Contemporary shoreline changes and consequences at a tropical coastal domain

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ABSTRACT
Coastal environment is affected by diverse human and natural activities, more than any other natural environment. The main aim of this study is to examine shoreline dynamics of the sandy beach of Mazatlán, a medium-sized tropical coastal city in north-west Mexico. This paper specifically investigates the shoreline change as impacted by natural and anthropogenic interferences on the Mazatlán coastline. The mean high water (MHW) shoreline positions were extracted from Landsat Images (2012–2016) and a 2016 GPS field survey data. Digital Shoreline Analysis System (DSAS) was then used to investigate the dynamics of the extracted shoreline movements and the relative changes. Results showed that 96% of the coastline is undergoing yearly small-scale erosion at two distinct rates. The first at $-1.9 \pm 0.9$ m year$^{-1}$ and the other at $-1.4 \pm 0.2$ m year$^{-1}$, which are noted at Cerritos and other sections of the coastline, respectively. Changes in the coastal behaviour, here, are attributed widely to suspected sea level rise; increasing tidal range in the region; and the lack of or inadequate accommodation space for sediment movement occasioned by landed assets alongshore. These factors are not only encouraging erosion but also causing the depreciation of landward assets.

1. Introduction
Intense conflicts between the natural environment and human activities are reported widely in literature (e.g., Brown et al., 2013, 2017; Larsen, 2016; Rhoads, Lewis, & Andresen, 2016; Waters et al., 2016). Perhaps no natural environment is more affected by human activity at the contemporary (shorter) timescale than the coastal environment (Brown et al., 2017). The coastal environments have served as a viable source of many valuable resources for man’s economic, social, and recreational activities (Cai, Su, Liu, Li, & Lei, 2009). Consequently, coastal geomorphology and processes are impacted by anthropogenic influence, directly or indirectly (Blum & Roberts, 2009; Brown et al., 2017), in addition to the mirage of natural environmental forcings, thereby presenting acute challenges within this natural environment (Teasdale, Collins, Firth, & Cundy, 2011). Shoreline is, perhaps, the most basic indicator of changes in coastal environment and, by implication, erosion, deposition, and subsequent recovery (Bouvier, Balouin, & Castelle, 2017; Davidson, Turner, Splinter, & Harley, 2017; Kroon et al., 2007; Oyedotun, 2016; Phillips, Harley, Turner, Splinter, & Cox, 2017; Robinet et al., 2016).

Our ability to understand shoreline variability remains one of the core issues in nearshore science as different timescales and processes involved in shoreline variability make it unsolvable challenge to many coastal managers and policy-makers (Stive et al., 2002). The inability to understand and predict shoreline variability can result in the misinterpretation of coastal change scenarios, and affect (directly or indirectly) decision-making and subsequent design of intervention plans (Stive et al., 2002). So far, the variability in shoreline position remains a reliable proxy to describe the overall coastal or beach changes (Absalonsen & Dean, 2011; Bouvier et al., 2017; Oyedotun, 2016, 2017). Shoreline dynamic/variability has often been used to study coastal changes at short (days to seasons, e.g., Pearre & Puleo, 2009; Stive et al., 2002) or long (decades to centuries, e.g., Harley, Turner, Short, & Ranasinghe, 2010; Goble & MacKay, 2013) timescales. Analysis of shoreline change is, thus, a well-established field (Burningham & French, 2017). However, the understanding of the change is often made easy by provision of multi-temporal data and robust quantification of the trends in the shoreline behaviour (e.g., Garcin et al., 2016). Contemporary shoreline change is the short-term behaviour (annual to decadal timescale) of the shoreline positions, especially as it relates to either the hydrodynamics processes (e.g., Hapke, Himmelstoss, Kratzmann, List, & Thieler, 2011; Hapke, Plant, Henderson, Schwab, & Nelson, 2016;
Hapke et al., 2010) or the local sediment budgets (e.g., Bradbury, Cope, Wilkinson, & Mason, 2013; Pye & Blott, 2016).

