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Impact of SLR on Beach-Tourism Resort Revenue at Sahl Hasheesh and Makadi Bay, Red Sea, Egypt; A Hedonic Pricing Approach

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Abstract: Coastal erosion and inundation represent the main impacts of climate change and the consequential sea level rise (SLR) on beaches. The resultant deterioration of coastal habitats and decline in beach tourism revenue has been a primary concern for coastal managers and researchers. Nevertheless, the extent of SLR on beach tourism in Egypt remains relatively unknown. Therefore, this study investigates the relationship between beach width shrinkage due to SLR and the loss in tourist resort revenue. We use the hedonic pricing approach, which combines economic and environmental variables, to determine the environmental impact on beach tourism along 14 km of the coast of Sahl Hasheesh and Makadi Bay, Hurghada, Egypt. The resort revenue depends on the cumulative benefits from the market price of the resort rooms, which is a function of morphological variables and tourism variables. Three regression models (semi-log, double-log, and custom-log) were used to select the most appropriate functional hedonic model. Three coastal slopes were considered (0.03, 0.06, and 0.12) to address the uncertainty in beach width. When 0.06 coastal slope is used, the expected losses in revenue are 84,000, 220,000, and 546,000 USD/day period (representing 3%, 7%, and 18%) for 2030, 2050, and 2100, respectively, considering the lowest scenario representative concentration pathway (RCP2.6); for the worst case (RCP8.5 SLR), the expected losses are 142,000, 369,000, and 897,000 USD/day period (representing 5%, 12%, and 30%) for 2030, 2050, and 2100, respectively.

Keywords: coastal erosion; beach tourism; resort revenue; hedonic pricing

1. Introduction

Tourism in Egypt is considered a key source of national income and foreign currency. The direct contribution of the travel and tourism sector to Egypt's gross domestic product was 5.6% in 2017 and 11.9% in 2018 [1]. Beach tourism is considered one of the major economic growth factors in the tourism industry. Beach tourism along the Red Sea of Egypt contributes a significant portion of the gross national product [2]. The Hurghada coastal region has recently experienced major economic growth in the tourism industry, particularly in associated resorts and villages [3]. The Hurghada coastal region is home to unique coastal and marine habitats, such as coral reefs and mangroves, and boasts golden beaches, blue water, sunny and warm weather, and good tourist facilities, making it an attractive coastal area for tourist and entertainment activities [4]. Furthermore, Red Sea beaches are ranked as the second-biggest attraction of foreigners to the country, following weather/climate features [5].

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2013) predicts that global sea levels will continue to rise in the future by higher rates than those projected in the past few decades [6]. Worldwide, sea-level rises (SLRs) contribute to different coastal hazards, in addition to varying the environmental conditions along coastlines (e.g., damaging coastal habitats, coastal inundation, erosion, etc.), and are becoming a major threat to beaches [7,8]. The Bruun Rule [9] is widely used at a global scale to estimate coastal retreat due to SLR. The rule assumes that the upper beach is eroded as the shore profile moves landward and that the eroded sand volume is transmitted offshore [10,11]. The Bruun Rule was used to project the future shoreline retreat along the sandy coastline of the Mediterranean Sea in Egypt [12]. Beach tourism will suffer from deterioration in terms of beach loss, destruction to beach tourism facilities, hotel, and resort damages, etc., which will negatively affect the tourism industry and cause a regression in tourism revenues [7,13]. The sustainability of coastal tourism is therefore an important issue that should be incorporated into integrated coastal zone management schemes to conserve beaches and avoid economic losses associated with coastal deterioration.

The hedonic pricing method [14] is used to evaluate the benefit of a non-market characteristic on market prices by observing the behavior of related characteristics in the market [15]. The method uses a value/price of a marketed good, which is readily observed through the market and then isolates the price of the characteristic through statistical regression analysis, keeping in mind that many market goods are considered a function of characteristics [14]. The hedonic pricing method is widely applied to variations in residential prices, reflecting the value of local environmental attributes in the tourism industry to measure the influence of different factors and the hotel room market [16].

Substantial research has been conducted on the relationship between changes in tourism revenues and beach retreat or beach value. For example, revenue changes due to the retreat of Delaware's ocean beach were assessed in 2001 [17]; hotel room prices in relation to beach characteristics and the location of the hotel in Costa Brava (Catalonia) were evaluated in 2011 [18]; the influence of the proximity to the Mediterranean sea on the value of hotel rooms was estimated in 2012 [19]. In 2015, beach value and losses in tourism profits for 10, 20, and 30 years were projected along the Rethymnon city coastline in Crete, Greece [20]. Similar research was conducted at Cua Dai beach of Hoi An, Vietnam (world heritage site), to assess the relationship between beach erosion (retreat) and tourism revenues in 2018 [21]. Moreover, the influence of sea views and beach accessibility on room prices were determined in three touristic areas of Veracruz (Mexico) in 2018 [22].

