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# Are Current UK Coastal Defences Good Enough for Tomorrow? An Assessment of Vulnerability to Coastal Erosion

Komali Kantamaneni[a], Louis Rice[b], Xiaoping Du[c], Belqais Allali[d] and Komali Yenneti[e,f]

[a]Faculty of Science and Technology, University of Central Lancashire, Preston, UK; [b]Centre for Architecture and Built Environment Research, University of the West of England, Bristol, UK; [c]Key Laboratory of Digital Earth, Institute of Remote Sensing and Digital Earth (RADI), Chinese Academy of Sciences, Beijing, China; [d]School of Science, Engineering & Environment, University of Salford, Salford, UK; [e]School of Architecture and Built Environment, University of Wolverhampton, Wolverhampton, UK; [f]Australia India Institute, University of Melbourne, Parkville, Australia

## ABSTRACT

Coastal vulnerability and its physical, economic and social consequences at national and international scales is of high scientific, political and policy interest. Anthropogenic climate change and coastal erosion threaten the very fabric of a society. Indications, that coastal hazards are impacting diverse coastal areas severely across the world, and it is no longer a vague future threat that can't be ignored. Rising eustatic sea levels synthesized by the growing frequency and scale of coastal hazards like storm surges, coastal erosion and coastal landslides threaten low-lying and unprotected coastal areas in the United Kingdom even if they have coastal defenses. However, there is still significant uncertainty about the degree of vulnerability along different coastal stretches, particularly in England. To fill this uncertainty, the current study estimated the coastal vulnerability of the coastal erosion hotspot Camber, England, by establishing a coastal vulnerability index. This index was developed by compounding various existing parameters and termed as Erosion Coastal Vulnerability Index (ECVI). Results illustrate that 67% of coastal area fall between high and very high vulnerability categories, and current coastal defenses are not strong enough to tackle the severe coastal erosion in Camber. Within the evaluation, thematic maps were generated to enable the intensity of the vulnerability for different coastal stretches to be identified. The evaluated vulnerable hotspot should be treated urgently by regional and national policy organizations to ameliorate the impacts of coastal erosion and other associated risks. Without action, the hotspot is likely to encounter unprecedented new vulnerabilities, disasters and humanitarian catastrophes. The current study results allow for a local, regional and national comparison that may help to evaluate changes in coastal erosion vulnerability.

**KEYWORDS**
Camber; climate change; coastal defenses; coastal erosion; coastal vulnerability; sea level rise

**CONTACT** Komali Kantamaneni kkantamaneni@uclan.ac.uk Faculty of Science and Technology, University of Central Lancashire, Preston, UK.

## 1. Introduction

Coastal erosion is a worldwide phenomenon. On a global scale, for the period of 1984–2015, the loss of permanent land in coastal areas amounts to nearly 28,000 km2 which is roughly equivalent to the area of Haiti (Mentaschi et al. 2018). However, the erosion rate is not even across various continental coastal stretches. The highest coastal erosion was observed at the delta of Indus river which stretches between India and Pakistan (Kalhoro et al. 2016). The recent projections given by the IPCC (Intergovernmental Panel on Climate Change 2019), 2019 specify that the global sea level raised more than expected levels, and future storms will be more intense with strong hurricane winds. Furthermore, these anticipated changes in the rate of sea-level rise, due to both the regional and global warming, would have significant impacts on the coastal areas, geomorphological structures and coastal infrastructure (Dawson et al. 2018; Langridge et al. 2014; Nicholls 2011; Nicholls et al. 2007; Tol, Klein, and Nicholls 2008). The protection and management of the coasts will be a significant problem in the future because of these various coastal threats and risk (Hallegatte et al. 2013). The majority of coastal erosion problems is increased by human action and artificially stabilized seafronts (Gracia et al. 2018; Pranzini 2018; Sánchez-Arcilla et al. 2016). Globally, between 20 and 90% of the current coastal wetland area is predicted to be lost by 2100, depending on diverse situations of climate change and associated factors (Blankespoor, Dasgupta, and Laplante 2014; Ward et al. 2016). Inland soil erosion stimulated by rainfall trends and the movement along riverbeds results in significant quantities of sediments to the coast (Salman, Lombardo, and Doody 2004). According to EUROSION (2004) statistics, 28% of Europe's sandy and gravel shorelines are eroding and this percentage will be increased in the near future. For the period of 1999–2002, nearly three hundred houses were uninhabited across the Europe due to coastal erosion risk and an additional 3,000 houses' market value was reduced by at least 10%(McInnes, Fairbank, and Jakeways 2006). Contending with coastal erosion can result in problems in different geographical areas, depending on the type of measures taken for the estimation of erosion rate (Kantamaneni et al. 2018). However, understanding the varying nature of the coastal verge is an important element in managing coastal erosion (Kantamaneni and Phillips 2016).