The main purpose of this study is to analyse contemporary small-scale changes on the sandy beach of Mazatlán, a medium-sized tropical coastal city in northwest Mexico. Based on the recent image analyses and fieldwork, this paper specifically investigates the shoreline change as impacted by the natural interferences and examines the effects of this on anthropogenic presence at the coastal environment. Although consideration of historical changes can show long-term effects and consequences of the interactions along the coastline. However, using Mazatlán coastline as the template for tropical regions, the findings presented in this study strongly suggest that we do not have to consider a distant past nor the large-scale measurement to be able to infer the pattern and effects of these nature–human interactions. Indeed, the implications of the continuous and contemporary small changes suggest that rapid attention to this small-scale investigation is highly essential if we want to avert long-term and permanent damage in the future.

2. Mazatlán coastline

Mazatlán, a southern city in the State of Sinaloa, is located on the 23°5’ and 23°19’ North and 106°17’ and 106°30’ West (Figure 1). The city is a mostly sandy tropical coastline oriented NW–SE, covering a length of approximately 20 km. The earlier studies of Montaño-Ley and Peraza-Vizcarra (1986) observed the net movement of sediment of 214,609 m³ yr⁻¹ south-eastward occasioned by changes in wave regimes, while Montaño-Ley and Gutiérrez-Estrada (1987) found erosional volumes of sediment with the maximum erosion at 15.7 m³ per metre of length of the beach and Montaño-law et al. (1988) observed an 8.5 m³ of eroded sediments along the beach. Mazatlán coastline is characterized by mixed tide with an average range of about 1.0 m, a prevailing NW wind and occasional tropical storms migrating along the Pacific Coast of Mexico from SW striking the Mazatlán city (Montaño-Ley et al., 2008).

Mazatlán city is with a population of around 400,000, a population density of 173 per km² and 87% of infrastructures that support tourism, fishing, industrial, and other diverse economic activities (INEGI, 2010). The city has a high pressure on the natural environment (Camacho, Ruiz-Luna, & Berlanga-Robles, 2016). Despite the economic well-being and financial benefits of the wetland coastal systems of Sinaloa State to the local communities (Camacho-Valdez, Ruiz-Luna, Ghermandi, & Nunes, 2013), the coastline has been subjected to high risks due to increasing land use changes which affect the supply and quality of this systematically transformed coastal environment (Camacho et al., 2016). Indeed, land use and land cover changes in Mazatlán and the entire Sinaloa State, like other tropical coastal cities, have grown over the last decades with noticeable urban growth at the expense of natural vegetation and agriculture (Ruiz-Luna &

Figure 1. Mazatlán showing the recent shoreline positions and profile areas shortlisted for analyses in this study. Inset: Map of Mexico showing the state of Sinaloa. Source: The data for the map was extracted from the GADM database (www.gadm.org), version 2.5, November 2015.
Berlanga-Robles, 2003). With increase in the population of this tropical city is the increase in the demands for the use of the coast and the nearshore waters for recreation, tourism, commercial, and other human uses. Interplay of the increasing human activities and natural forcings, is making the coastal management in this part of the world to be problematic for the coastal managers. The findings from the Mazatlán coastline are expected to serve as baseline information on the trend of this form of interactions in the State of Sinaloa, Mexico, and the entire tropical region in providing a scientific guidance on coastal management and policy decision-making.

