Socio-economic data in coastal vulnerability indices: constraints and opportunities

Authors: McLaughlin, S., McKenna, J., and Cooper, J.A.G.

Source: Journal of Coastal Research, 36(sp1) : 487-497

Published By: Coastal Education and Research Foundation

URL: https://doi.org/10.2112/1551-5036-36.sp1.487

Journal of Coastal Research	SI 36	487-497	(ICS 2002 Proceedings)	Northern Ireland	ISSN 0749-0208

Socio-economic data in coastal vulnerability indices: constraints and opportunities

S. McLaughlin, J.McKenna, J.A.G. Cooper

Coastal Research Group, School of Biological and Environmental Sciences,
University of Ulster, Coleraine, Co. Londonderry, Northern Ireland, BT52 1SA, UK

ABSTRACT

Most previously developed coastal vulnerability/sensitivity indices acknowledge that the addition of socio-economic variables would assist in defining vulnerable areas. This study investigated the incorporation of socio-economic variables into a GIS based coastal vulnerability index for wave-induced erosion in Northern Ireland.

In this application, a socio-economic sub-index was developed to contribute potentially one third of the overall index score; the other components consisted of coastal forcing and coastal characteristic sub-indices. All variables were ranked on an arbitrary 1-5 scale with 5 being most vulnerable. The variables were merged within sub-indices and then the sub-indices were combined to produce the overall index.

Several problems were encountered in assessing socio-economic vulnerability indicators. These relate to the inherent difficulties involved in ranking socio-economic data on an interval scale. Temporal aspects also caused difficulties as socio-economic variables vary over time as coastal populations and policies change. There were also problems in relation to the size of the unit used to display the data and how this affected the vulnerability of certain areas. Larger, more fundamental, problems in relation to human perceptions of vulnerability were also investigated. The final results of the combined index were tested against field and desk-top studies and although they correlated well with expected outcomes, the results did suggest an under representation of the socio-economic index. Suggestions are put forward to alleviate this problem in any future developments.

ADDITIONALINDEXWORDS: *Vulnerability indices, socio-economic data, coastal management, GIS*

INTRODUCTION

In the last several years there has been a substantial increase in the number of vulnerability indices developed for specific coastal areas (GORNITZ *et al*., 1993; LEGGETT and JONES, 1996; O'RIAIN, 1996; CAMBERS, 1998). There are a number of explanations for this ranging from intensified development and use of the coastal area itself, to a general increase in the utilisation of databases and Geographical Information Systems (GIS) in coastal scientific studies. Indices have been used in coastal areas to study a range of perturbations related to factors such as sea level rise, human impact, wave erosion, and oil spill impact. The main objective of most coastal indices is the classification of the coastline into units that exhibit similar attributes or characteristics. These classifications can then assist in the implementation of preventative management strategies in sensitive areas.

A thorough study of the literature on the development of coastal vulnerability and sensitivity indices was undertaken to assess the present state of the art in this area. The majority of authors use multidisciplinary data in the development of their classifications; however, the indices reviewed in COOPER and MCLAUGHLIN (1998) and those examined since reveal a general acknowledgement that there is a need to include socio-economic variables in the classification procedure. In fact the inclusion of socioeconomic factors is the most popular suggestion for future studies in the published literature. GORNITZ *et al*. (1993) noted that the omission of demographic or economic factors from their coastal vulnerability index potentially limited its evaluation of vulnerable areas. Surprisingly, in many cases they are still not included in later studies by the same authors who made this recommendation. The reasons for this can vary from lack of suitable data to the inherent difficulties in ranking socioeconomic data on an interval or ratio scale. In contrast the ranking of readily quantifiable marine variables such as wave height is relatively simple.