While the UK coast has been severely altered through human interventions, it is one of the most degrading shoreline countries in the Europe (Pontee and Parsons 2010). The United Kingdom (UK) has the longest coastline of Europe i.e., 17,381 km and bounded by four water bodies (Atlantic ocean, North Sea, Irish Sea and English Channel) (Masselink et al. 2020) and contains four administrative regions: England, Wales, Scotland and Northern Ireland. Coastal erosion and vulnerability is not even across the country and rising SLR (sea level rise) and flooding are two of the main causes for erosion vulnerability (Kantamaneni, Gallagher, and Du 2019). The English coast is more vulnerable than Wales. Interestingly, the majority of coastal sites in Scotland are not under threat of erosion due to isostatic land uplift (Graham Allsop, Hambly, and Dawson 2017). Coastal erosion is not a significant and immediate concern in Northern Ireland too, owing to the water currents and landscape of the coastal geology (Zsamboky et al. 2011). High onshore waves quicken coastal erosion rate and damage the rail network, sea walls and other coastal infrastructures in the UK. The latest UK sea-level rise predictions are higher than earlier estimates, suggesting increased coastal-flood risk across the country (Haigh et al. 2020). Coastal infrastructure in several coastal areas will be highly vulnerable to the increased rates of erosion, flood and weather fluctuations (Haigh et al. 2020; Kantamaneni and Phillips 2016). However, coastal erosion is highly determined by site-specific elements such as topology, landscape, geology, coastal hazards and climate change, etc. A deeper understanding of the vibrant nature of the coastal verge is an important element in managing coastal erosion (Hinrichsen 2016).

Already 17% of the UK coastline is affected by erosion (Masselink et al. 2020). In the UK, more than six million properties including 5.2 million English properties and 220,000 Welsh properties are at risk from river and sea floods under the current scenarios (Moores and Rees 2011). According to the British Geological Survey (BGS) (2012) 113,000 residential and 9000 commercial properties are at risk of coastal erosion across the Wales and England and this number will increase. Yearly damage to properties due to flooding: in between £1.7 and £4.5 billion by the 2050, this rising to about £2.1 and £6.2 billion by the 2080s (Ramsbottom, Sayers, and Panzeri 2012). In the UK, nearly 1,600km of road, >90 railways stations and 12 substations and several nuclear power stations could be affected by coastal erosion or flood risk by 2100. The estimated flooding and coastal change costs per year will be £1 billion per year (Climate Change Commmittee 2020). However, erosion risk depends on the coastal defenses in a particular area.

Substantial extra investment will be needed to support coastal defenses in highly eroding sites. However, to know the level of erosion risk in UK coastal erosion sites at current scenarios, coastal erosion vulnerability assessment is needed. Therefore, the current study assesses the erosion vulnerability of one of the UK hotspots sites (Camber). The location was chosen based on evaluation derived from academic articles, reports and gray literature. Consequently, the research established a coastal erosion vulnerability index using various parameters to evaluate site specific vulnerability. In addition, GIS (geographic information system) based coastal erosion vulnerability maps were generated to identify the intensity of erosion at a coastal stretch.

## 2. Study area

### *2.1. Selection of coastal erosion hotspot*

Published work (literature) and recent events were used to recognize the coastal erosion hotspot with varying physical and economic characteristics. According to Climate Central (2020), several areas of East Sussex including Camber will be crumbled into the sea or would be totally submerged within 80 years if the climate change is not minimized. Due to these predictions, the current research has been selected Camber as case study for the assessment of coastal erosion vulnerability.

Camber is a coastal village (Figure 1) or small coastal town located in East Sussex, England at 50.936710 Latitude and 0.795299 Longitude. It has a 1,722 and 583 households (East Sussex City Council 2020). The population reaches up to 20,000 during the summer months and holidays, and this number creates more anthropogenic pressures in this coastal area. The village is positioned on the tip of the Romney Walland Marsh which is a large open marshland and low-lying area (Rother District Council