3. Methods

Shoreline geometry is one of the basic indicators in evaluating coastal changes and this has been used extensively in investigating historical trend/pattern of coastal dynamics (Oyedotun, 2014). Differences in historical and recent rates of change along a coastline are mostly reflected in shoreline movements, and here, the mean high water (MHW) shoreline positions (Boak & Turner, 2005) were analysed for the shoreline changes. The wet/dry lines along the beach are used as proxies for the position of MHW (Boak & Turner, 2005). These lines, perpendicular to the coast, were extracted from Landsat Imagery covering the period from 2012 to 2016 after they have been pre-processed through the application of radiometric calibration and atmospheric correction in ESRI® ArcGIS, following the guidance described in USGS instruction guides USGS (2016a, 2016b). All the images were collected almost at the same time in summer season in good quality so as to eliminate the effects of sea level rise and waves (Vu, Lacroix, Than, & Nguyen, 2017). The Landsat data sourced from U.S. Geological Survey, USGS, (www.glovis.usgs.gov) are Landsat 7 (Enhanced Thematic Mapper, ETM) and Landsat 8 (Operational Land Imager, OLI – Thermal Infrared Sensor, TIRS) 30 m spatial resolution images at World Reference System (WRS) path/row 31/44. For the Landsat 7, the image was acquired on 17 September 2012 while that of Landsat 8 images were acquired on 12 September 2013, 17 October 2014, 16 July 2015, and 04 September 2016, respectively.

The imagerys were transformed to Geographic Projection (Universal Transverse Mercator (UTM) WGS84 Datum, Zone 13N) before being preprocessed in ESRI® ArcGIS 10.3 for image enhancement (including radiometric calibration, atmospheric correction, gap filling, pan-sharpening) and geometric rectification to eliminate imageries defects (e.g., wedge-shaped gaps, radiometric distortion, presence of noise, etc.) (Lillesand, Kiefer, & Chipman, 2008). To extract the exact shoreline from the images, a non-linear edge-enhancement technique was performed in MATLAB to delimit the land–water boundary of the images. RGB (Red Green Blue) Colour composites of 543 (for Landsat TM and ETM+) and 652 (for Landsat OLI images) were then applied on the images to enhance the objects and distinguish clearly between soil, land, and water. The distinguished shoreline position was then extracted by digitizing and imported into DSAS module in ArcGIS environment.

Position accuracy of the 2016 shoreline (extracted from Landsat Image) was confirmed with the global positioning system (GPS) Field Survey carried out alongshore the study site using the Garmin GPS Model 120 (programmed to measure coordinates in UTM 13 N continuously as we walk along the beach) between 25 October and 9 November 2016.

Digital Shoreline Analysis System (DSAS) (Thieler, Himmelstoss, Zichichi, & Ergul, 2009) was then used to investigate the dynamics of shoreline movements and the relative changes at shorter scale along the Mazatlán beach. Although the utilization of DSAS is widely used in Historical Trend Analysis (e.g., Jabaloy-Sánchez et al., 2013; Oyedotun, 2014, 2016), it has also been applied for short-term investigations of shoreline variations and short-term coastal changes (e.g., Hapke, Kratzmann, & Himmelstoss, 2013).

Shoreline change analyses were performed through the generation of shore-normal transects at 50 m intervals along the open coast of Mazatlán from Punta Cerritos to Punta Tiburón (Figure 1). A range of statistical analysis were calculated for each of the transects at 99.5% Confidence Interval, applied to the minimum of four (4) shoreline intersection threshold. Here, specifically, results of Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), Linear Regression Rate (LRR), and End Point Rate (EPR) of change (Oyedotun, 2014, 2016; Thieler et al., 2009) are presented. SCE measured the total change in position of all the shorelines under consideration; NSM, the distance between the 2012 and 2016 shoreline positions; LRR determined the rate of change statistic by fitting the least square regression to all the shorelines at each of the transects while EPR in this study was derived by dividing the total shoreline movement by the time period considered (5 years in this study). The Mazatlán coastline, for this study, was divided into four sections (Figure 1) to allow for a more systematic analysis and interpretation of the rates of shoreline dynamics. At the recent (contemporary) timescale, erosion trends are presented as negative values and the depositional/accretional trends as positive values. The shoreline change analyses in this study are used as metric to evaluate the modifications alongshore the coastline of Mazatlán on a local scale. Assessment and interpretation of the broader influence of shoreline movements was modified after description by Hapke et al. (2011) while the consequence of this influence on the system and adjoining anthropogenic presence on the coast, is from the field observation and insights provided by Cooper, O’Connor, and McIvor (2016).
4. Results and discussion