This study aims to evaluate the relation between beach retreats caused by SLR, considering representative concentration pathway (RCP) scenarios issued by the IPCC (2013) and the consequential loss in resort revenues in the coastal areas of Sahl Hasheesh and Makadi Bay, Hurghada, Egypt, using the hedonic pricing approach, which incorporates both economic and environmental variables.

2. Materials and Methods

2.1. Study Area

Hurghada city is located on the Red Sea Coast of Egypt (about 350 km south of the Suez governate). The Hurghada coastline extends for about 35 km along the seashore [23] and includes several resorts and tourist facilities. The tourism industry in Hurghada is essential to its economic growth. In 2017, Hurghada was named the capital of the Arab resorts (http://sis.gov.eg/Story/132731?lang=ar). The target coastal area for the present investigation covers approximately 14 km of the coastal area from Sahel Hasheesh to Makadi Bay (Figure 1), including one of the top-ranked beaches (golden beaches) along the Red Sea, according to the Egyptian Tourism Authority (http://www.egypt.travel/). Sahl Hasheesh and Makadi Bay are extremely appealing tourist destinations due to their warm climate, coral-reef scenery, and range of activities (e.g., diving, sightseeing from glass boats or small submarines, and underwater photography), beach recreational activities, sports, and fishing activities [4].

Figure 1. Satellite image of the study area (Sahl Hasheesh and Makadi Bay, Hurghada, Egypt).

The Red Sea is categorized as a semi-enclosed basin. In Egypt, the Red Sea coast extends for about 1200 km from the Suez governate at the north (Lat. 30° N) to the south of the Egyptian border with Sudan (Lat. 22° N). Geomorphologically, the Red Sea shoreline varies in shape and composition from rocky to sandy beaches, with both a low- and high-relief topography of cliffs and headland [24]. The shoreline is backed by a wide coastal plain, followed by rugged mountainous terrain, and the main source of sediments to the Egyptian Red Sea beaches are terrestrial deposits transported from the fringing mountains during the runoffs through the existing numerous wadis to the Red sea [25].

The tidal range of the Red Sea is semi-diurnal, with a maximum peak every 12 h and a mean tidal range of about 0.8 m, and the mean sea level shows seasonal variations that are about 0.5 m higher in the winter than in the summer [4,26]. The prevailing wind direction is mainly from the northwest, where winds mostly arrive from the NW (about 54%) and N (about 20%) during most of the year, whereas it blows from the south and southeast during the monsoon period [25,27].

The waves are commonly moderate, with an observed maximum significant height of 4 m at the buoy deployed in the central Red Sea, while the average significant wave height spatially varies between 0.6 and 1.2 m and the average wave periods are between 4 and 6 s [28]. The average significant wave heights of approximately 1.3 m with a wave period of 4.5 s approach from the NW direction to the Hurghada coastline. This wave component is responsible for creating prevailing currents towards the south [24]. Generally, currents in the Red Sea could be generated by the tidal current, wind-driven current, wave breaking on shoals, or littoral current, generated by a wave breaking close to the shoreline. The littoral currents are prevailing in the study area and are too weak to disperse coarse-grained beach sediments towards the south [25]. Consequently, the impact of man-made structures, such as groins, marina structures (quays and platforms), or offshore hard structures of resort boundaries, which are located at the north of the study area, were neglected. Additionally, the wide coastal strip, which is rich in reefs, provides a natural defense system against storms. Therefore, the impact of waves on tourism facilities and activities could be neglected.

The Coastal Sensitivity Index (CSI) was used to evaluate the response of the Red Sea coast to SLR using six different variables, namely coastal geomorphology, coastal slope, width of the coastal plain, shoreline exposure, fauna/flora, and land use [27]. The results indicate that 30% of the Red Sea coastline is highly sensitive and susceptible to deterioration, particularly the inhabited coastal areas (Hurghada, Safaga, and Marsa Alam). Sandy beaches are generally more prone to erosion by waves and swells [29,30]. Additionally, gently sloping coasts, such as the Hurghada coastline, are more vulnerable to the effects of SLR, such as retreat and inundation, than steeply sloping coasts.

The shoreline of Hurghada was investigated in 2015, using satellite images and field observations, and the landfilling (accretion, about 7.56 km^2) and dredging (erosion, about 2.67 km^2) activities were detected along the coast of Hurghada for the expansion of tourist beaches and facilities from 1972 to 2011. The processes affected the natural shoreline, the biodiversity, and the coral reef communities, which inhabited the coastal area, and contributed to further deterioration of the marine ecosystem. However, conserving reefs (preventing the landfilling and dredging activities of coral reefs) had effective benefits to protect the waterfront/recreational facilities and the surrounding coastal environment. Furthermore, the results reinforce the fact that the natural shoreline variations will not be easily distinguished from man-made variations considering the reef and rocky nature of the coast and the absence of strong waves and littoral currents [23].