A further problem in including socio-economic data, e.g. population, in vulnerability indices is that the data is time-constrained. Actual data can change over time with the building of new houses and roads etc. Perceptions of threat and of appropriate response to it, may also change with time. For example in the nineteenth century defence of the land against ‘attack’ by the sea was the predominant view and many promenades, groynes and sea walls were constructed at this time (CARTER, 1993). However, in Great Britain, at the end of the 20th century, conservation bodies such as English Nature and The National Trust are deliberately breaching sea defences to allow regeneration of salt-marshes on former grazing marsh e.g. Northey Island in Essex (CARTER, 1993). Another example of how policies can change can be illustrated by the European Community’s (EC) agricultural policy of ‘set aside’. As there is now over-production in agriculture, farmers are being paid not to farm the land. This is an indication of how temporal changes can be important in terms of coastal management. An area can change within the space of a few years from being one of agricultural value to one of solely conservation value. Therefore in quantifying socio-economic variables a review period of approximately 5 years may be appropriate to take account of variable and policy changes. This coincides with a typical review period for many local authority planning activities and may therefore be appropriate for environmental management applications. Particular problems also arise in the ranking of socio-economic variables, as it is difficult to assign a meaningful value to them. Unlike a simple cost-benefit analysis it is not easy to apportion a monetary value.

Despite these difficulties the inclusion of socio-economic variables is of great importance, perhaps even essential, in the development of valid coastal vulnerability indices. DOORNKAMP, (1990) noted that "studies of coastal management problems have shown that different human and social reactions will manifest themselves according to the size of the population of the affected area, the economic activity within the area, and the prevailing social conditions". GORNITZ *et al*. (1993) summed up the reasoning for including socio-economic data when they remarked that "..it is the perceived social and economic worth of the resources within the region at risk that will determine which, if any, efforts are made to protect a given area". It is the economic cost of the loss of houses and infrastructure that will inherently influence the vulnerability of an area. Socio-economic parameters thus appear to be an essential component in any vulnerability index.

Development of a vulnerability index for the Northern Ireland coast

A questionnaire survey of government and non-government organisations was undertaken to investigate the practices of coastal management and to gauge the overall perception of the development of a GIS based Coastal Vulnerability Index for Northern Ireland. The results showed an encouraging and positive response from Northern Ireland coastal information users, indicating that there would be a demand for such a system if it were made available.

The production of the overall index is presented in MCLAUGHLIN (2001), however a brief synopsis is necessary here. A Coastal Vulnerability Index (CVI) was developed in relation to wave-induced coastal erosion. The index was developed at three hierarchical scales: a Northern Ireland coarse-resolution scale (500x500m), a regional scale for Coleraine Borough Council area (25x25m) and a local scale for Portrush East Strand, Co. Antrim at a resolution of 1x1m. The ArcView GIS system (ESRI) was used to calculate the index and map the results. Variables were selected and ranked on a 1-5 scale according to their perceived vulnerability to wave-induced erosion (with 5 being the most vulnerable and 1 least vulnerable). The variables selected were separated into three sub-indices: a coastal characteristics sub-index to determine the coast’s resistance to erosion, a coastal forcing sub-index to quantify the forcing variables, and a socio-economic sub-index to identify the infrastructure potentially at risk. Each sub-index was given equal input in the final index score (i.e. one third). Variables were adapted according to the scale of the study. Some variables became more detailed as the resolution of the study increased, while others became obsolete as they remained constant at the local scale and therefore did not differentiate between areas. The results were documented in the form of colour-coded vulnerability maps thus enabling the more vulnerable areas to be easily identified. In this paper only the socio-economic sub-index is discussed.

Selection of socio-economic variables

There are many potential indicators of socio-economic value. In deciding which variables to include, the desirability of including a parameter must be balanced against the availability of up-to-date data that is in a useable format. Therefore the variables chosen for inclusion in the index were those for which data could be easily obtained, and which were also deemed to be of relevance to coastal areas. The socio-economic variables selected for inclusion in the socio-economic sub-index are listed below:

- Population
- Cultural heritage
- Roads
- Railways
- Landuse
- Conservation status

Of these six variables, roads and railways are the simplest environmental assets to incorporate into an index. They occupy defined space, are of defined widths and the costs of protecting, replacing or relocating them are relatively simple to evaluate. Therefore this paper concentrates on the remaining four variables and discusses the problems encountered in using them in a socio-economic index.

