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Willingness to restore jetty-created erosion at a famous tourism beach

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ABSTRACT

This research revealed the intangible benefit of preserving the downdrift eroded shoreline at Cha-Am beach, Thailand. It integrated coastal engineering and environmental economics to urge for the beach restoration. Although providing some benefits, the jetty at Cha-am beach has also created severe downdrift coastal erosion. The research began with gathering the field data required to simulate the future shoreline position. After a satisfactory model calibration was attained, the future coastline change was predicted. It was found that the updrift part of the beach would be widened by approximately 8 m/yr, while the downdrift side of the jetty would experience severe coastal erosion by as much as 13 m/yr. A valuation of the downdrift eroded shore was consequently undertaken using a willingness-to-pay (WTP) study. Four hundred sets of questionnaires were surveyed using 10 different bid amounts. A logit model was implemented and the mean WTP was analyzed. It was found that the value of the downdrift eroding shoreline was approximately THB 20.1 billion or USD 609.9 million per year. Such a huge non-market value of the downdrift beach might urge decision makers to initiate certain continuous beach restoration measures.

1. Introduction

Coastal erosion has been a problem in many countries around the world (Boateng, 2012; Cao and Wong, 2007; Cellone et al., 2016; Fitton et al., 2016; Martínez et al., 2018; Rangel-Buitrago et al., 2018). It has damaged land, property, and infrastructure (Mukhopadhyay et al., 2018; Saengsupavanich et al., 2009). Coastal erosion is a result of both human activities and environmental changes. Human intervention alters the coastal dynamics, especially waves and currents which link with sediment transport and beach morphology (Pranzini et al., 2018). Coastal structures such as offshore breakwaters, jetties, and groins induce wave diffraction and changes in sediment movement, often resulting in updrift accretion and downdrift erosion. The erosion is also a result of mangrove destruction and its conversion to aquaculture because the natural erosion buffer is destroyed (Anthony and Gratiot, 2012; Saengsupavanich, 2013). In some cases, the erosion is resulted from decreased alluvial sediment supply (Wang et al., 2012). Dams or land use changes reduce sediment discharge, altering coastal sediment balance. Moreover, land consolidation, groundwater pumping as well as petroleum exploitation create coastal subsidence (Nutalaya and Rau, 1981; Lio and Tosi, 2018), exposing the shore to bigger waves.

A jetty is a coastal structure that orients perpendicularly to the shore in order to prevent longshore sediment from depositing in river mouths or inlets. Its side-effects have been identified in the literature (Leont'yev, 2007; Kamphuis, 2000). The updrift side of the jetty experiences sediment deposition because the alongshore sediment transport is intercepted by the structure (Garel et al., 2015; Thiruvenkatasamy and Girija, 2014). On the downdrift side, coastal erosion occurs (Flor-Blanco et al., 2015). The accreted side usually creates positive side effects such as widening the beach, increasing tourist activities, and fostering beach-related businesses. In contrast, the eroded side is continuously swallowed by the ocean, damaging properties and livelihoods. Management options are available (Isla et al., 2018; Williams et al., 2018), but putting them into action requires some considerations, particularly regarding their economic feasibility, as every erosion measure involves financial investments and returns. Like other coastal projects (Huxham et al., 2015; Oh et al., 2018; Roebeling et al., 2018; Segura et al., 2018), if the return is greater than the cost, the erosion measure may proceed. Sometimes, the downdrift erosion management bears a huge investment cost that the return cannot cover financially. Non-use values of the eroding beach may play a vital role in increasing the benefits of the coastal protection, enabling decision makers to convert intangible benefits into monetary value. This research integrated coastal engineering and environmental economics and used Cha-Am beach, one of the most visited beaches in Thailand as a demonstration. Other beach managers may undertake a similar approach to support the downdrift erosion management in their countries.