The Bruun rule (1962) is a widespread model for shoreline/sandy beaches retreat projections as a result of long-term SLR, where it gives a linear relationship between SLR and shoreline recession based on equilibrium profile theory. The Bruun rule presumes that, as sea level rises, the beach profile moves upward, keeping its initial profile shape. Simultaneously, the beach profile moves landward in a parallel approach to compensate the increased amount of sediment. The shoreline retreat (Δy) is expressed as follows:

$$\Delta y = \frac{S * y^*}{(h^* + B_h)} \tag{1}$$

where S is the SLR, h* is the closure depth, y* is the horizontal distance to h*, B_h is the berm height, and the previous form could be presented as follows:

$$\Delta y = \frac{S}{\tan\ \alpha} \tag{2}$$

where tan α is the beach slope. However, some research refers to Equation (2) as a tangent rule.

The rule is applied along the sandy coasts of the Mediterranean Sea of Egypt, where shoreline retreat and associated beach loss were easily predicted [9]. Unfortunately, the Bruun rule in the original form (Equation (1)) was not applicable for the study area, which is considered to have a constrained beach perched on underlying reef carbonate rocks [2]. In addition, existing data on beach equilibrium profile conditions and closure depths are limited. Therefore, beach width retreat for the Hurghada coast was determined by considering the inundation by SLR only, hereinafter referred to as the tangent rule (Equation (2)), and by using the values of the coastal slope, which are presented in a previous study [27] in 2015, where coastal slope ranges from 3 to 12% (moderate slope) at reef shores and less than 6% (gentle slope) at sandy beaches. According to this study, coastal slope was estimated in digital elevation models via applying the slope tool of the spatial analysis provided in ArcGIS Software. The coastal slope was measured at 10 km of the coastal strip perpendicular to the shoreline.

The utilized SLR dataset includes averaged regional ensemble mean SLR data (1 latitude-longitude resolution) from 21 CMIP5 models for the RCP2.6 and RCP8.5 scenarios in 2081–2100, relative to the reference period 1986–2005 (IPCC 2013). Along the Red Sea coast of Egypt, the ensemble means that regional SLR ranged between 0.313 and 0.331 m for RCP2.6 and 0.546 and 0.564 m for RCP8.5. Thus, the averaged ensemble mean SLR values are 0.32 m and 0.55 m for RCP2.6 and RCP8.5, respectively. Beach erosion due to inundation as a result of SLR was estimated for the years 2030, 2050, and 2100. Meanwhile, the future beach width for each sector of the investigated area was estimated as follows: (future beach width (m) = present beach width (m) − shoreline retreat (m)).

2.2. Hedonic Pricing Method

The hedonic pricing method [14] is applicable to determine the economic values for different environmental variables or amenities, which affect market prices. This model was applied in our research to the coastal areas of Sahl Hasheesh and Makadi Bay to determine the effects of environmental variables on coastal tourism. Figure 2 shows the applied framework for the designed research steps to estimate the loss in revenue of coastal resorts based on beach retreat/erosion due to SLR. The resort revenues (RR) could be expressed as the cumulative benefits from the market price of all the resort rooms (RP), while RP is considered as a function of morphological variables (environmental conditions: beach width (BW) and distance to the city center (DS)) and tourism variables (economic data: number of resort rooms (RN), coastal businesses (CB), tourist area (TA), and beach attendance (BA)). More specifically, the applied hedonic pricing model for the investigated study area can be expressed as follows:

$$RP = f\ (BW, DS, RN, CB, TA, BA) + C \tag{3}$$

where C is the coefficient.

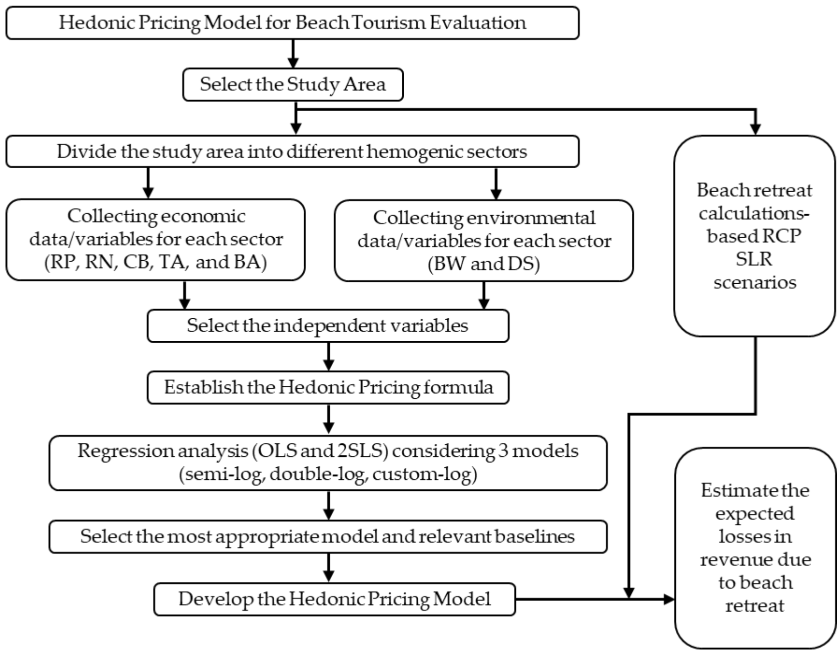


Figure 2. Methodological framework for developing a hedonic pricing formula.