Population

The use of population as a variable is not common in published coastal vulnerability indices. HUGHES and BRUNDRIT (1992) did not include it but acknowledged that an area with a greater population would have an increased economic value. They concluded that further studies should focus on population dynamics and the effects of increasing urbanisation. GORNITZ (1990) also omitted population but noted that further studies should take into account coastal populations to help rank vulnerable areas.

Population can be viewed as an "economic" variable because people in densely populated areas act to protect their properties from erosion (DILLEY and RASID, 1990; DEVOY, 1992; RIVAS and CENDRERO, 1994). They are reluctant to abandon their houses, land, possessions and infrastructure that has built up over many years. They incur economic costs if they lose or protect their possessions. Areas where few people live may not suffer the same pressure on the environment or have the same resources for protection. However, population can also be interpreted as a direct "erosion-inducing" variable because the presence of large numbers of people near the coast may produce damaging impacts on the coastal area in general. "Damage" in this sense is a human value judgement, for example erosion on an uninhabited island might be viewed as a "process" or "event" rather than "damage" as there are no negative impacts on human lives. Both views of population in relation to coastal vulnerability are complementary as each reinforces the effect of the other in increasing or decreasing vulnerability (see Figure 1).

A recurring problem in using population or settlement data lies in the size of the unit used to display the data. Potential errors can occur in statistical calculations with the use of different spatial areas. An example of this is the use of census data at an Enumeration District (ED) level. An ED is the smallest administrative area used to code population, however, it can produce misleading information. In the study area this is well illustrated by the example of Portstewart Strand. In Figure 2 the strand is classified as having a population of 400-600 people as it is part of the Strand ED in Portstewart. However the figure should be zero as no-one lives on the beach, but because the census data is attached to the centre point of the ED, the population in it is allocated evenly over the whole area. This illustrates how the graphical display of data can be misleading. Although the data is correct at the resolution of the study, its accuracy depends on the unit area used to display the information. This is known as the "modifiable areas unit problem" or MAUP as identified by OPENSHAW (1983).

To overcome this problem population data was obtained from the Northern Ireland Census Office in point format. The point data consisted of population counts for 100m grid squares in urban areas and for 1km grid squares in rural areas. Figure 3 which utilises this data gives a more realistic picture of the population of the Portstewart Strand ED.