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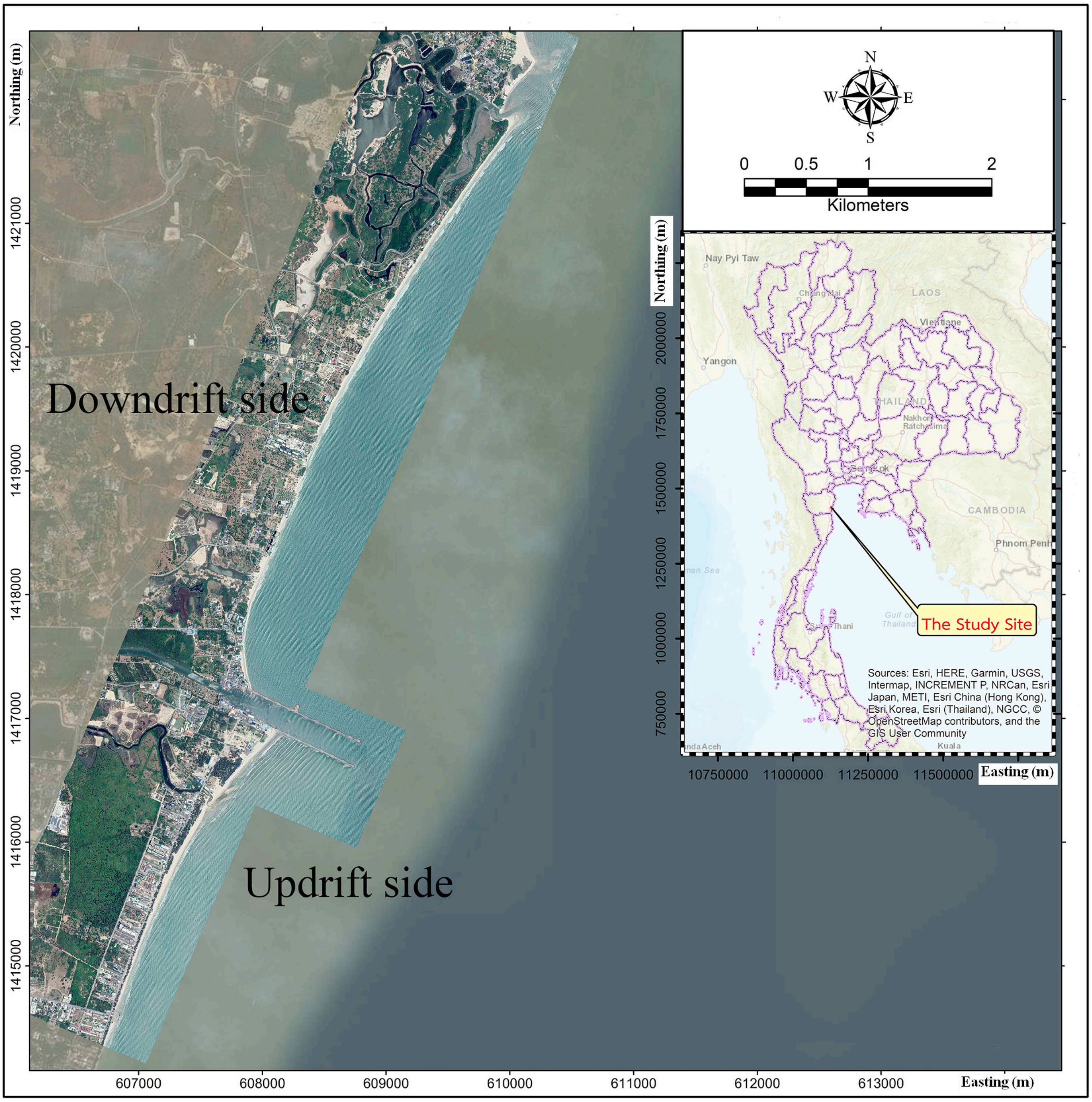

Fig. 1. Cha-Am beach.

1.1. Study site

Cha-Am is a district in Phetchaburi province, Thailand (Fig. 1). Cha-am beach is a popular recreational beach with more than 5 million visitors per year ((Department of Tourism, 2018; Tourism Authority of Thailand, 2018). One of the reasons that the stretch of the beach at Cha-Am is long and wide is because of a jetty at the Cha-Am canal. The jetty extends approximately 1 km from the shoreline, intercepting all alongshore sediment transport within the surf zone. The jetty was constructed more than 20 years ago, resulting in sediment building up on the updrift side while eroding the downdrift side annually (Fig. 2). Based on an overlay of past satellite images (from 2014 to 2018), the author analyzed the coastal change around the jetty. On the updrift side, the jetty induced sediment deposition by as much as 19 m/yr within 100 m from the structure, and the deposition gradually reduced further away. The ever-widening beach on the updrift side became an important tourism location. Along the downdrift part, man-made coastal erosion was evident. The downdrift beach has continued to disappear and this forced some property owners to put up their own concrete revetments. Although the revetments could protect the properties in front of them, they postponed the erosion further downdrift. The erosion rate at the end of the existing revetment was approximately 6.8 m/yr.

2. Methods

This research was a multi-disciplinary study, intertwining coastal engineering and ecological economics. The coastal engineering predicted future shoreline response due to the jetty while the environmental economics monetized value of the eroded beach.