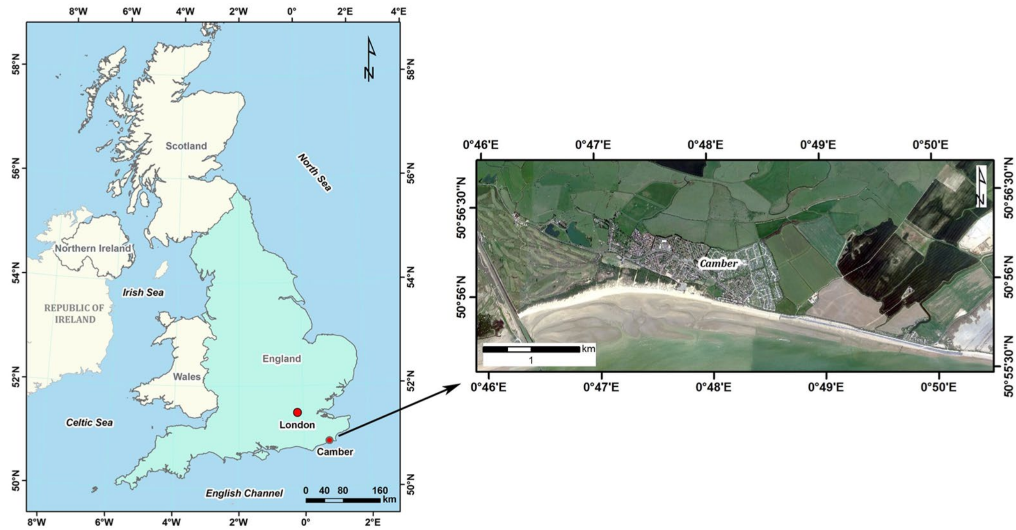


**Figure 1.** Study area – Camber coastal frontage.

2020). Originally this area was a salt marsh and submerged at high tides. Later, in the middle ages, it was reclaimed from the sea. Camber consists of a 2.5 km coastline but the current study evaluated the extended coastline which is 4.5 km as shown in Figure 1. A band of dunes are located at the southern edge of the village and these structures act as natural defenses by protecting the village from high winds and erosion (Rother District Council 2020). However, at present, the dunes are under higher threat from the pressure of visitors and high intensity winds. This further leads to faster erosion even at dunes area along with non-dunes area (some of the coastline has dunes and other part does not have the dunes). Coastal infrastructure development and redevelopment activities also impacts the coastline negatively. While the Camber coast is protected by three varieties of coastal defenses, however, these are not strong enough to fully protect the coast. In the UK as well as globally, several coastal defenses are used to protect the coasts/beaches as shown in Table 1 and Figure 2(a–c).

## 3. Methodology

Coastal vulnerability assessments have become a commonly used method in the field of environmental geography and associated subjects to provide policymakers with the knowledge and data they require in order to understand the impacts of climate change and to develop appropriate policies and to address adaptation measures and build resilience. Several different vulnerability methodologies and tools have been developed globally taking into account a range of factors including environmental, economic and social issues (and combinations thereof). In these existing methodologies, indicator- and index-based methods are more popular when compared with other methodological procedures. There have been a number of developments and refinements to these CVI methodologies over time. Gornitz and Kanciruk (1989) methodological procedure has

**Table 1.** Types of coastal/sea defenses modified from East Riding of Yorkshire Council (2020) (https://www.eastriding.gov.uk/coastalexplorer/pdf/4defendingtheercoastline.pdf).

| No | Type of coastal defence | Advantages | Disadvantages |
|---|---|---|---|
| 1 | *Sand dunes*<br>Either artificial or natural | • Helps energy divertissement<br>• Environmental/wildlife/ecological value. | • Vulnerable to coastal erosion |
| 2. | *Sea walls*<br>Several designs, either vertical or near vertical and made-up with stone or concrete wall | • Efficient in averting erosion.<br>• Protect from severe exposure and also act as a public walkway path<br>• Many types.<br>• Sung/secure for the community use | • Expensive to construct and maintain<br>• Little energy absorption<br>• High wave reflection<br>• High carbon footprint for concrete |
| 3. | *Groins*<br>Maintain beach levels<br>Prevent longshore sand movement | • Efficient in beach building<br>• Easy to construction with wide range of materials | • Expensive to construct and maintain<br>• Un attractive structures |
| 4. | *Rock armor*<br>Open or solid structures | • Cost effective construction<br>• Little alimentation | • Expensive<br>• Poor energy absorption |
| 5. | *Nourishment* | • Looks very natural | • Maintenance is very expensive<br>• Requires dredging |


**Figure 2.** (a) Sand dunes; (b) Sea wall; (c) Groins; (d) Revetments rock armor, (e) Nourishment. Source: Bramley & Teal (2020); Mackley (2014); Wright (2008); Eastern Solent (2015).

emerged as one of the simplest and most popular approaches for the appraisal of coastal vulnerability. Gornitz (1991) and Gornitz et al. (1994) amended their CVI procedures to differentiate the impacts of extreme storms on coastal vulnerability by introducing more meteorological parameters. Pethick and Crooks (2000) Pethick and Crooks (2000) evaluated coastal vulnerability geomorphological aspects. Gui-Shan et al. (2001) evaluated the Jiangsu coastal plain vulnerability with GIS and remote sensing data. Kumar et al. (2010) assessed Odisha (India) coastal vulnerability by using eight risk variables. Balica, Wright, and van der Meulen (2012) developed a coastal city flood vulnerability index (CCFVI) applied to nine cities globally. Hoque et al. (2019) developed a coastal vulnerability index of multi-hazardous events for the eastern coastal region of Bangladesh by using eight parameters. Kantamaneni et al. (2018, 2020) established physical (PCVI), economic, combined (CCVI) and agricultural coastal vulnerability indices using GIS and associated tools and survey methods. Along with these approaches, several researchers established more diverse assessment methods. These approaches were used to emphasize areas with high and low coastal vulnerability and eventually generated vulnerability maps. In those, coastal erosion is one of the main factors.

A coastal erosion vulnerability index was established to assess the erosion vulnerability in the selected case study area of the UK for the current study. For the index development, a basic part of Kantamaneni et al. (2018)'s methodology was adopted for this study.

Kantamaneni et al. (2018) established three indices: physical coastal vulnerability index (PCVI) , economic coastal vulnerability index and combined coastal vulnerability index (CCVI) to estimate coastal vulnerability of the UK using a combination of novel and existing parameters. Accordingly, the coastline of 11 selected case study areas were divided into 1 km and 0.5 km cells and subsequently ranked according to the relative vulnerability as: low, moderate, high and very high. Relative coastal risk was identified along diverse segments of the UK coastline. PCVI, consisting of 6 physical parameters, was used to evaluate the UK case study areas' vulnerability for physical aspects. Economic CVI was used to evaluate economic vulnerability and consists of 7 parameters, most of which are economic but also includes some non-economic parameters such as population, in order to undertake evaluation in terms of economic vulnerability. The combined coastal vulnerability integrates the PCVI and Economic CVI results, to generate GIS overall vulnerability.