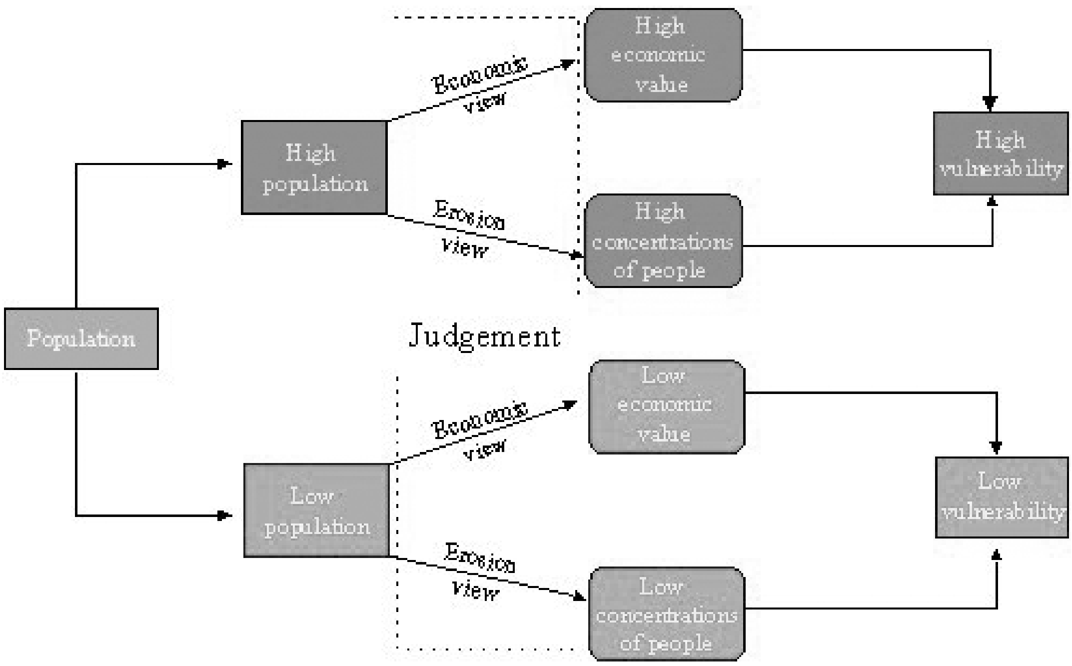

Figure 1. Two views of population as a variable in studies of coastal vulnerability.

The population numbers were then ranked on a 1-5 basis with the assumption that larger numbers of people being affected by (or causing) erosion are directly correlated with increasing vulnerability. Even this decision can cause problems; one counter argument is that large settlements are more likely to have engineered coastal defences, e.g. the Thames Barrage for London, while sparsely inhabited places are left to the mercy of nature.

Cultural Heritage

The inclusion of cultural heritage variables produced problems when it came to vulnerability ranking. Archaeological and historical monuments are important not only in economic terms but in social and cultural terms. They form part of the cultural resource and are irreplaceable. There was for example high public interest when it was announced that the 18th century Mussenden Temple at Downhill on the north coast near Castlerock, Co. Derry was endangered by erosion of the cliff on which it stands. However, the owners, the National Trust secured funds for a cliff stabilisation project. HOPLEY (1992) noted that although coastal retreat in some areas is inevitable in relation to a rising sea level, complete protection in situ is warranted for certain sites "because of the amount of investment, the historical and/or heritage value, or because of the lack of alternatives". This underscores the value and vulnerability of cultural heritage sites in the coastal zone.

Archaeological data was available from the Department of the Environment's Environment and Heritage section in a database known as the Sites and Monuments Records (SMR). Sites owned by the National Trust were also included. The ranking of the sites was considered carefully. Initially the study considered differentiating between 'more important' and 'less important' sites. One possible method of doing this was to place State-owned or National Trust-owned monuments in the highest ranked category on the basis that their acquisition/designation indicates high value.

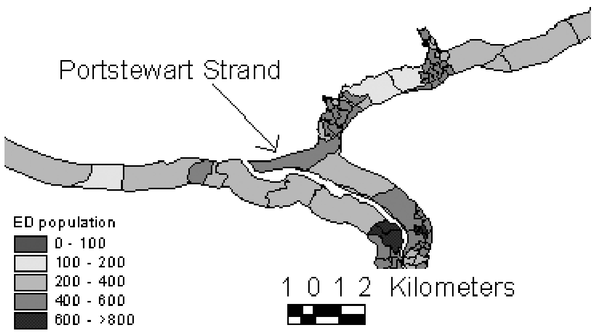

Figure 2. ED population density map for Portstewart and Portrush. (Source: 1991 ED census data).

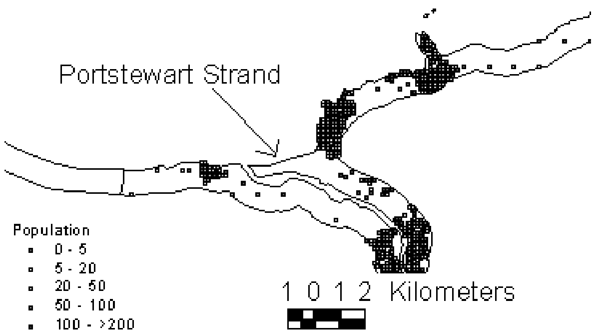

Figure 3. Point based population density for Portrush and Portstewart. (Source: 1991 ED census data in point format).