4.1. Contemporary shoreline dynamics

The shoreline change metrics and trends (NSM, SCE, and time-averaged LRR) are shown in Figure 2. Although the net shoreline change in some areas along the coastline is minimal, the overall trend of shoreline movement is erosional (Figure 2(a)) with 96% of the system undergoing erosion at small scale ($>$−1 m). The subsection with highest negative erosion net rate, for the last five years, is between Punta Cerritos and El Sábal to the north. This is followed by the coastline between El Sábal and Punta Camarón. At this contemporary timescale, the spatial pattern of shoreline variability along Mazatlán coast corresponds closely to the net rate of shoreline movement (Figure 2(a) and (b)), that is, NSM and SCE correspond. This indicates that continuous and persistent change in shoreline position is prevalent in the last five years. The consistent erosional rates of the shoreline are significant here as the NSM and SCE are exactly and effectively the same for the erosion hotspots, which are predominantly between Punta Cerritos and El Sábal section than other sections of the coastline. Across much of the Mazatlán coast, the aggregate amount of shoreline erosion was between 5 and 7 m where the MHW shoreline positions shifted landward. This notable change was highest in Cerritos area. In other section of the beach, the total shoreline movement (landward) is mostly between 5 and 1 m (Figure 2(a)). There was also, interruption of low volume of ($\sim$−1 m) erosion at a few discreet locations especially in areas where the envelope of variability (SCE) were substantially moderate (2.1−5 m) (Figure 2(b)).

Results of the geomorphic shoreline assessment indicate that the most erosional dynamic part of Mazatlán coast is at Cerritos. This was the section that exhibits the alternate stretches of high yearly rates of erosion of between −0.5 and 1.8 m year$^{-1}$ (Figure 3) which corresponds to maximum net retreat rate of −2 m year$^{-1}$ (Figure 2(c)). The retreat at this stretch of the beach could be attributed to the availability of sediments, the reshaping of available berms at the northern end of the beach or the limited coastal defence. Pocket of shoreline progradation sparsely occurred around El Sábal, Punta Camarón, and Punta Tiburón sections (Figure 2(c)) but these did not match the overall magnitude of persistent erosion rates of change in almost these sections. The pockets of shoreline accretion rates, here, can be associated with the lateral alongshore movement and deposition of eroded sediment at the spot of occurrence. However, the 20 km stretch coastline was largely marked by erosion, although with variation of yearly rate (Figure 3). Progradation are sparsely localized at the rate of $<0.5$ m year$^{-1}$ which did not match the overall erosion observed.

![Figure 2. Shoreline change metrics and trends for Mazatlán coastline, showing (a) Net Shoreline Movement (NSM), (b) Shoreline Change Envelope (SCE), and (c) average rate of change, Linear Regression Rate (LRR). Source: Georeferenced Location data was extracted from the GADM database (www.gadm.org), version 2.5, November 2015.](image-url)
Comparison of retreat rates at this contemporary scale (Figure 4) showed significant differences in behaviour between all the sections. The envelope of variability (SCE) is highly obvious in Punta Cerritos (Quartile 1 (Q1) where the 25% of the distribution is 7 m; Q3 (75% of the distribution) is 10 m; median is 8 m and the highest value is 15.2 m). SCE at El Sábalo is also high (Q1 is 6.3 m; Q3 is 8.4 m; median is 7 m; and the highest value is 9.6 m), moderate at Punta Camarón (Q1 is 2.7 m; Q3 is 6.2 m; median is 3 m; and highest value of 9.6 m) and low at Punta Tiburón (Q1 is 3 m; Q3 is 5 m; median is 4 m; highest value of 8.7 m) (Figure 4(a)). Despite the envelope of variability being strong in the far north sections of this system, the yearly erosional rates are also higher at this area than the other three sections (that is, at El Sábalo, Punta Camarón, and Punta Tiburón, respectively) (Figure 4(b)–(d)).

