	407723.5	3473273	-3.3	-5.1	-9.46	-8.44
Correlation coefficient values				0.788597	0.741629	0.768229

SUMMARY AND CONCLUSIONS

Although the eight shore-parallel detached breakwaters have succeeded to mitigate beach erosion at Ras El Bar resort, drowning of swimmers appeared as the most significant impacts resulted from constructing these structures. An analysis of ten scenes of landsat sensors (MSS, TM and ETM+) at unequal intervals spanning 35-year period between 1972 and 2007, was undertaken to quantify erosion and accretion pattern along the northeastern coastline of Nile Delta, from Damietta harbor to Damietta spit. Pre- and post- long-term rates of beach changes have been determined from the processing of Landsat multi-temporal image data between 1972 and 2007, along the ~20 km length of the northeastern part of the Nile delta. The large-scale rate of beach changes along the study area is now being altered as a response of hard structures built within the littoral cells in particular at Damietta harbor, Ras El Bar and Damietta promontory. As a result, the erosion and accretionary patterns formed along the two littoral cells, namely Burullus and Damietta sub-cells, have been locally disrupted by these structures. Under these circumstances, the major protected areas which originally had been acting as a source of sediment for sink areas along promontory saddles and embayments is now diminished. The dramatic erosion centered the tip of the Damietta promontory is terminated due to construction of the 6-km long seawall, originally was -43 m/yr prior to construction. Approximately, 1.5 km cross-shore distance has been lost between 1972 and 2007 as a result of this erosion. Moreover, the chronic erosion along Ras El Bar resort is now replaced by accumulation of a series of continued tombolo formation (15 m/yr) due to the construction of eight detached breakwaters. This former erosion reached up to -5 m/yr prior to protection of this area. As a consequence, the active gyres generated in the gab areas between these breakwaters have caused hazardous effect to swimmers in summer holydays.

Construction of the Damietta harbor has disturbed the shoreline stability by inducing down drift erosion and up drift accretion on both sides of the harbor breakwaters. The alongshore variations in the rate of beach changes resulted in a series of nodal points. These points position areas of transport from erosion to deposition or vice versa that result from the orientation changes of the shoreline. Although, the geographical boundaries between these sub-cells correspond for the most part to those defined by **[Frihy et al., (1991)]**, they have been changed following protection. Therefore, the coastal instability in the study area is mainly due to the combined effects of natural coastal processes (wave-induced current) and construction of protective structures.

In the present study a new safety protection measure is recommended to avoid or decline the number of drowning and enjoy the beach in safety. A series of shore-parallel recycled docks fixed with an anchoring-chain system are proposed to be deployed at the safety setback line. These docks will act as a buffer line for swimmers who trying to approach the rip current areas between the detached breakwaters.

RECOMMENDATIONS

From the economic point of view, we recommend not installing all the entire docks once at the same time along the safe protection line, but in successive stages. Deployment a group of docks will allow designers to practically observe their performance in place, including stresses & resistance against storm waves, relocation of docks, swimmer's reaction and feasibility. Visual observations will allow the designers a good practicing to modify design specifications of docks used at each site, since waves and currents energies are not spatially uniform allover the entire safe line. Watching the behavior of a group of docks in the field resembles a 1:1 scaled "physical modeling technique", in which a structure's performance can be examined at various magnitudes of waves and currents. Also, we recommend providing the rescue team work with new motor cycles, binocular, and talky wacky for communications.