The investigated coastal area was divided into 19 sectors, representing 19 resorts (Figure 1). Based on resort boundaries and hotel management areas, each resort is responsible for specific relevant beach activities, tourism facilities, and recreational activities. For each sector, different types of economic data and environmental characteristics were collected through the period between June to August 2019; these are summarized in Table 1.

Open data sources, such as websites, tourism facilities, Google Earth tools, and the official websites of resorts, were used to collect the required data. For instance, the www.booking.com website (largest online reservation for hotels and resorts [19]) was used to obtain the average price of double rooms for a 15-day stay, which is considered the normal holidaying period in Hurghada and in the high season (from June to August 2019). The official website of each resort was used to acquire essential information about the number of rooms, cafes, restaurants, bars, souvenir shops, tennis/gulf areas, pools, etc., for each resort. This information is an indicator of the coastal business in these areas. The areas utilized by tourists for recreational activities (gulf, green, pool, and aqua-sport areas) were collected as an indicator for a tourist area. Figure 3 presents an individual resort (resort no.5), showing the recreational areas for tourist activities. Google Earth tools were used to estimate the beach length, width, distance to the city center, and the number of sun umbrellas (which are assumed completely occupied through the high season), which are used as a proxy for beach attendance for each sector.

Table 1. Hedonic pricing variables, description, and statistical summary.

Variables		Description	Statistics			
			Mean	St. d	Min	Max
Room Price (USD/15 Days/Double Room)	RP	Average Price of Double Rooms for 15 Days in High Season (June to August 2019), Reserved Early	1989	808	600	3750
Beach Width (m)	BW	Average Width (in Meters) of Beaches per Sector	49	11	20	70
Beach/Sector Length (m)	L	Length (in Meters) of Beaches per Sector	394	258	100	1065
Distance (m)	DS	Distance (in Meters) to the Center of Hurghada City	31,752	4117	24,800	36,800
Tourist Area (m^2)	TA	Area Used by Tourists for Recreational Activities per Sector	44,746	22,601	8000	91,460
Coastal Business	CB	Number of Tourism Facilities (Restaurants, Bars, Cafes, Souvenir Shops, Tennis/Gulf Areas, Pools, etc.)	23	13	9	61
Number of Rooms	RN	Number of Rooms per Sector	768	530	110	1936
Beach Attendance	BA	The Number of Sun Umbrellas per Sector (Used as a Proxy for Beach Attendance)	305	246	10	920

Figure 3. An example for the tourist area (satellite image resort number 5).

The estimations of this model were based on a multi-regression approach; the dependent variable (resort room price (RP)) was the natural logarithm and the baseline values for different hedonic pricing variables were estimated considering the regression analysis of ordinary least squares (OLS) and two-stage least squares (2SLS). Three regression models (semi-log, double-log, and custom-log) were developed and applied to determine the most appropriate functional hedonic model form for the RP, in terms of environmental and economic variables. The three mathematical expression/regression models could be expressed as the following:

1. Semi-log, $\ln(Y) = b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 \pm C$
2. Double-log, $\ln(Y) = b_1 \ln(X_1) + b_2 \ln(X_2) + b_3 \ln(X_3) + b_4 \ln(X_4) + b_5 (X_5) + b_6 \ln(X_6) \pm C$
3. Custom-log, $\ln(Y) = b_1 \ln(X_1) + b_2 X_2 + b_3 \ln(X_3) + b_4 \ln(X_4) + b_5 (X_5) + b_6 X_6 \pm C$

where, ln (Y) is the natural logarithm of the dependent variable (ln (RP)), while, b_1, b_2, b_3, etc., are the coefficients of explanatory variables (X_1, X_2, X_3, etc.).

3. Results and Discussions

The results of shoreline retreat-based RCP SLR scenarios were projected, and the future beach widths were estimated. Additionally, the hedonic pricing model was established, and the economic results were estimated to evaluate the expected losses in revenue for 2030, 2050, and 2100.

3.1. Future Beach Width

Beach retreat/erosion based on SLR negatively impacts beach-tourism revenues and will be a challenge for the national government, which requires more attention and the implementation of strategic management plans. Several methods for prediction of coastal response to SLR have been developed over the past 50 years. These methods include empirical and modeling approaches, photogrammetric assessment, SBEACH (numerical model for simulating storm-induced beach change), the Bruun Rule, the shoreline evolution model, and the shoreline response model. The shoreline evolution model includes the effect of reefs, headlands, break walls, and other structures, wave climate, and longshore transport in predicting recession, due to SLR, which are the main constraints in the Bruun rule application [10].