Two distinct yearly rates of erosion are evidence in this coastline. The first is at $-1.9 \pm 0.9 \text{ m year}^{-1}$ and the other which hovers at $-1.4 \pm 0.2 \text{ m year}^{-1}$ are the main bulk of the erosional distribution. The first is noted at Cerritos while the later at the other sections of the system (Figure 4(b)). Alongshore sequence of shoreline movement at the central and southern parts indicated that the average shoreline rates of erosion spread over $-0.5 \pm 1 \text{ m year}^{-1}$ (Figure 4(c)) at El Sábalo, which is lower than at Punta Camarón ($-0.5 \pm 0.0 \text{ m year}^{-1}$) and Punta Tiburón ($-0.7 \pm 0.7 \text{ m year}^{-1}$), respectively. There is a minimal accretion at El Sábalo and Punta Tiburón. This observed average rates of shoreline movement corresponds with the total shoreline migration, with only El Sábalo having a cumulative accretion of $\geq 1.8$ m. The envelopes of change associated with migration of shoreline movement at Punta Camarón are far wider than the one experiences at other sections (Figure 4(a)).

Changes in coastal behaviour are attributed widely to long-term tidal cycles (e.g., Gratiot et al., 2008), climate change (e.g., Nicholls & Cazenave, 2010) or sea level rise (e.g., Zhang, Douglas, & Leatherman, 2004). The insights from the examination of temporal Mazatlán shoreline dynamics at the recent times (Figures 2 and 3) are pointers to the influence of strong coastal forcings which are obviously compelling the landward movement of shoreline positions (e.g., Castelle et al., 2018; Hapke et al., 2016). Although this study did not examine the exact coastal forcing evidence compelling the observed change, the recent investigations of sea level rise in the region (e.g., Kopp et al., 2016; Lluch-Cota et al., 2010; Páez-Osuna et al., 2016; Ruiz-Fernández et al., 2016) suggest the ostensible rise in the sea level and storm surge.

Sea level rise is an important forcing along the Pacific coastline of both North and South America (Enfield & Allen, 1980; Páez-Osuna et al., 2016). Indeed, the increase in water levels or surge in sea levels is documented significant drivers of sedimentary shorelines movements, whether at short- or long-term scale (Páez-Osuna et al., 2016). The coherence in the consistent erosional behaviour of Mazatlán coastline can possibly be linked to a gradual rising sea level and relative stormy swell as the localized analyses presented here suggest. This kind of assertion should, however, be made with caution as there are many other forces (waves, weather, etc.) for example, elevate surge levels (e.g., Woodworth, Flather, Williams, Wakelin, & Jevrejeva, 2007), high waves (e.g., Dodet, Bertin, & Taborda, 2010), strong winds (e.g., Burningham & French, 2013), etc. which have the potentials in enforcing coastal change in this shoreline or any other similar tropical shorelines of the world. This caution is highly needed based on the observation by Schumm and Lichty (1965) that shorter timescale changes are intrinsically and essentially linked with stringent cause–effect association at smaller spatial scales, like Mazatlán, than at a broader and wider spatial scale or at longer term. As an example, in the 1970s, anomalies of monthly sea level, coastal sea surface temperature and alongshore wind force were modifying the

![Figure 3](image-url). Yearly rate of change (EPY) along Mazatlán coast, from Punta Cerritos to Punta Tiburón.
the impacts of coastal forcing obvious. These anthropogenic instances are leading to shoreline planform squeeze with glaring effects on the coastline and the landed assets alongshore. This study did not, however, investigate whether there is (or there is no) any evidence of geological control on the shoreline behaviour as it is the norm with similar studies (e.g., Burningham & French, 2017).