2.1. Data gathering

A bathymetric map was surveyed by using echo-sounding in August 2018. The average beach slope was approximately 1:50 to a depth of-2 m relative to the national mean sea level (MSL) then 1:420 to a depth of −5 m MSL (Fig. 3). Twenty-five years of wind data from the nearest meteorological station recorded by the Thai Meteorological Department

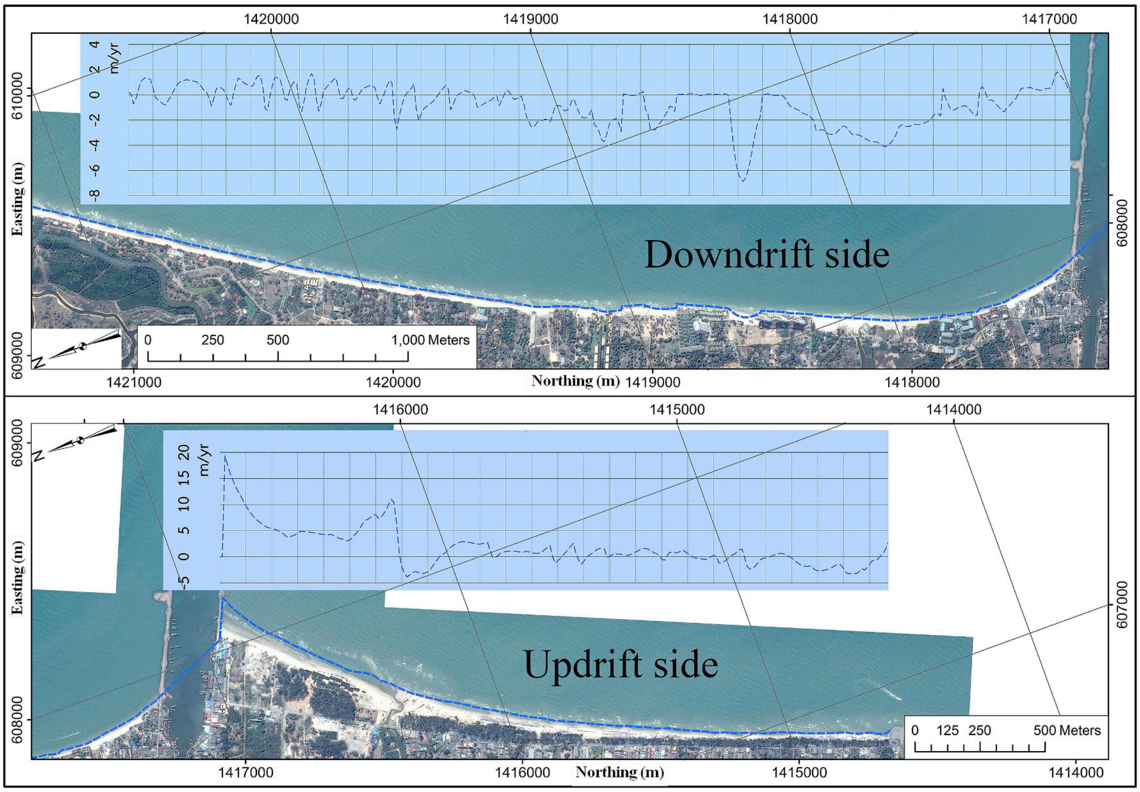

Fig. 2. Coastal change rate from 2014 to 2018 (The background image is the study site in 2014, while the dotted blue line is the digitized 2018 shoreline) (positive rate means coastal accretion and negative rate means erosion). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

was averaged to obtain the annual wind rose. The annual wave rose was then synthesized by JONSWAP method (Kamphuis, 2000). The wave characteristic at Cha-Am beach was moderate and the predominant wave direction was south-southeast (SSE) (Fig. 3), indicating that alongshore sediment moved from south to north. High waves (larger than 3 m) occurred during February to April. Tidal information was gathered from the Marine Department and all elevations were referred to the MSL. Local mean sea level was 0.11 m MSL. The long-term tidal record indicated that the tidal range during neap tide was roughly 1.24 m, and 1.72 m during spring tide. Beach sediments were sampled and examined by the sieve-hydrometer analysis. The sand on beach berm had a median diameter (D_{50}) of 0.33 mm, but the grain size reduced to 0.22 mm in the surf zone. Such information provided the necessary inputs for predicting the future shoreline at Cha-am beach.

2.2. Future shoreline prediction

Shoreline change in the vicinity of the jetty was predicted using the LITPACK software package (DHI, 2018). It is a one-line model that relies on the continuity equation for sediment volumes (Eq. (1)). The software is able to forecast the behavior of a non-cohesive beach due to effects of coastal structures and has been applied by numerous researchers (Khalifa et al., 2017; Noujas and Thomas, 2018; Prasad et al., 2016; Saengsupavanich, 2012). Necessary inputs to the LITPACK simulation were shoreline positions digitized from past satellite images, beach profiles extracted from the surveyed bathymetry, sediment properties, annual wave climate, tidal information, and the locations of existing coastal structures (Nassar et al., 2018).

$$\frac{\partial y_c(x)}{\partial t} = -\frac{1}{h_{act}(x)}\frac{\partial Q(x)}{\partial x} + \frac{Q_{sou}(x)}{h_{act}(x)\Delta x} \quad (1)$$

where $y_c(x)$ is the coastline position from baseline (m), t is time (s), $Q(x)$ is longshore transport rate (m^3/s), and $Q_{sou}(x)$ is the supply of sediment from sources (m^3/s). The total height of the active profile $h_{act}(x)$ consists of three contributions; the active depth relative to mean water level, the height of the beach above mean water level, and possible dunes which may erode if the coastline reaches their position during erosive states, but will not accrete again (DHI, 2018).