Other sites with actual upstanding remains were placed in the next category, followed by sites with no upstanding remains, and finally 'find spots' where single items had been found. However, it is difficult to put a value on a cultural heritage resource. Although one site may be better preserved than another, this does not mean that it is more important. For example, although the Medieval Dunluce Castle, Co. Antrim is still upstanding and in good condition this does not necessarily mean that it is more important than the Mesolithic site at Mountsandel in Coleraine which has no visible surface expression, yet is the oldest settlement site yet recorded in Ireland. Any method of ranking is therefore subjective. Archaeologists were consulted as to whether sites could be ranked in order of importance. It became obvious that even professional archaeologists could not agree if such a ranking system could be implemented (C. BREEN, T. MCERLEAN *pers. comm*., 2000). Therefore it was decided to abandon the ranking of archaeological sites and to rank all sites in the highest category (5), with areas of no recorded heritage value ranked as 1.

Ideally sites should be studied individually and a detailed survey of each site recorded; however, time limitations and the scale of the study curtailed the level of detail recorded. Finally it must also be remembered that in areas where there is no positive evidence for the presence of archaeological sites, it can equally be said that there is a lack of evidence to prove their absence. Every piece of land, especially along the north coast of Ireland, has the potential to contain important information on the cultural past (MARSHALL, 1991). For example peat outcrops at Portrush West (Mill) Strand were dated to about 5,000 BC (WILSON and CARTER, 1990) and so could potentially contain deposits of Neolithic material.

Landuse

The protection of an area deemed vulnerable will only be considered if the area is sufficiently 'important' in economic, cultural or environmental terms to justify protection. Therefore landuse type is of significance in determining vulnerability.

The 'value'of land can be defined in a variety of different ways. This can be in monetary terms, or replacement cost or in aesthetic terms or conservation value. For example, in monetary terms a marsh or bog would probably lie very low in the value ranking. However, in terms of conservation it is of much higher ecological and biological value as a feeding ground for birds or a place where unusual plants occur. Other indices that incorporate landuse as a variable include those of MCCUE and DEAKIN (1995), FLEMMING and TOWNEND (1989), LEE *et al*. (1991), and O'RIAIN (1996). HUGHES and BRUNDRIT (1992) suggested that, in the ranking of landuse variables, a rateable value would give a better indication of the locations of economically valuable areas. However, they acknowledged that such data are often difficult to obtain in an up-to-date format. Other authors who noted the importance of landuse as a variable include GORNITZ *et al.* (1993) who stated that in future landuse data may be added to the coastal risk assessment database to overcome the existing lack of data on anthropogenic activities. TOWNEND and FLEMMING (1994) also decided that landuse must be incorporated in order to derive management units from their coastal process units. For the purposes of this present study, landuse types were grouped and then ranked according to monetary value. It was initially intended to obtain data from the Rates Office on the rateable value of different landuse types, and then to use these values to classify the landuse categories. However, although promised, the data were never forthcoming. Therefore the rationale used for the economic ranking was based on subjective assessment of which landuse types were more or less valuable to humans than others, see Table (1). Previous work has been carried out on the use of "a benefit-cost analysis" such as that by CHAPELLE and WEBSTER, 1993 (IN CENDRERO and FISCHER, 1997). HOWEVER, IT WAS NOTED BY CENDRERO and FISCHER, 1997 that this methodology requires a "great deal of expertise and creativity to value the relevant elements" and therefore was not within the scope of this study.

It must be noted that this ranking scheme does not take into account potential value, e.g. a field currently used for agriculture on the outskirts of Portstewart may be potentially much more valuable as a site for a future housing development. The results merely portray the economic status of the coastal resource at present.