These methods include approaches based on past recession rates, basic geometric principles, and more complex process-based assessment. Additionally, they are based on similar underlying processes and assumptions and could have variations in the definition of model parameters (e.g., closure depth). Generally, two-dimensional numerical models consider the spatial and temporal waves and hydrodynamic and geomorphic processes and provides more realistic estimates and predictions. However, these models require skill, computational effort, and extensive input data, which were not available for this study. In addition to the absence of historical records, lack of sufficient monitoring tools, and the limitation of strong waves and drifting currents at the study area, Equation (2) is found to be the simple method to estimate the future shoreline retreat for Sahl Hasheesh and Makadi Bay, as it assumes that the slope of the response profile remains similar to the existing beach slope ($\tan \alpha$), and landward shifting (retreat, Δy) is expected due to SLR. The projected shoreline retreat along Sahl Hasheesh and Makadi Bay due to SLR was estimated using four RCP scenarios for the 2081–2100 time period.

The shoreline retreat ranged from 10.8 m to 18.3 m for 3% coastal slope, 5.4 m to 9.2 m for 6% coastal slope, and 2.7 m to 4.6 m for 12% coastal slope, considering RCP2.6 and RCP8.5 SLR, respectively. Consequently, the lost beach areas were projected between 40,419 m^2 for RCP2.6 and 68,613 m^2 for RCP8.5, considering 6% of coastal slope, representing 10.7–18.1% of beach loss for RCP2.6 and RCP8.5, respectively. The uncertainty caused by the coastal slope ranged from 21.3 to 36.2 % of beach loss for RCP2.6 and RCP8.5, respectively, for 0.03 coastal slope, and from 5.3 to 9 % of beach loss for RCP2.6 and RCP8.5, respectively, considering 0.12 coastal slope. Beach losses significantly impact tourism revenue since they limit the available area used for tourism activities and raise the potential risks for the deterioration of tourism facilities and relevant infrastructure on the beach. Figure 4 shows the results of current beach widths (m) for each sector and the projected beach widths (m) for the year 2100 using the RCP2.6 and RCP8.5 scenarios, considering the coastal slopes of 0.03, 0.06, and 0.12.

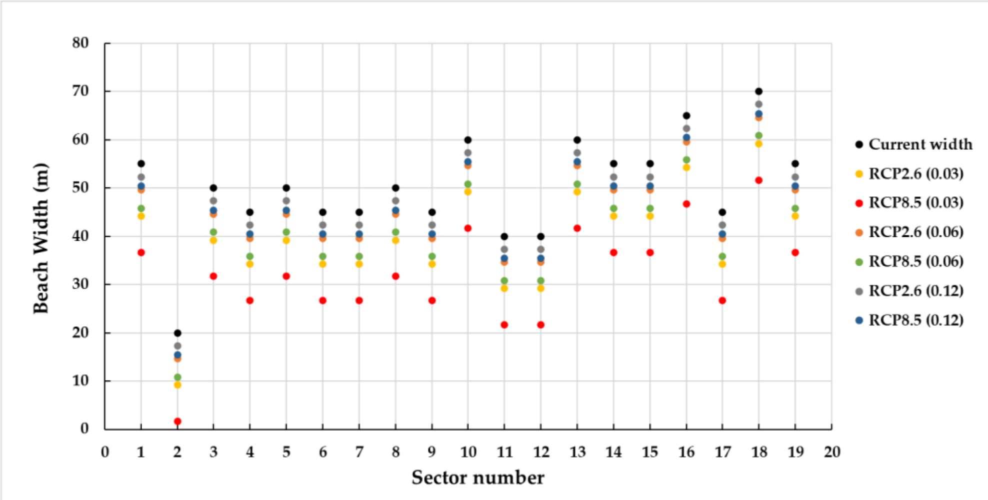


Figure 4. Beach widths (m) per sector considering the current and expected situation in 2100 for the representative concentration pathway (RCP)2.6 and RCP8.5 sea level rise (SLR) scenarios and coastal slopes 0.03, 0.06, and 0.12.

3.2. Econometric Results

To apply the hedonic price model, various environmental (BW and DS) and economic variables (RN, CB, TA, and BA) representing the tourism attitude were collected for each sector to relate the resort revenues (RR) in terms of the market price of the resort rooms (RP) and the beach width variation. Descriptive statistics for the environmental and economic variables are presented in Table 1. The average beach width is 49 m (St.d = 11). The widest beach occurs in sector 18 (70 m wide and 490 m long), whereas the narrowest beach occurs in sector 2 (20 m wide and 120 m long). Distances to the city center (DS) increase from sector 1 to sector 18, with the average distance being 31,752 m (St.d = 4117). Tourist areas (available areas used by tourists for recreational activities) have a mean value of 44,746 m^2 (St.d = 22,601). The smallest tourist area was observed in sector 2 (8000 m^2), while the largest area was present in sector 9 (91,460 m^2). The average number of coastal businesses (CB) that represent tourism facilities, such as bars, cafes, souvenir shops, and restaurants are 23 (St.d = 13) per sector, whereas the average number of rooms per sector is 768 (St.d = 530). In addition, the average beach attendance, which is represented by the number of sun umbrellas per sector, is 305 per day (St.d = 246). The average market room price (RP) is 1989 USD (St.d =808) for a double room during a 15-day period in the high season, whereas the maximum and the minimum prices are 3750 USD and 600 USD, respectively.