Another important step in simulating the future shoreline was model calibration. The 2014 (Pleiades) and 2018 (WorldView3) satellite images were acquired since they were taken roughly in the same period during summer (March and April). Time of imaging was approximately 10:30 a.m. (GISTDA, 2019). Tidal elevation at the time of imaging was used to adjust shoreline position. Comparing the satellite photos taken from different seasons might lead to misinterpretation. The 2014 digitized shoreline was used as the starting point to predict the 2018 shoreline. A grid step of 10 m was chosen. All existing coastal structures were inserted into the simulation. No sediment discharge from the canal was added to the LITPACK simulation. Based on the surveyed bathymetry, there was no shoal at the tip of the jetty. Therefore, it was assumed that the sediment discharged from the canal was negligible. The simulated 2018 shoreline position was then compared with the digitized one (Fig. 4). The root-mean-square-error (RMSE) was calculated. Calibration parameters were the height of the active beach (being 3 m) and the active depth (being 3 m). The sediment transport table was not modified. The calibration result yielded a RMSE value of 5.35 m. After the satisfactory model setup was achieved, the future shoreline position in the next 25 years was simulated and then later used for the willingness-to-pay study.

2.3. Contingent valuation and survey design

Willingness-to-pay (WTP) has been applied in various non-market valuations. It has been a main tool for coastal conservation and management (Alves et al., 2015; Halkos and Matsiori, 2018; Piriyapada and Wang, 2014). There are a number of studies on coastal erosion