Conservation Designation

The incorporation of conservation designations is probably the most difficult of all variables to include in a vulnerability index. There are problems involved in deciding how to rank designated sites; the question being whether they should receive a high ranking or not. 'Protection' of a conservation site can hardly include protection from the operation of natural wave forcing processes. In many cases the unique character of a site is due entirely to the operation of such processes, e.g. a storm shingle ridge by definition is built by storms. In other cases the maintenance of a conservation site demands that natural processes continue to operate, e.g. occasional salt-water inundation is essential to salt marsh survival. In such cases the potential for erosion is actually a fundamental part of the protection. For example, in 1996 Coleraine Borough Council was refused permission to build a seawall at Portballintrae, Co. Antrim. This was because the proposed seawall fronted a geological section previously designated as an Earth Science Conservation Review (ESCR) 'Single Interest Locality' (SIL) site, by the DoE (NI) Environment

Table 1. Landuse vulnerability ranking.

	1	2	3	4	5
Landuse	Bare rocks Sparsely vegetated areas Marsh/bog/moor Water bodies	Coastal areas Natural grasslands	Forest	Agriculture	Urban and industrial Infrastructure

and Heritage Service and the Countryside Nature Conservation Council (CNCC). The site was protected from the seawall development because erosion is necessary to keep the section fresh and prevent its ‘degradation’by slope movements or vegetation development. Many natural sites cannot be harmed by the operation of natural processes. Indeed they may well depend on such processes e.g. the Giant’s Causeway, Co. Antrim would degrade in the absence of wave impact.

The example above shows that the ranking of designated coastal sites raises an interesting philosophical argument. It could be argued that even if the infrastructure associated with the management and use of a site, e.g. paths, car parks, visitor centres, is vulnerable to wave attack, this "secondary" vulnerability should not dominate management considerations and vulnerability assessment since the operation of natural processes is necessary for the maintenance of the primary site interest.

Since the purpose of this index was to assess vulnerability in relation to erosion from marine forces it was decided to rank the designated areas on the basis of whether they held national or international designations. See Table 2 for the rankings. National areas were allocated higher vulnerability ratings than international areas as there is arguably a greater chance that their management systems will be weaker, e.g. resources are fewer in terms of both expertise and finance. This is probably valid as a generalisation but the situation on the ground is quite complex and there are many anomalies. Dealing with the Republic of Ireland MCKENNA *et al*. (2000) (pg. 88-89) point out the wide disparity in the degree of protection offered by conservation designations, ranging from virtually none in some of the national designations to strong statutory protection for the European designations of Special Protection Areas (SPA) and Special Areas of Conservation (SAC). Surprisingly, however, the prestigious international designations of Ramsar and World Heritage Site bestow no protection per se; one reason why they are designated is that they are already well protected by other designations e.g. SPA in the Ramsar case.

It is conceded therefore that the overall ranking in Table 2 may be crude, however data are not available to support a more refined ranking system.

There can be dilemmas involved in ranking areas of conservation designation. In nature things change. If a site has been designated because it is a salt marsh, should it be allowed to revert to a mudflat if that is its natural evolutionary pathway? Or should the site be constrained by human efforts to stay in its former but now non-equilibrium state? A classic example of this occurred at Porlock in west Somerset, England where the National Trust opposed a Wessex Water scheme to strengthen a threatened gravel barrier. The Trust believed that natural processes should be allowed to operate even if a designated freshwater/brackish wetland would suffer marine flooding as a result and thereby transform into a marine habitat (Carter, 1993).

Computation of the socio-economic sub-index

The overall variables and their rankings are shown in Table 4.3. Each of the six variables was gridded in ArcView GIS and then the rankings added together. The resulting scores were then normalised by converting them to a range of the maximum and minimum scores (the minimum score in Table 3 is 6 and the maximum is 30, therefore 6 was subtracted from the total score, the result was divided by 30 and finally multiplied by 100).

The coastal characteristics and the coastal forcing sub-indices were calculated in a similar manner and the three sub-indices were then added as shown below.