Table 2 shows the results of the economic regression analysis for this study based on the hedonic pricing model. The dependent variable (resort room price (RP)) is the natural logarithm, while the baseline values were calculated using OLS and 2SLS regression analysis, considering three models (semi-log, double log, and custom log).

Table 2. Econometric analysis results.

Dependent Variable: Natural Logarithm of RP (Ln RP) Number of Observations: 19								
Semi-Log			Double-Log			Custom-Log		
Variable	**OLS**	**2SLS**	**Variable**	**OLS**	**2SLS**	**Variable**	**OLS**	**2SLS**
Coefficient (C)	13.74	13.65	C	17.83	18.23	C	19.83	−5.864
Beach Width (BW)	0.003	0.15	ln (BW)	0.007 *	0.095 *	ln (BW)	0.178 *	1.886 **
Coastal Business (CB)	−0.014	−0.01	ln (CB)	0.063 *	0.08 *	CB	0.002 *	0.078*
Number of Resort Rooms (RN)	0.002 **	0.002 **	ln (RN)	1.284 ***	1.29 ***	ln (RN)	1.299 ***	0.088 ***
Distance to the City Center (DS)	−0.00052	−0.00069	ln (DS)	−1.48	−1.53	ln (DS)	−1.474 *	0.345 *
Tourist Area (TA)	0.00016 *	0.00015 *	ln (TA)	0.280 *	0.257 *	ln (TA)	0.00065 *	0.725 *
Beach Attendance (BA)	0.00016 *	0.00015 *	ln (BA)	0.280 *	0.257 *	BA	0.00065 *	−0.003 *
Coefficient of Determination (R^2)	0.76	0.75		0.89	0.89		0.88	0.88

*** Statistical significance at 1% ($p < 0.01$); ** statistical significance at 5% ($p < 0.05$); * statistical significance at 10% ($p < 0.1$).

The results of the semi-log model show that the explanatory variables BW, RN, TA, and BA had positive coefficients; however, BW was not statistically significant. TA and BA were significant at the 10% level ($p < 0.1$) and RN had significance at the 5% level ($p < 0.05$), while CB and DS had negative values. In the double-log model, results show that the whole coefficient of the explanatory variables was positive except for DS, and they had significance at the 10% level, except for RN, which had a significance at the 1% level ($p < 0.01$). In the custom-log model, the results show positive coefficients for all the explanatory variables, except for DS in the OLS specification and fixed-term in the 2SLS specification. In the OLS, all explanatory variables had significance at the 10% level, except for RN, which had a significance at the 1% level. In the 2SLS scenario, CB, DS, TA, and BA had significance at the 10% level ($p < 0.1$), BW had significance at the 5% level ($p < 0.05$), and RN had significance at the 1% level ($p < 0.01$).

Regarding the 2SLS regression analysis, two instrumental variables were considered as endogenous for BW. The first was the presence of a coastal road next to the beach, which was constructed mainly for tourist transportation purposes, and the second was the sector/beach length, affected by coastal retreat. The validity of the proposed instrumental variables was evaluated using the first-stage regression of the coefficient of determination (R^2). Hence, the proposed variables were weak, the null hypothesis was rejected, and BW was an endogenous variable. Therefore, the 2SLS specification results of the custom-log model were more accurate, considering the statistical significance of the applied variables. Accordingly, Equation (4) was formulated. It incorporates natural logarithmic expressions of the dependent variable, RP, and the explanatory variables of BW, RN, DS, and TA. The other explanatory variables were expressed as non-logarithmic. The coefficient of BA was negative, but it had significance at the 10% level.

$$\mathrm{Ln}\ (\mathrm{RP}) = 1.886 \ln\ (\mathrm{BW}) + 0.078\mathrm{CB} + 0.088 \ln\ (\mathrm{RN}) + 0.345 \ln\ (\mathrm{DS}) + 0.725 \ln\ (\mathrm{TA}) - 0.003\mathrm{BA} - 5.864 \quad (4)$$

For each sector, the expected revenues were estimated based on Equation (4), using three coastal slopes (0.03, 0.06, and 0.12) for the years 2030, 2050, and 2100, considering the lowest and worst RCP SLR scenarios (RCP2.6 and RCP8.5, respectively). The estimations of total loss in the resort revenues considered 15 days from June to August 2019, which represents the high tourism season in Hurghada. Table 3 presents the results of the current beach width, the corresponding resort revenues, and the expected resort revenues for each sector along Sahl Hasheesh and Makadi Bay, due to SLR using coastal slope 0.06 and considering the lowest and worst cases of RCP2.6 and RCP8.5, respectively, for 2030, 2050, and 2100.

Table 3. Beach width and resort revenues along Sahl Hasheesh and Makadi Bay due to SLR (coastal slope = 0.06).