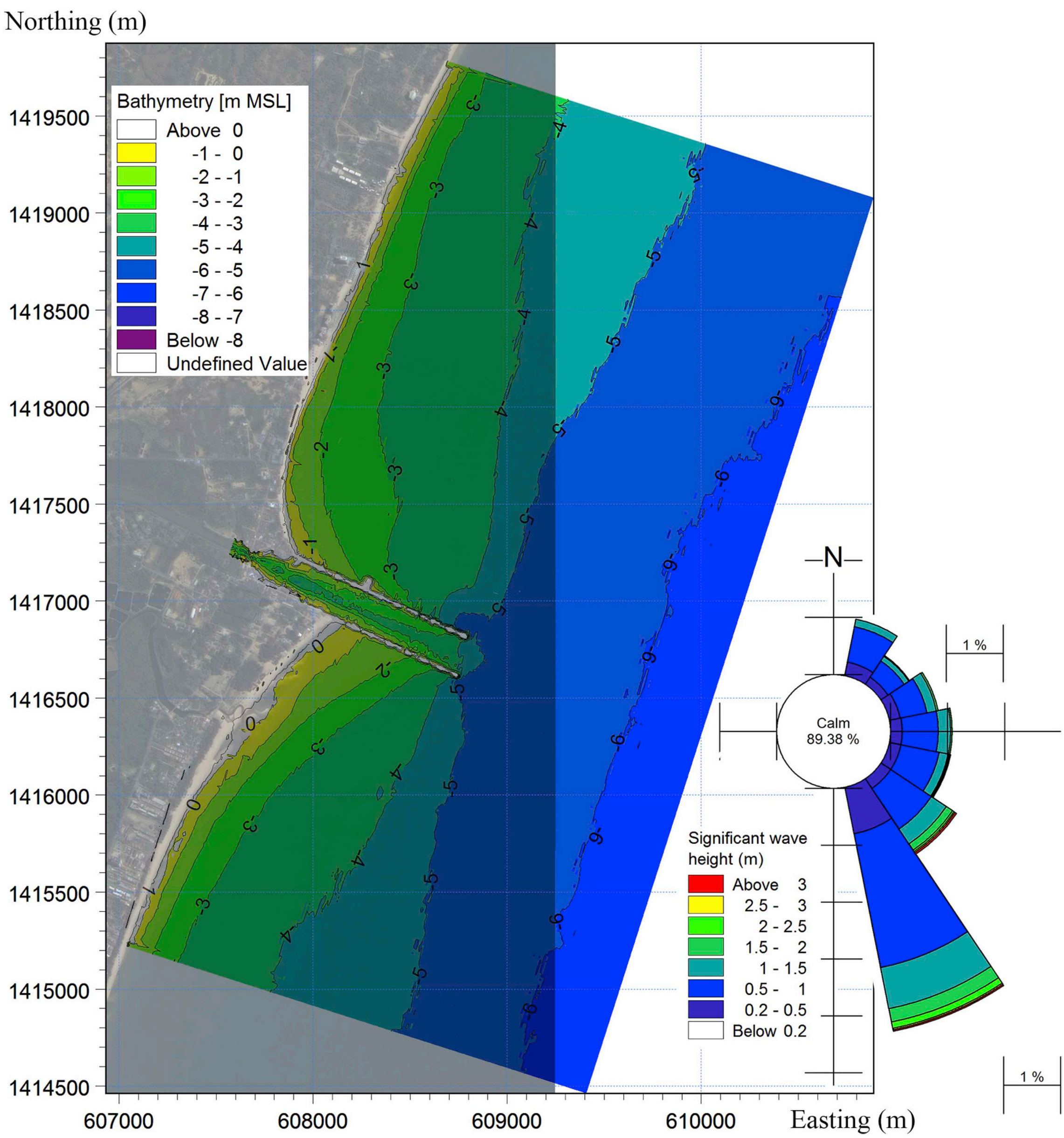

Fig. 3. Bathymetric map and annual wave climate at the study site.

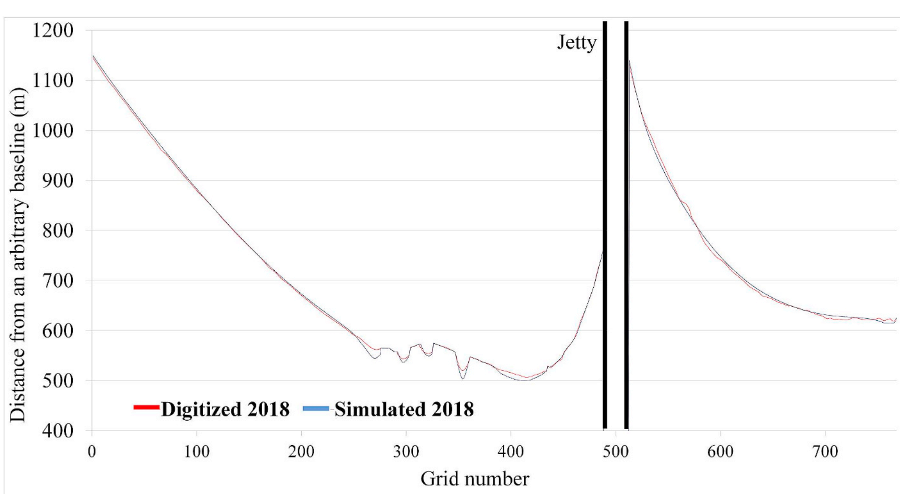

Fig. 4. LITPACK calibration result (each grid is 10 m).

management that apply WTP to demonstrate the necessity of coastal protection (Dribek and Voltaire, 2017; Marzetti et al., 2016; Saengsupavanich et al., 2008). The underlying logic is that individuals are willing to pay for goods or services that are currently not available. For this study, the payment's objective was to "buy sand to restore the downdrift eroding beach". The beach nourishment had to be undertaken every month, demanding a continuous flow of monetary contributions from the respondents. A critical assumption was that the interviewees were able to translate a wide range of criteria into a single monetary amount, representing their voluntary monthly payment.

The research applied the dichotomous choice (DC) approach to elicit respondents' WTP in order to restore the jetty-created downdrift erosion. The DC approach was used because the respondents could be assisted to complete a valuation process by choosing between "to pay" or "not to pay" (Venkatachalam, 2004). The take-it-or-leave-it scenario was quite similar to that encountered by consumers in their usual market transactions (Asafu-Adjaye and Tapsuwan, 2008). Strategic behavior might be minimized in the DC technique since it was incentive-compatible (Carson et al., 1996, 2001; Hanemann, 1994; Venkatachalam, 2004). A single-bounded approach was utilized in this study because it does not suffer from the "yes-saying" effect, the indignation and guilt effect, and the weariness effect (Bateman et al., 2001; Yoo and Kwak, 2009).

The questionnaire was designed to provide respondents with adequate and accurate information. Thirty sets of questionnaires were initially used to test their validity and to elicit the likely range for the payment amount, but excluded from the WTP analysis. After some adjustments were made to the initial questionnaire, 400 interviewees were consulted for the WTP analysis. The interviewed respondents were tourists on the beach, business operators of resorts and restaurants, and their employees at the updrift side. The people at the updrift area gained benefits from the sediment deposition so they had a sense of paying to restore the downdrift beach. Moreover, there were very few people along the downdrift area since the downdrift beach was very narrow, thus no tourism activity existed.

The interview was divided into three parts. The first part explained the future shoreline in the next 25 years with illustrations to facilitate the interviewees' understanding. They were also informed that there was no right or wrong answer and their sincere responses would be appreciated. The second section of the questionnaire contained questions on WTP. Bid amounts were THB 20, 50, 100, 150, 200, 300, 500, 800, 1,000, and 1500 per month (USD 1 equals about THB 33). In order to attain the 95% confidence level with 5% precision level, four hundred sets of the WTP questionnaires were collected (Yamane, 1967). Forty people were interviewed for each bid amount. The THB 1500/month bid was selected as the highest bid because almost 100% rejection was achieved, while the THB 20/month bid was chosen as the lowest bid since it achieved almost 100% acceptance. Respondents were also asked to state their determination for whether they would actually be able to pay the amount they stated as a measure of the sincerity of their answers. If they were not sure (confidence level lower than 50%), it was assumed that they had not answered sincerely and their responses were taken as "no" (Amirnejad et al., 2006). The last section of the questionnaire contained personal social, economic, and demographic information of the respondent such as gender, age, income level, occupation, educational level, and frequency of beach visits.