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الملخص العربى

"طرق جديدة لمعالجة مشكلة الغرق بسبب انشاء الحواجز الخراسانية الثمانية علي طول ساحل راس البر بدمياط-مصر"

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قسم علوم البيئة-كلية العلوم فرع دمياط-جامعة المنصورة

علي الرغم من نجاح الحواجز البحرية في تقليل نحر الشاطئ لمصيف راس البر فقد ظهرت مشكلة غرق المصطافين. التحليل الاحصائي لعدد الغرقي بين ان نسبة الغرقي تتراوح مابين ١٨ و ١٣٥ منذ انشاء هذة الحواجز عام ١٩٩٥. ويعتبر التيار الساحلي العكسي هو المسئول عن مثل هذة الحوادث. ولتحديد حل هذة المشكلة كان لابد اولا من دراسة مظاهر النحر والترسيب ومعدلاتة وشكل تضاريس القاع ونمط التيارات البحرية السائدة بالمنطقة.

ولتقدير التطور الزمني لخط الساحل ومعدلات النحر والترسيب فقد استخدمت احدث الطرق في مجال تطبيقات الاستشعار من بعد باستخدام صور الاقمار الصناعية كأسلوب غير تقليدي لرصد خط الساحل عبر ازمنة متعاقبة. فقد تم تحليل عشر صور فضائية للقمر الصناعي لاندسات التقطت علي فترات زمنية مختلفة غطت ٣٥ عاما، منذ عام ١٩٧٢ وحتي عام ٢٠٠٧. ولقد غطت هذة الصور خط الساحل من ميناء دمياط حتي المنطقة الواقعة علي مسافة ١٠ كم شرق بوغاز فرع دمياط. وبداية تم تحديد خط الشاطئ لهذة المنطقة بطريقة آلية لمجموعة الصور الفضائية العشرة في هيئة متراكبة Superimposed. ولقد استخدم برنامج DSAS لحساب معدلات النحر والترسيب علي امتداد الساحل عند ٢٤٢ نقطة (قطاعا عموديا علي خط الشاطئ) وبمسافة بينية بينها بلغت ١٠٠ متر علي طول خط الشاطئ. ولتقييم اثر اقامة الحواجز الثمانية علي منطقة الدراسة فقد تم حساب معدلات النحر والترسيب قبل انشاء الحواجز من عام ١٩٧٢ الي عام ١٩٩٠ وبعد انشاء الحواجز من عام ١٩٩٠ الي عام ٢٠٠٧. ولتحقق من دقة نتائج هذة الدراسة فقد تم عمل مقارنة احصائية بين المدلات المحسوبة من الصور الفضائية والمقدرة مساحيا بواسطة باحثين متخصصين، وتوصلت عملية المقارنة الي وجود توافق كبير في النتائج بلغ معامل الترابط بينهما ($r=0.79$) وبدراسة نمط النحر والترسيب فقد وجد ان هناك تغير ملحوظ في شكل الشاطئ علي امتداد منطقة الدراسة نتج بفعل حواجز الحماية.فعلي سبيل المثال فقد بلغ معدل نحر لسان دمياط قبل انشاء الحواجز حوالي ٤٣ م/سنة ، توقف هذا النحر تماما بعد بناء حاجز الامواج الذي اقيم منذ بناء حاجز الامواج الذي اقيم منذ عام ٢٠٠٠ علي امتداد ٦ كم شرق فرع دمياط. اما بالنسبة لشاطئ مصيف راس البر فقد تحول النحر عندة من حوالي ١٠ م/سنة قبل أعمال الحماية المذكورة الي ترسيب بلغ ٢٥م/سنة بعد انشاء حواجز الحماية الثمانية في الفترة بين ١٩٩١-٢٠٠٢. في هذة الدراسة تم اقتراح وسيلة عملية لحماية المصطافين من الغرق والتمتع بالشاطئ في امن وامان. وتتمثل هذة الوسيلة علي تثبيت صف من الاعمدة المعدنية خلف الحواجز الخرسانية الثمانية في قاع البحر وتتصل فيما بينها بمجموعة من البلوكات او الشبندورات البلاستيكية ذات الاشكال والالوان الفاتحة يسهل رؤيتها والمصنعة من المخلفات البلاستيكية حتي اذا فقدت أو تلفت يسهل شراء غيرها لرخص ثمنها.