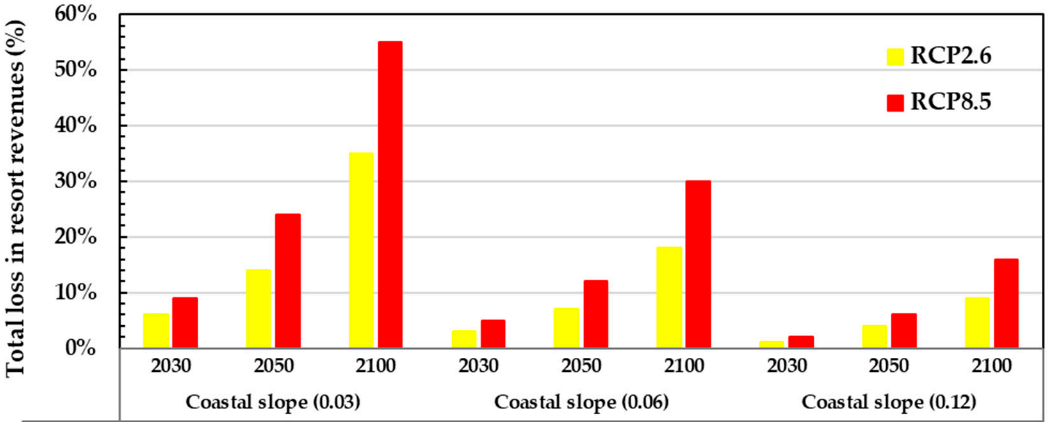
Beach Sector	Beach Width (m)	Resort Revenues (10^3 USD/15 days)	Resort Revenues (10^3 USD/15 Days) RCP2.6 SLR			Resort Revenues (10^3 USD/15 Days) RCP8.5 SLR		
	2018		2030	2050	2100	2030	2050	2100
S1	55	1529	1488	1420	1258	1459	1346	1083
S2	20	57	53	46	32	50	39	18
S3	50	1032	1001	951	832	980	897	703
S4	45	394	381	360	310	372	337	256
S5	50	1396	1355	1288	1126	1326	1213	952
S6	45	639	618	584	502	603	546	415
S7	45	476	460	435	374	449	407	309
S8	50	980	961	913	798	941	860	675
S9	45	3220	3184	3007	2587	3108	2814	2138
S10	60	463	423	405	363	416	386	317
S11	40	892	859	806	679	836	747	545
S12	40	2500	2313	2169	1827	2252	2011	1467
S13	60	2388	2329	2233	1999	2288	2126	1745
S14	55	8185	7964	7603	6735	7811	7206	5795
S15	55	4259	4144	3956	3505	4064	3750	3015
S16	65	2430	2374	2283	2063	2336	2183	1822
S17	45	623	602	569	489	588	532	404
S18	70	3702	3624	3495	3182	3569	3352	2838
S19	55	9623	9392	8967	7943	9211	8498	6834
Total Revenues (10^3 USD/15days)		44,788	43,527	41,490	36,603	42,661	39,252	31,332
Total Loss in Resort Revenues (10^3 USD/15 Days)			1261	3299	8185	2127	5536	13456
Total Loss in Resort Revenues (10^3 USD/Day)			84	220	546	142	369	897
Total Loss in Resort Revenues (%)			3	7	18	5	12	30

* The resort' revenues (RR) equal the summation of the market price (RP) of all rooms per resort.

Narrow beach widths impact resort revenues significantly, as estimated for sectors 2 and 12, which were found to be the most influenced sectors by beach retreat. For the lowest scenario RCP2.6 SLR, the expected losses for 2030, 2050 and 2100 were 7%, 19%, and 45%, respectively, for sector 2 and 7%, 13%, 27%, respectively, for sector 12. For the worst scenario RCP8.5 SLR, the expected losses were 12%, 31%, and 69%, respectively, for sector 2 and 10%, 20%, 41%, respectively, or sector 12.

The expected resort revenue loss for Sahl Hasheesh and Makadi Bay due to SLR were 84,000, 220,000, and 546,000 USD/day, considering the lowest scenario RCP2.6. For the worst-case (RCP8.5 SLR), the expected losses were 142,000, 369,000, and 897,000 USD/day for the years 2030, 2050, and 2100, respectively, when the coastal slope 0.06 was considered. Meanwhile, the corresponding losses when coastal slope 0.03 was applied were 166,000, 431,000, and 1,037,000 USD/day for RCP2.6 SLR and 142,000, 369,000, and 897,000 USD/day for RCP8.5 SLR for the years 2030, 2050, and 2100, respectively. The lowest losses in resort revenues were projected when coastal slope 0.12 was considered, and the losses were 43,000, 111,000, and 280,000 USD/day, considering RCP2.6 SLR, and 72,000, 188,000, and 468,000 USD/day for RCP8.5 SLR for the years 2030, 2050, and 2100, respectively.