For the current study, the formulation concept proposed Kantamaneni et al. (2018) was adopted, and accordingly ECVI was developed which is explained further in subsequent paragraphs. Five parameters are considered for the assessment of the erosion vulnerability of Camber, UK. They are: Coastal slope (1), Beach width (2), Dune width (3), Built structures behind the back-beach (4), and coastal defenses (5). As part of appraisal, the Camber coast (4.5 km) is divided into 0.5 km cells and allocated vulnerability ranks, derived from the qualities of each of the parameters, ranging from 1 to 4. Rank 1 indicates low vulnerability and rank 4 representes very high vulnerability (Table 2). The highest score 4 was given to the cells which did not score anything. The ECVI was then developed by allocating CVI scores in between one and four; these values were summed up for each segment/cell to give a comparative CVI score using the following equation:

$$ECVI = CS + BW + DW + BB + CD \tag{1}$$

Where $C_S$ = Coastal slope; $B_W$ = Beach width; $D_W$ = Dune width; $B_B$ = Built structures behind the back beach; $C_D$ = Coastal defenses.

Once the rankings were assigned, these values were then totaled to give a relative ECVI (vulnerability index) score. ECVI (Erosion Coastal Vulnerability Index) = $C_s$ + $B_w$ + $D_w$ + $B_B$ + $C_D$ where the each letter was equivalent to the rating score for each parameter and ranged from 5 to 20. Subsequently these scores were compared with the following table (Table 3) in order to classify the total relative level of erosion vulnerability.

**Table 2.** Parameters and ranking adopted from the Kantamaneni et al. (2018).

| No. | Erosion vulnerability parameters | Vulnerability threshold | | | |
|---|---|---|---|---|---|
| | | Low (1) | Moderate (2) | High (3) | Very high (4) |
| 1 | Coastal slope (%) | >12% | 12 – 8% | 8 – 4% | <4% |
| 2 | Beach width (m) | >150 m | 100 – 150 m | 50 – 100 m | <50 m |
| 3 | Dune width (m) | >150 m | 50 – 150 m | 25 – 50 m | <25 m |
| 4 | Built structures behind the back beach (m) | >600 | 200 – 600 m | 100 – 200 m | <100 |
| 5 | Coastal defenses (%) | >50% | 20 – 50% | 10 – 20% | <10% |

### 3.1. Data and parameters measurement

As shown in Table 2, data regarding five parameters were collected from different organizations. Data of the coastal slope elevation was obtained from (NASA)-Google Earth Pro—2019. The data of Built structures behind the back beach, dune width and beach width was collected from Ordnance Survey aerial, raster and vector maps. Coastal defenses data was obtained from the East Sussex Council, East Riding Yorkshire Council, and Environment Agency. Based on these data sets, five parameters were assessed.

The procedure to establish each parameter was based on the methodology proposed by Kantamaneni et al. (2018). Firstly, transect lines with 0.5 km × 0.5 km cell spacing were drawn perpendicular to the coast at 4.5 km from the coastline (Figure 3). The back beach was used as a stand-in baseline. Then, the measurement was extended to a line drawn almost parallel to the baseline at 0.5 km in an average low-water seaward direction. Accordingly, the measurements of each parameter were recorded along each transect.

**Table 3.** Total relative vulnerability score modified from Kantamaneni et al. (2018).

| Total relative vulnerability score | Vulnerability |
|---|---|
| <11 | Low |
| 11–13 | Moderate |
| 14–16 | High |
| 17–20 | Very High |