When faced with binary choice situations, the logit model is preferred (Asafu-Adjaye and Tapsuwan, 2008; Hanemann and Kanninen, 1999; Saengsupavanich et al., 2008). For the logit model, the probability of saying "yes" (P) by an individual is given by Eq. (2).

$$P(yes) = \frac{1}{1 + \exp(-\alpha + \beta A)} \tag{2}$$

where β is a coefficient of the bid parameter (A). Socio-economic factors were also considered in this study because they might influence the probability of a "yes" response. Where the WTP must be greater than or equal to zero, Eq. (3) applies:

$$\text{Mean WTP for logit model} = \frac{\ln(\exp^{\alpha^*} + 1)}{\beta} \tag{3}$$

where $\alpha *$is the adjusted intercept which is added by socio-economic terms to the original intercept term of α ($\alpha * = \alpha + \gamma\, Y + \theta\, S$)(Amirnejad et al., 2006). The income factor (Y) was expected to have the positive income coefficient (γ). The coefficient of the bid amount (β) would have a negative sign. For other socio-economic parameters (S), their coefficients (θ) could be either positive or negative. Calculations were performed by the LIMDEP software.

3. Results

The result section is divided into two parts. This first part provides the prediction of the future shoreline which in turn was used to produce a scenario for the WTP interview. The second part discusses the WTP analysis.

3.1. Future shoreline in the next 25 years

The calibrated LITPACK simulation indicated that the jetty would continue to intercept all alongshore sediment transport. The updrift part of the beach would be widened by as much as 200 m or approximately 8 m/yr. The deposition rate would gradually decrease farther away from the jetty. On the other hand, the downdrift side of the jetty would experience severe coastal erosion. The erosion would happen at some distance away from the jetty since some land owners who lived next to the jetty had already constructed their own revetments (Fig. 5). The existing revetments at around 0–700 m from the jetty as well as the intermittent revetments at 1000–2000 m from the jetty postponed the erosion further downdrift. The erosion would happen between gaps of the adjacent revetments and the most severe erosion by as much as 13 m/yr would occur at the end point of the last revetment. The downdrift beach berm width would be narrow and a lot of properties would be devastated. These findings were artistically illustrated and then used to assist visualization for the respondents during the WTP interviews (Fig. 6).

3.2. The WTP result

After 400 sets of the WTP questionnaire had been completed, characteristics of the interviewees were obtained and the mean WTP was calculated. The numbers of male and female respondents were roughly equal. The average age of the interviewees was 36.5 years, with the average income of THB 16,987/month. Other socio-economic characteristics are summarized in Table 1. Responses on WTP are summarized in Table 2.

The logit model was utilized. It was found that the requested bid was the only statistically significant variable at the 5% level (Table 3). The model was re-analyzed by taking out the statistically insignificant variables (Table 4). Then, the mean WTP was calculated (Eq. (4)):

$$\begin{aligned} Mean\ \ WTP &= \frac{\ln(\exp^{-0.286698} + 1)}{0.001979} \\ &= \text{THB 283/month (or approximately USD 8.58} \\ &\quad \text{/month or USD 102.96/yr)} \end{aligned} \tag{4}$$

Considering the annual number of visitors at Cha-am beach allowed the author to realize how much value the eroded beach had. According to the Department of Tourism, there were 5,700,319 visitors to Cha-am beach in 2014 and this increased to 5,923,321 visitors in 2015 (Department of Tourism, 2018). Multiplying the number of visitors in 2015 with the mean WTP yielded the annual value of the downdrift eroding shoreline; being approximately THB 20.1 billion or USD 609.9 million.