Figure 5 shows the results of the expected total loss in resort revenues (%) for the coastal slopes 0.03, 0.06, and 0.12, considering the lowest and worst RCP SLR scenarios, respectively (RCP2.6 and RCP8.5), in 2030, 2050, and 2100. The estimated uncertainty in the total loss of resort revenues' ranged from 6 to 35% and from 9 to 55% for RCP2.6 SLR and RCP8.5 SLR, respectively, using a very gentle coastal slope of 0.03. Meanwhile, the estimated uncertainty in the total loss of resort revenues ranged from 3 to 18% and from 5 to 30% for RCP2.6 SLR and RCP8.5 SLR, respectively, for the gentle coastal slope 0.06. Otherwise, the estimated uncertainty in the total loss of resort revenues ranged from 1 to 9% and from 2 to 16% for RCP2.6 SLR and RCP8.5 SLR, respectively, for the moderate coastal slope 0.12.



	2030	2050	2100	2030	2050	2100	2030	2050	2100
RCP2.6	0.06	0.14	0.35	0.03	0.07	0.18	0.01	0.04	0.09
RCP8.5	0.09	0.24	0.55	0.05	0.12	0.30	0.02	0.06	0.16

Figure 5. Expected total loss in resort revenues (%) in 2030, 2050, and 2100 for the RCP2.6 and RCP8.5 SLR scenarios and coastal slopes 0.03, 0.06, and 0.12.

The impact of climate change on tourism has been the main topic of numerous studies, several of which have used the hedonic pricing method, which is widely applied in tourism studies along coastal areas to investigate different targets, such as evaluating the expected variation in hotel or tourist beach revenues in terms of environmental attributes, such as beach retreat, hotel location, and room view. This method was used in Greece to assess the beach value and losses in tourism profits [20]. It was also applied to the World Heritage coast in Vietnam to express the relation between beach retreat and expected loss in tourism revenue [21]. Both studies depended upon the beach value as an independent variable (beach rental value through tourism season (USD) and land value (USD/m^2)). In contrast, the method was applied in this study to evaluate the losses in resort revenues in terms of beach retreat for the lowest and worst RCP SLR scenarios. Due to a lack of information on beaches, the hedonic pricing method was adapted to use the market price per room (USD/15-day period) as the dependent variable. The economic data (market room price, tourist area, coastal business, resort room numbers, and beach attendance) were collected from open-source data, the official resort's website and brochure, and tourist guidelines provided by the tourism ministry with the assistance and guidance of academic tourist staff. Additionally, Google Earth tools were utilized to collect the environmental data (beach width and length), which could contain minor errors and could produce relevant errors in the tourist revenues loss. The loss estimations are expected to exacerbate when considering the entire season, rather than only 15 days of the high season. In addition, planned expansion projects and investment plans will be affected due to the probable decline in tourist numbers as a result of the deterioration of beach features and recreational activities.

Conserving and protecting beaches, particularly popular tourist beaches, is therefore the main priority for researchers, engineers, and stakeholders to ensure the survival of the tourism industry in Egypt. Further research and the implementation of protection procedures to prevent deterioration are required. In addition, existing protection measures for coastal inundation, which include hard structures (seawalls, revetments, etc.) and soft solutions, should be implemented. Environmentally soft protection measures, such as sand nourishment and sand geotextile containers, are highly recommended, considering the environmental conditions of the study area along the Red Sea. Nourishment plans, if considered for protection, should be rationally addressed, and environmental impact assessments must be conducted on a regular basis. Furthermore, sand sources should be carefully selected [31].

4. Conclusions

In this study, the relationship between beach erosion due to inundation via SLR and beach-tourism revenues was investigated along 14 km of the coast of Sahl Hasheesh and Makadi Bay in the Hurghada region, using the hedonic pricing method. Beach erosion due to SLR reduces the beach width, which, in turn, affects the existing tourism facilities and beach activities. For the lowest scenario (RCP2.6 SLR), and using average coastal slope 0.06, a 5.4-m retreat in the beach width along the investigated coast, representing 8–27% of the available beach width, is expected by the year 2100. This will contribute to an economic loss in resort revenues in this region of 3%, 7%, and 18% in 2030, 2050, and 2100, respectively. For the worst-case scenario (RCP8.5 SLR), and using average coastal slope 0.06, a 9.2-m retreat in the beach width along the study area, representing 13–46% of the available beach width, is expected by 2100. The relevant economic loss in the resort revenues are expected to be 5%, 12%, and 30% in 2030, 2050, and 2100, respectively. The losses in resort revenues were estimated for a 15-day period in the high season, and the expected percentage of the total loss in resort revenues are 35% and 55% in 2100 for RCP2.6 and RCP8.5 SLR, respectively, when the coastal slope is 0.03. Otherwise, the loss percentage is ranged from 9 to 16% in 2100 for RCP2.6 and RCP8.5 SLR, respectively, when the coastal slope is 0.12. The results of this study provide an indicator of the expected loss in beach-tourism resort revenues due to SLR, which should be addressed by coastal managers and stakeholders in Egypt to prevent significant losses from being incurred by the tourism industry.

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