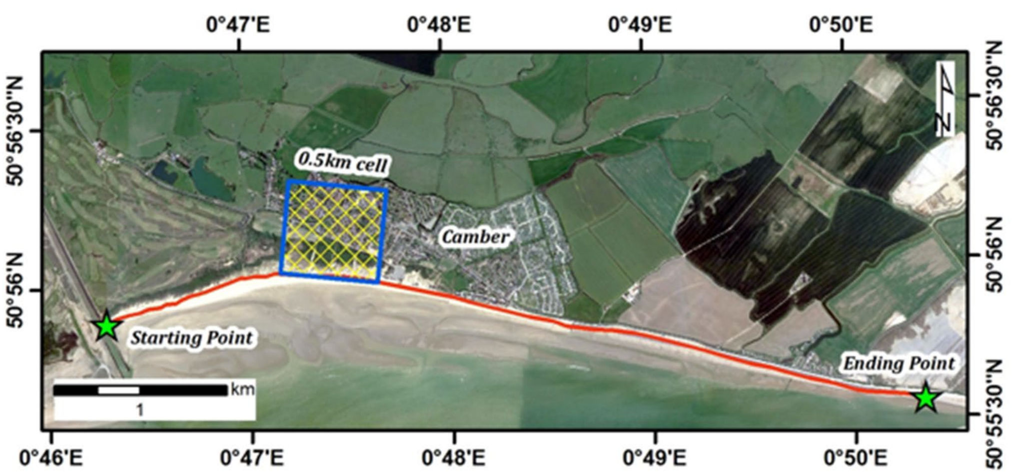


**Figure 3.** 0.5 km grid cell – Coastal cell measurement on a shoreline.

The following describes the methods for measuring each parameter. The coastal slope was measured by GIS (Geographic Information System) using the Google Earth Pro mapping tool. A 0.5 km line was established for the back beach on the Camber coastline, and then each individual cell was measured. Using ArcGIS and Ordnance Survey maps, the beach width was analyzed from the back beach to the mean low-water level. Using the GIS spatial database, the dune width was measured as the space between the predetermined back beach coordinates and the next man-made structure. Ordnance survey aerial maps and spatial data were used to measure this parameter. The built structures were measured from the NASA-Google Earth pro aerial maps. The distance of 0.5 km was chosen to consider the distance of the built structure behind the beach. Coastal defenses were measured according to the percentage of the coastline/shoreline coverage within each unit of the ordnance survey aerial map.

## 4. Results

### 4.1. CVI analysis for individual parameters

#### 4.1.1. Coastal slope

The coastal slope is one of the most important parameters to determine the coastal vulnerability evaluation studies. Therefore, this parameter was considered one of the significant parameters for this study and subsequently analyzed. Study results revealed that the average CVI score was 3.6, and six cells recorded the highest ECVI score (4); most of the high values were recorded at the lower end. The CVI scores for coastal slope suggest a high vulnerability in 67% of the survey area with some site-specific variations (Figure 4).

***4.1.2. Beach width.*** There are no considerable differences between the cells for CVI scores for beach width (Figure 5). The average CVI score for beach width was 1.1, and only one cell (9th cell-11%) scored 2 which falls into the medium vulnerability category. The remaining cells scored the lowermost vulnerability score i.e., 1. CVI scores for beach width parameter clearly indicate that Camber does not have the high vulnerability for beach width parameter at current scenarios.

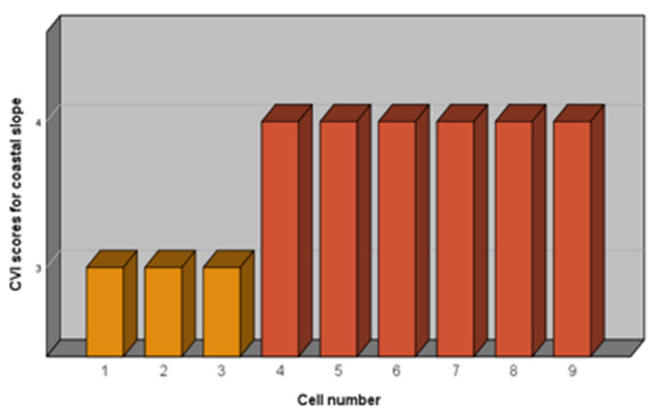


**Figure 4.** Coastal slope – CVI scores.

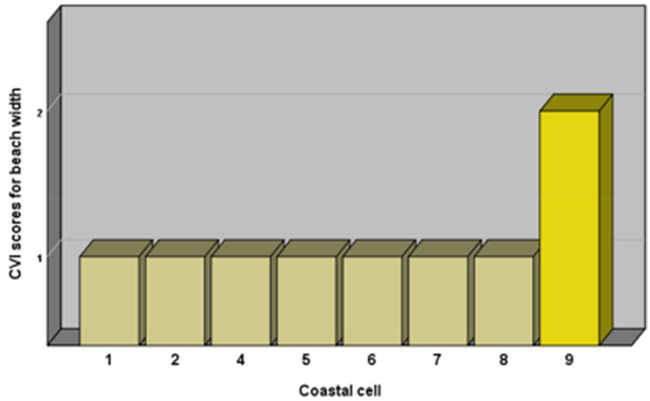


**Figure 5.** Beach width – ECVI scores.

***4.1.3. Dune width.*** Coastal dunes, in particular, act as a natural buffer and protect the coast from floods, rough waves and erosion during natural disaster events. Because of these significant factors, dune width is one of the critical parameters in physical geographical studies. Accordingly, for the current study, dune width is also considered an important parameter. Based on the analysis, it was identified that a considerable variance exists between the dune width CVI values among the coastal cells (Figure 6). The average CVI score for dune width was 3.1, and the highest score of 4 was recorded in 55% of cells . 33% of cells fall into low and moderate vulnerability classifications. The CVI scores dune width denote that 66% of the coastal cells show high and very high coastal vulnerability for dune width parameter.

***4.1.4. Built structures behind the back beach.*** There was a significant difference amongst the ECVI scores for the built structure behind the back beach parameter (Figure 7). The average CVI score for this parameter was 3.2 and the highest score was 4, recorded at 66% of cells. 33% of cells falls into lower and medium vulnerability categories. A significant portion of the Camber coastline has the highest vulnerability for the built structures parameter.