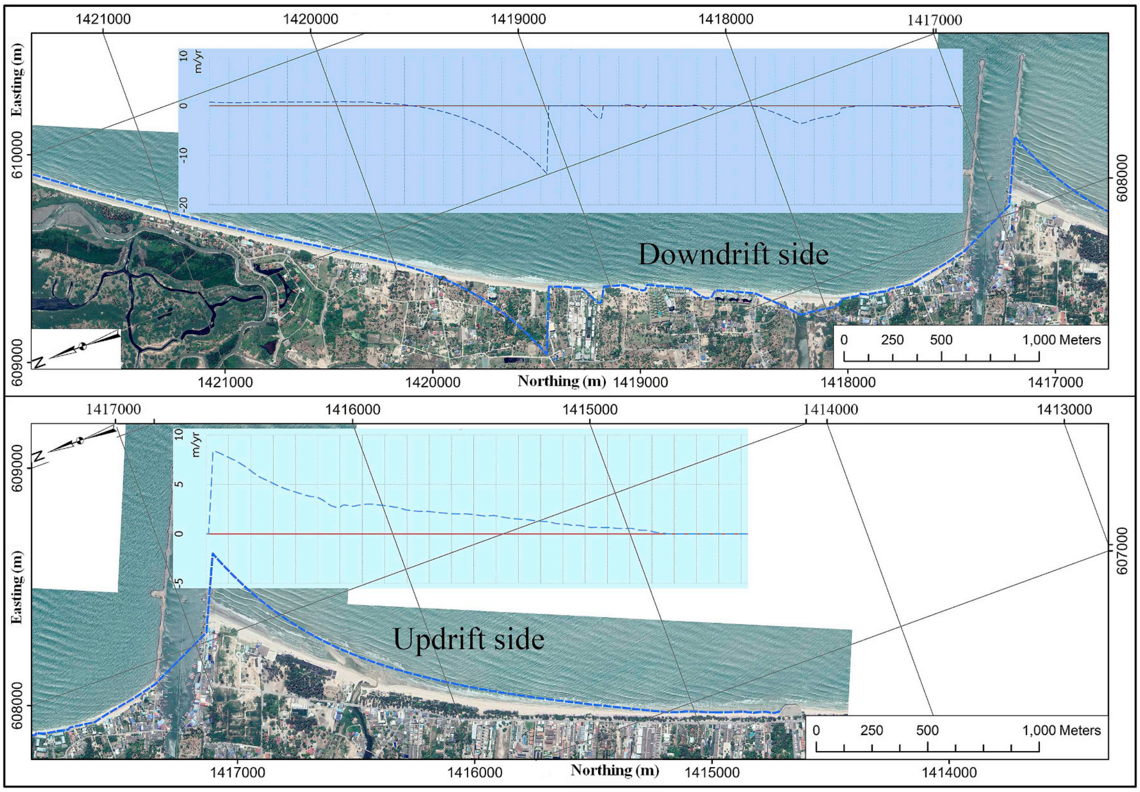

Fig. 5. Simulation of 2043 shoreline (blue dotted line) using the 2018 satellite image as the background (positive rate means coastal accretion and negative rate means erosion). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

4. Discussion

Literature on WTP for erosion protection and beach nourishment was surveyed in order to compare with this study. Silberman et al. (1992) found that the mean WTP (one-time contribution) for the nourished beach in New Jersey ranged from 9.34 USD to 19.65 USD. Logar and van den Bergh (2014) examined the WTP of beach visitors for preventing beach erosion in the form of daily beach entrance fees in Crikvenica, Croatia and found that the stated WTP per adult per day for avoiding beach erosion was 1.69 EUR for the paid beach and 2.08 EUR for the free beach. Alves et al. (2015) reported that 86.5% of the interviewees were conscious of beach erosion in Cadiz, Spain, and found that the mean WTP for beach improvement was 1.66 EUR per adult and visit. In French, Rulleau and Rey-Valette (2013) found that the mean WTP for beach protection on the French Mediterranean was 36.4 EUR per household per year. Dribek and Voltaire (2017) reported that Djerba Island (Tunisia) experienced critical coastal erosion and found that the tourists and residents on the island were willing to pay 5.02 EUR/yr and 5.09 EUR/yr respectively for the government to protect the coastline. Koutrakis et al. (2011) explored the WTP for beach protection

Fig. 6. Artistic impressions to assist respondents in the WTP interview.

Table 1
Characteristics of respondents.

Characteristic	Number of respondents (n = 400)
Gender	
Male	192 (48%)
Female	208 (52%)
Occupation	
Personal business	44 (11.00%)
Laboring	99 (24.75%)
Governmental officer	34 (8.50%)
Company employee	88 (22.00%)
Selling things	74 (18.50%)
Others and unemployed	61 (15.25%)
Visit frequency per year	
once	201 (50.25%)
2 times	63 (15.75%)
3 times	28 (7.00%)
4 times	17 (4.25%)
more than 4 times	91 (22.75%)
Living in Cha-am	
Yes	62 (15.50%)
No	338 (84.50%)
Educational level	
Uneducated	4 (1.00%)
4th grade (6 years of education)	26 (6.50%)
6th grade (8 years of education)	36 (9.00%)
9th grade (11 years of education)	54 (13.50%)
High school (14 years of education)	115 (28.75%)
Bachelor degree (18 years of education)	154 (38.50%)
Higher than Bachelor degree	11 (2.75%)

Variable	Mean	Standard Deviation
Monthly income (THB)	16,987.5	7665.5
Age (years)	36.46	11.86

Table 2
Distribution of WTP responses (total number of respondents = 400).