4.2. Anthropogenic influences and consequences

As common with any coastal areas with beehive of tourism activities, coastal defences are the main key structural control on the coastal morphodynamics along Mazatlán coastline. One of the main objectives of this study is the examination of the influence of the contemporary changes in the modifications of anthropogenic presence in this study area. Most Punta Cerritos – El Sábalo section of the coastline is characterized as having moderate development (after Hapke et al., 2011) as there are moderately spaced, privately owned landed/family properties and houses which are not clustered in this section. Here, there is little to limited tourist infrastructures, no massive commercial development projects except sparse hotels and there are some open spaces between the communities of family homes.

The anthropogenic infrastructural development levels between El Sábalo and Punta Camarón, on the other hand, can be described as dense (after Hapke et al., 2011, 2013) as there are a sizeable number of single-family houses, hotels, continuous communities of buildings, sizeable hotels, a good number of tourist infrastructures and commercial buildings. Developments between Punta Camarón and Punta Tiburón can be described as heavy as there are conspicuous and predominant multi-story buildings, hotels, diverse condominium complexes, various tourist infrastructures alongshore, and visible commercial properties at this section of the coastline. The visual assessment of the influence and consequence of the yearly rates of change along the different sections of Mazatlán coastline are obvious. The exposure of this coastline to the influences of sea level rise and other coastal forcings like tidal influences and wave energy (e.g., Dickson, Walkden, & Hall, 2007; Nicholls & Cazenave, 2010; Woodroffe & Murray-Wallace, 2012) results in the landward movement of the shoreline – the effects of which are visible on not only the landed properties along the coast but also the coastal defence structures (Figure 5). The consequences of these structures are not only observable in the inhibition of the natural response of the beach and coastline to natural processes like storms, they also increase erosion and disruption of alongshore sediment movement (Figure 5), the phenomena which are also common in other coastal areas (e.g., Hapke et al., 2013). This is also causing the wearing and tearing of the coastal defence structures and dynamics in coastal zones in this Pacific region (Enfield & Allen, 1980).

Figure 4. Classification of shoreline statistics and behaviour based on each of the four sections of the coastline. I – Punta Cerritos; II – El Sábalo; III – Punta Camarón; IV – Punta Tiburón. (a) – SCE; (b) – EPR; (c) – LRR, and (d) – NSM.
This suggests that other assets not yet affected, may be in danger of erosional force in a period not far from now. The results of this study have, however, shown that human modifications along coastlines influence shoreline change both historically and contemporarily, and are also influenced by the coastal processes. From this study, it can be inferred that the rates of shoreline change are highly dependent on the level of human interference along the coastline. Between El Sábalo, Punta Camarón, and Punta Tiburón where anthropogenic developments are heavy, the yearly erosion rates are minimal \(-0.5 \pm 1.0 \text{ m year}^{-1}\) (Figure 4) but the wear and tear of the land-based assets along these sections of this coastal environment are obvious (Figure 5).

At Cerritos area, on the other hand, the yearly rates of erosion are higher \(-1.0 \pm 1.5 \text{ m year}^{-1}\) (Figure 4) but there is no evidence of wear and tear on the landed assets, except the incursion of coastal sediments along the landed properties, clogging of stairways of properties with coastal sediments, etc. (e.g., Figure 5(a)–(c)). However, whether the effects of shoreline migration

![Figure 5. Examples of effects and consequences of shoreline erosion on landward assets alongshore Mazatlán coast. (a)–(c) (Punta Cerritos), (d)–(f) (El Sábalo), (g)–(i) (Punta Camarón), and (j)–(l) (Punta Tiburón).](image-url)
inland have erosional effects on the human assets or not, one thing that is obvious is that the shorelines in this study site are experiencing a coastal squeeze, reinforced by both the natural processes (e.g., sea level rise, storm surges, increasing wave, tidal flooding, etc.) and anthropogenic interventions in most areas, except the sections where there are sparse levels of infrastructural developments at the nearshore. This sort of human influence is known to control the geomorphic regime along sandy tropical coastal environment, not only interfering in sediment movement and budget, but in encouraging erosion through sediment starvation (e.g., Blum & Roberts, 2009; Brown et al., 2017).