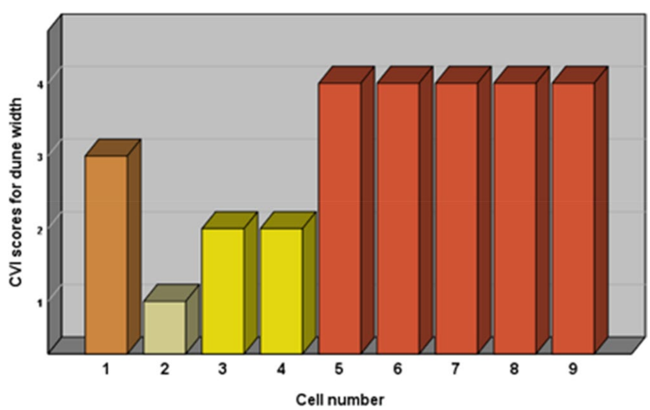


**Figure 6.** Dune width – CVI scores.

***4.1.5. Coastal defenses.*** Several governments across the globe, including the UK, have already implemented several types of coastal defenses to protect the coast, low-lying areas and beachfront properties. Because of this, sea defenses or coastal defenses play a vital role in evaluating coastal erosions' vulnerability subjects. Therefore, this study also considers coastal defenses as one of the most significant parameters. Based on the analysis, the results revealed that the average and highest CVI score for coastal defenses was 4, which all cells (100%) recorded (Figure 8). Based on the surveyed site, the CVI scores for sea defenses emphasize that the vulnerability for the Camber site requires more coastal protection measures to tackle the current susceptibility rate.

## *4.2. Overall CVI scores and trends*

Considerable variations exist between the 9 coastal cells CVI values (Figure 9). A larger number of cells fall into the high vulnerability category (Figure 10). The average value was 15.1, which belongs to the high category. However, the maximum ECVI value (18) was obtained for the 9th cell, while the lowest (11) was obtained for the

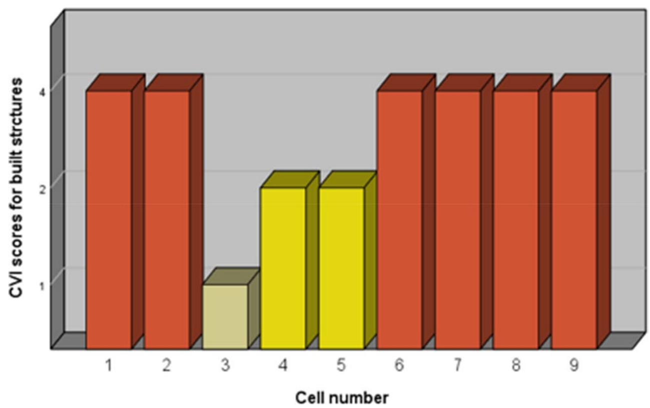


**Figure 7.** Built structures CVI scores.

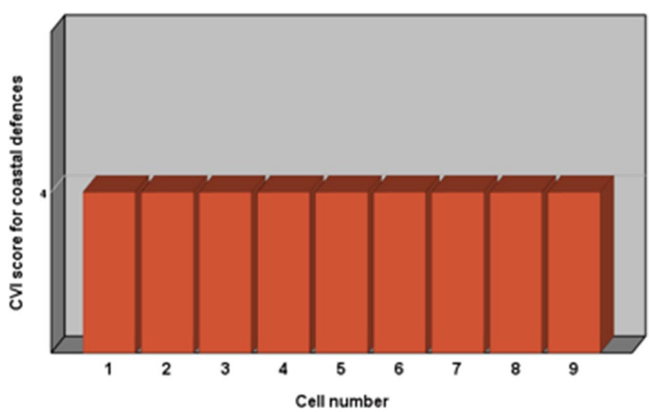


**Figure 8.** Coastal defenses – CVI scores.

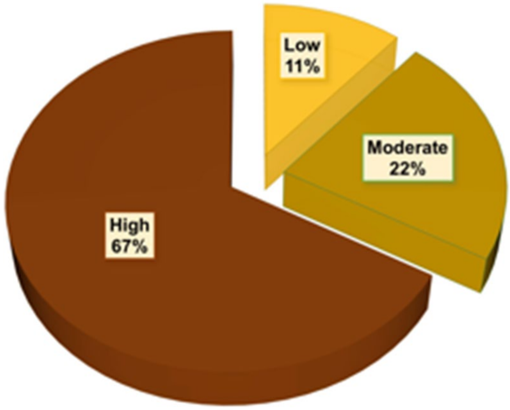


Figure 9. Overall trend of ECVI scores.

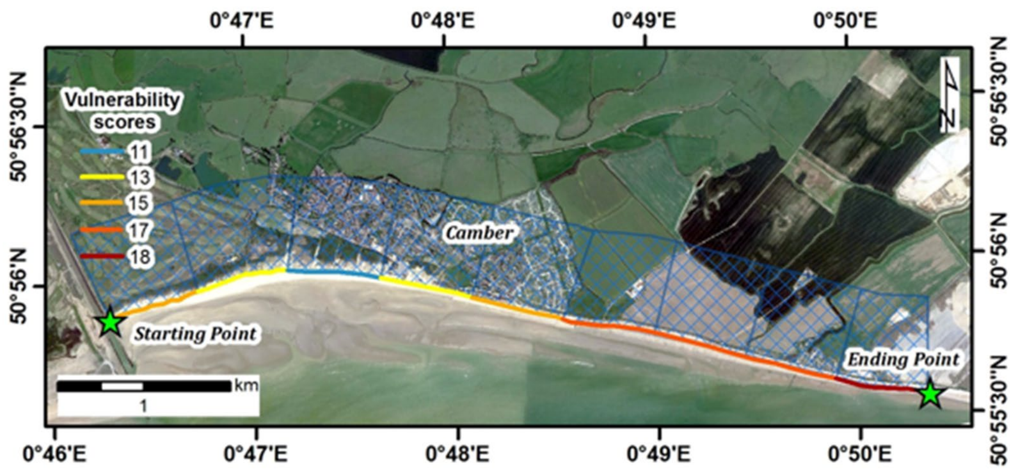


Figure 10. Coastal vulnerability map.