Requested bid amount (THB/month)	"Yes" frequency	"No" frequency
20	25 (62.50%)	15 (37.50%)
50	19 (47.50%)	21 (52.50%)
100	12 (30.00%)	28 (70.00%)
150	10 (25.00%)	30 (75.00%)
200	11 (27.50%)	29 (72.50%)
300	10 (25.00%)	30 (75.00%)
500	6 (15.00%)	34 (85.00%)
800	6 (15.00%)	34 (85.00%)
1000	7 (17.50%)	33 (82.50%)
1500	1 (2.50%)	39 (97.50%)

Table 3
Results of the logit model, including all variables.

Parameter	Coefficient	P Value
Constant	−0.744454	0.3018
Requested bid (THB/month)	−0.002001	0.0000
Gender	−0.511921	0.1785
Age (years)	−0.005905	0.5961
Monthly income (THB)	0.000003	0.8608
Educational level (years)	−0.039225	0.2560
Visit frequency	−0.052719	0.3232
Living in Cha-am	0.730040	0.1394

Table 4
Results of the logit model, removing all statistically insignificant variables.

Parameter	Coefficient	P Value
Constant	−0.286696	0.0689
Requested bid (THB/month)	−0.001979	0.0000

in three European countries: Nestos Delta coastal zone (Greece), Languedoc-Roussillon Region (France), and Emilia-Romagna Region and Liguria Region (Italy) and found that the mean WTP was 1.49–1.99 EUR for Greece, 0.77–3.94 EUR for France, and 0.50–2.86 EUR for Italy. Landry et al. (2003) examined economic efficiency of beach nourishment on Tybee Island (Georgia, USA) and found that the annual mean WTP for beach nourishment ranged from 6,070,167 USD to 8,821,697 USD. Rodella et al. (2019) evaluated the economic value related to beach preservation in Italy and found that the respondents would be willing to pay 14.84 EUR/yr per user in order to preserve the beach. Finally, a study in Thailand by Saengsupavanich et al. (2008) estimated a value of a local tourism beach that suffered from port-induced erosion and found that the mean WTP of a beach visitor was 25.6 USD/yr. Although results from these studies were different, they implied the same principle that coastal erosion induced both tangible and intangible economic losses and should be managed.

Cha-am beach is one of the most famous tourism destinations in Thailand. Its importance as a tourist attraction partly originates from its wide sandy beach, where a variety of tourism activities take place. However, the wide beach did not occur naturally, but was the side-effect of the jetty constructed at the Cha-Am canal. While producing numerous benefits such as preventing sediment deposition in the navigational channel, mitigating inland flooding, and widening the updrift beach, the jetty induced severe downdrift coastal erosion. Some private land owners constructed their own coastal defense, while waiting for the government to rectify the problem. Unfortunately, the government had not been successful in solving the problem.

One of the obstacles for the government might be that sustainably solving the downdrift coastal erosion would require a continuous annual budget allocation, which is almost impractical in Thailand. Annual beach nourishment along the downdrift coastline is a possible but unlikely solution. Although the nourishment project might be allocated funding initially, it would inevitably fail if the budget were not allocated in successive years.

This study forecasted what would happen in the next 25 years if no mitigation measures were taken. The downdrift coastline would experience severe erosion by as much as 13 m/yr, while the updrift coastline continued to deposit. Such a clear contrast discriminated between the livelihoods of the people living either side of the jetty. This article attempted to show that the downdrift eroded beach not only had a market value, but also a large non-market value. If preserved, the downdrift eroded beach could produce annual non-market benefits of approximately THB 20.1 billion or USD 609.9 million. This figure might play an important role in how decision makers choose to manage Cha-am beach.

Other implications can be made from this study. The non-market value of the downdrift eroding beach might be equated to the valuation of the negative impacts on the shoreline produced by the jetty. Currently in Thailand, after a new Act to promote the management of marine and coastal resource was enforced in 2015 (Department of Marine and Coastal Resources, 2018), there have been discussions on deconstructing coastal structures interrupting alongshore sediment transport. Monetizing both the benefits and disadvantages of the impacts of the coastal structures can be a key to determine which way to proceed.

5. Conclusions

This research presented an integrated approach between coastal engineering and environmental economics to manage the coastal erosion problem induced by the jetty at Cha-am beach, Thailand. Although providing some benefits, the jetty has also created severe downdrift erosion which, if neglected, would swallow land by as much as 13 m/yr. The coastal erosion originated by the interception of alongshore sediment transport requires mitigation measures that must continue for as long as the alongshore sediment is still trapped. A market value of the erosion-prone area alone might not be sufficient to persuade the Thailand government to initiate any unceasing beach restoration measures. Non-use values of the eroded beach reflected the intangible benefits of protecting the downdrift beach. Developing the coastal area and looking after the negative externality should be coupled so that sustainable coastal development might be achieved in the end.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2019.104817.

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