4.3. Implications

It is confirmed that seas and oceans, all over the world, are rising faster in this and last century than at any other time of the last 28 centuries, principally because of greenhouses gases from human emissions (Kopp et al., 2016). The effects of this kind of phenomenon are already attracting media attention in other parts of the world (e.g., Gillis, 2016; Strauss, 2016). For example, it was reported that tidal flooding in places like Miami Beach, Charleston, and Norfolk are becoming a routine which are making life miserable for their inhabitants and communities (Gillis, 2016). With the projection of continuing sea level rise in this twenty-second century (Kopp et al., 2016), the rates of shoreline erosion will increase and may be far worse, not only for Mazatlán, but for many coastal communities and cities worldwide, likely resulting in the abandonment of those cities (Gillis, 2016). Mazatlán coast is thriving today because of the growth of tourism, which is encouraging the developments of diverse facilities along the coast. If strategic actions and policies are not put in place to give room for the expected and continuous sea level rise, increasing wave and storm surges, etc. and the resultant landward shoreline movement, the coastal environment will soon start witnessing perennial saltwater/coastal flooding, clogging of drains with sea sediments, blocking of the nearby roads and streets with seawater and sands, and depreciation of the landward assets. One legitimate concern in support of the debate for societal response for coastal defence/protection is the perceived and the real threat of coastal flooding and erosion to the human infrastructure (Penning-Rowsell et al., 2013).

Although this fear may be justified, it is a pointer to the fact that many of these infrastructures are in hazardous locations and thereby have detrimental effects on coastal landscape, coastal ecosystems, and coastal habitat (Cooper et al., 2016). With real estate agents considering how close a property is to the water edge before making efforts for the sales and the worth of a property, and the buyers now concerned on how far such properties are to the tide (Urbina, 2016), this shows that the likely future depreciation or appreciation in value of any landed properties depend on the closeness of such to shorelines. Key lessons here is that the decisions and policy-makers, henceforth, should be taking into consideration the future trend in shoreline movement in the formulation of policy for shoreline and coastal management, the erection of human infrastructures along/within the coastal environment. If these are not critically considered as soon as possible, it is not only the coastal geomorphological system that will be permanently affected but also the landed assets which contribute to the disruption of the coastal geomorphic system. As warned recently, this kind of policy consideration need to happen as fast as possible because of the possibilities of economic collapse of coastal assets in the face of sea level rise and coastal erosion/flooding, which are perennially real and could be worse than the bursting of property/financial markets crises of 2000 and 2008 (Urbina, 2016). These will affect the whole economy of the tropical coastal communities, not only of the property owners, property developers, mortgage lenders, financial institutions but to all and sundry who depend on the benefits that the coastal regions offer, for example tourism.

5. Conclusion

As no natural environment has become more affected by human activity at the contemporary timescale than the coastal environment, this study was aimed at investigating geomorphic response at the tropical coastline of Mazatlán, Mexico, in the context of natural and anthropogenic influence. Shoreline positions investigated through DSAS showed that there is a continuous and persistent landward movement of shoreline positions in Mazatlán in the last five years. Changes in coastal behaviour, here, are attributed widely to strong coastal forcings which are obviously compelling the landward movement of shoreline positions, and also the lack of/inadequate accommodation space for sediment movement, occasioned by landed assets alongshore. These are not only encouraging erosion but also causing the depreciation of landed assets. With the projection of continuing sea level rise, increasing storm surges, etc. in this twenty-first century, there is the urgent need for the decision and policy-makers to factor-in this reality in coastal and shoreline management, and in the allocation of coastal land to the property developers. It is not only the geomorphic system along the coasts that will be permanently affected, the anthropogenic structures will not be spared also – both physically and economically – if no consideration is given to the reality of shoreline changes in this area and other similar tropical coastal communities.
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