3rd cell. As shown in Figure 11, more than 67% of cells were rated as having high vulnerability (15–18), and 22% of the cells were rated as moderately vulnerable (11–14). In addition, only 11% of the cells were found to fall into the low vulnerable category (<11), but the overall CVI scores noticeably specified that the 67% of cells had high erosion vulnerability in the Camber study site.

## 5. Discussion

Presently, rapid coastal erosion occurring due to various factors including anthropogenic pressure is widespread across the world. Many traditional, innovative and natural coastal defenses are no longer sufficiently protective for several coastal areas of the UK including Camber. Proposed and systematic planning for the management of coasts depends upon an understanding of the physical procedures which are accountable for coastal morphology structures. In Camber, the government has already implemented

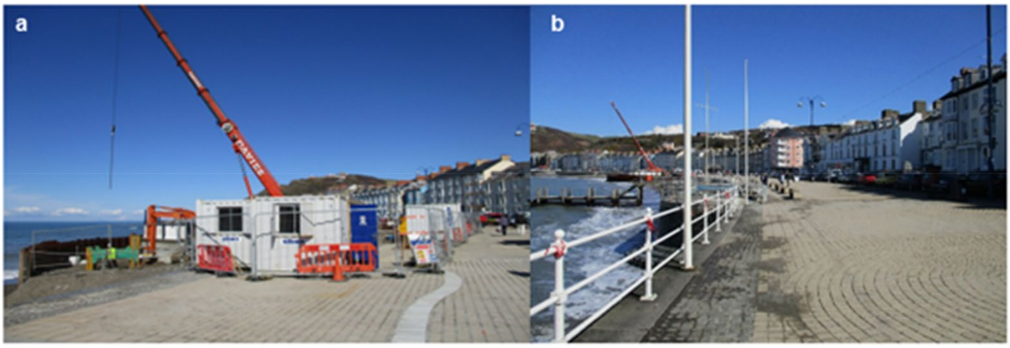


**Figure 11.** (a) New coastal wall construction in 2015 – Aberystwyth; Figure 11(b) coastal infrastructure (commercial and residential properties). Source: Kantamaneni (2016).

some coastal defenses such as coastal wall and rock armor at the lower end of the coast. However, coastal erosion vulnerability is high in some coastal stretches due to strong winds and waves. In Camber, sand dunes act as a natural coastal defence and protects the Camber area from erosion and other natural hazards such as floods.

Furthermore, sand dunes also offer a future supply of sand to conserve the beach. However, in recent decades, these dune systems are depleting and are under pressure from a wide range of human activities such as redevelopment of coastal infrastructure and high visitors in holiday periods. Substantial dune erosion can happen in just a few hours, whereas full recovery of sand dunes can take several years (Waikato Regional Council 2020). A key finding of this research is that 67% of coastal cells fall into high and very high vulnerability categories for the dune width parameter. The average value of this parameter is 3.1 which indicates that dunes are under threat in Camber; therefore, dune width is one of the most significant parameters for this research.

Construction of coastal defenses is very expensive, and several Councils of the UK are not able to afford to build these defence structures. On the other hand, the most significant parameter for this study is coastal defenses which has highest coastal vulnerability and scored the highest average CVI score i.e., 4 (more than any other parameter). This indicates that coastal defenses such as seawalls (hard) are not strong enough to protect the coast from high energy waves and there is a chance these waves may damage the seawall. Aberystwyth seawall is an example of this: the previous coastal wall was damaged several times because of high waves, and a new coastal wall was constructed in 2015 as shown in Figure 11.

Poorly controlled urban settlements and high visitor numbers in coastal regions increases pressure, both physically and economically, which leads to further vulnerability and risk (Nicholls et al. 2007). Great Yarmouth and Skegness are facing similar situations (Kantamaneni 2016), and Camber joins these sites as being at risk. Furthermore, surprisingly, beach width is one of the most insignificant parameters score in this study, scoring on average 1. Usually, beach width impacts coastal vulnerability by acting as a defence, dissipating wave energy, and the wider the beach width the greater the protection from severe weather events (Davies 2012). As a result of the great width of beach width in Camber, beach width parameter has low vulnerability.

Overall, on an average, 67% of coastal cells exhibit high vulnerability which indicates that Camber needs more robust coastal management and protection procedures. The current study results reveals the importance of coastal defenses and maintenance, and the coastal erosion vulnerability of Camber. These results should help coastal managers and researchers to identify the intensity of the vulnerability for this particular site.

### 5.1. Coastal defenses and budget

The reduction of coastal erosion has become a vital part in coastal management because of the significant use of natural resources in coastal zones for the development of new infrastructure, including tourism. Since the last century, the anthropogenic activities' impact on coastal areas has increased greatly, and these changes will be blamed for coastal disasters, such as coastal flooding and land loss (Scavia et al. 2002). According to Small and Nicholls (2003) nearly >158,000 people in Europe will suffer from either coastal erosion or flooding in 2020. Therefore, proper and timely management of coastal erosion is essential in coastal zone management. It enables governments and regional councils to defend communities from sea-level rise (SLR), erosion and other associated risks. In the coming years, the UK government is planning to spend >£2 billion for 1,500 projects across the country to protect its infrastructure from all types of floods (Environment Agency 2015).

Coastal defenses in and around the Romney (including Camber) area are managed by three risk management authorities: (1) the Rother District Council (Camber sand dunes), (2) the Folkestone & Hythe District Council (Greatstone sand dunes and Folkestone to the Hythe frontage) and (3) the Environment Agency. According to these three organizations (2020), the Folkestone to Cliff End Strategy will be implemented to reduce the coastal erosion risk along the coastline of Romney over the next century. Whilst this is welcome, there is still ambiguity on the implementation of this plan, and there is no substantial evidence on the starting and ending dates. Though, the most vital thing is that £130 million worth of coastal defenses have already been established in the UK. An additional £33 million was spent to construct and extend sea defenses from the Suttons at Camber to the western boundary of the Lydd Ranges. However, some of the existing defenses at some of the coastal stretches around the Romney (including Camber) area will end their lifespan soon, and these areas will be at high risk of erosion. These existing coastal defenses are not sufficient for tomorrow's needs, and a rigorous, robust strategy will be needed to tackle the current and future coastal erosion and vulnerability in the Camber area.

However, it is not possible to prevent coastal erosion completely, and there are some procedures that can be implemented to manage these risks and decrease the impact on infrastructure and communities. Irrespective of which process (soft or hard engineering) is used, the prominence of suitable coastal management strategy is an essential factor. Moreover, another vital thing is that keeping the coast healthy is not only the government's duty; it also depends on the communities as well.

### 5.2. Coastal vulnerability and nature based solutions (NBS)

Human-made defenses and protection against coastal retreat is an expensive process and not an implementable solution on all occasions, even for wealthy countries. Alternative methods for consideration could include nature-based solutions and blue-green infrastructure, such as planting more trees, water-sensitive urban design

**Figure 12.** Mangrove forests including newly planted mangroves in Legazpi city, Philippines – 2019.

(WSUD) and other greenery and expanding the quantity and quality of green-spaces along coastal areas. In the UK, examples of coastal NBS include introducing artificial wetlands and dunes; elsewhere globally the introduction of mangrove forests in low lying and vulnerable coastal areas, have been proven to be economically and physically feasible solutions for reducing erosion rates. In the Philippines, the local and national governments enhanced the mangrove fields to minimize the erosion impact of tsunamis wave speed and floods (Figure 12) (Kantamaneni 2019).

Also, blue-green infrastructure management will be one of the appropriate solutions to reduce the rate of climate change and storm activities in vulnerable areas (Ruckelshaus et al. 2016; Rice 2019). The Republic of China introduced the 'sponge cities' concept in selected 16 urban cities across the country in 2015 to store and manage the flood water (Qiao, Liao, and Randrup 2020; Woods-Ballard 2021). This concept helped to increase the amount of greener areas in public spaces and reduce urban water problems (Kantamaneni; Liu, Jia, and Niu 2017). Nature-based solutions also help to achieve UN sustainable goals (Goal 13, 14 and 15) by reducing climatic changes, severe storm activity and carbon emissions. The involvement of governments, NGOs, educational organizations, the private sector and general public involvement is necessary for the successful implementation of nature-based solutions in a geographical area.

## 6. Conclusions

Several sites in England are eroding more rapidly than predictions despite having a variety of coastal defenses. However, updated knowledge on the current status of erosion and erosion contributing factors in several coastal vulnerability sites of the England is limited. Accordingly, the current study measured the coastal erosion vulnerability of an identified hotspot, Camber, which is a small town in England by establishing an ECVI (Erosion Coastal Vulnerability Index). The ECVI was developed with existing parameters in line with Kantamaneni et al.'s (2018) methodology. Results revealed that erosion vulnerability varies across the cells. Overall results showed that 67% of the shoreline frontage exhibited high coastal vulnerability and is prone to various coastal hazards such as frequent waves, erosion, redevelopment of coastal infrastructures, high numbers of visitors during holiday and summer periods along with human activities. Current coastal defenses are not strong enough to deal with the severe coastal erosion risks in Camber. All of these factors cumulatively are critical for the Camber shoreline. The evaluated vulnerable hotspot should be treated urgently by regional and national policy organizations to reduce the intense impact of coastal erosion and other associated hazards. Without action, this area may face new susceptibilities, disasters and humanitarian catastrophes and further erosion by the sea. The present study outcomes allow for a local, regional and national comparison that may assist to identify and monitor the changes in coastal erosion vulnerability and strategies.

## Disclosure statement

The authors declare no conflict of interest.

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