Table 2. Classification scheme for conservation designations in Northern Ireland.

INTERNATIONAL	**Score**
Ramsar site Special Protection Areas Special Areas of Conservation World Heritage Site	3
NATIONAL Areas of Special Scientific Interest Areas of Outstanding Natural Beauty National Nature Reserves Environmentally Sensitive Areas	5

Table 3 Socio-economic characteristics vulnerability classification scheme for Northern Ireland index.

Variable	**1**	**2**	**3**	**4**	**5**
Settlement	No settlement	Village	Small Town	Large town	City
Cultural heritage	Absent				Present
Roads	Absent		A'Class		Motorway Dual carriageway
Railway	Absent				Present
Landuse	Water bodies Marsh/bog and moor Sparsely vegetated areas Bare rocks	Natural grasslands Coastal areas	Forest	Agriculture	Urban and industrial Infrastructure
Designated conservation areas	Absent		Inter-national		National

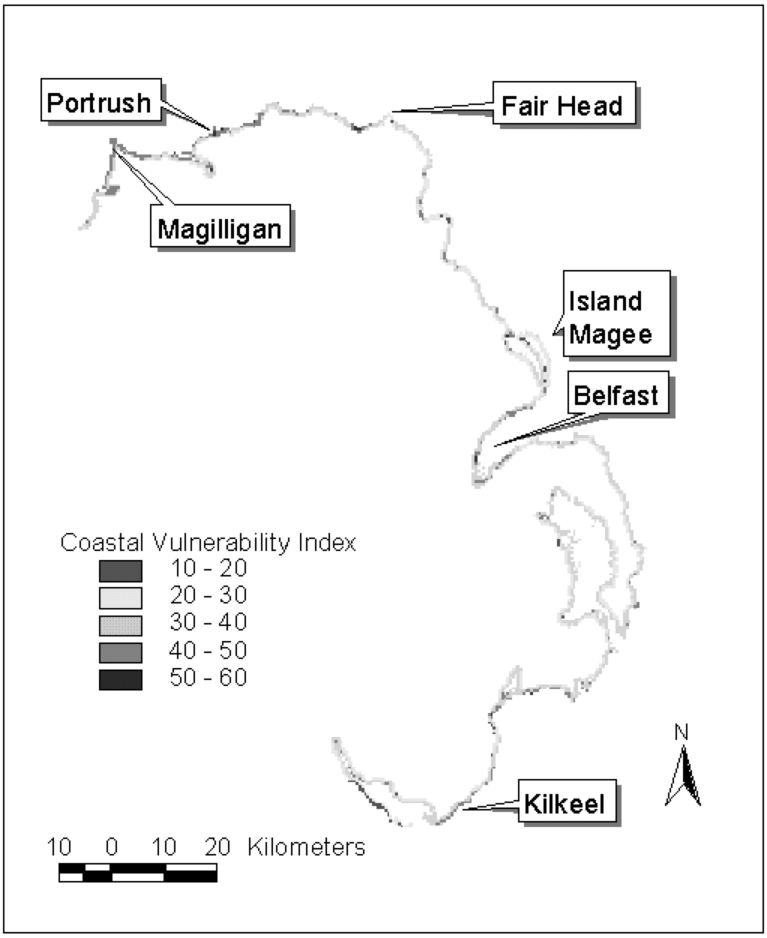

Figure 4. Coastal vulnerability index for Northern Ireland*.
*As colour is an essential element of the index figure 4 is for illustrative purposes only. A colour version can be seen at www.science.ulst.ac.uk/crg/coastalgis

CVI =
(coastal characteristics + coastal forcing + socio-economic) / 3
sub-index sub-index sub-index

In Figure 4 areas such as Magilligan, Portrush, Belfast and Kilkeel are highlighted as being of high vulnerability, with areas such as Fair Head and Island Magee showing low vulnerability.

To test the influence of each of the three sub-indices in the overall result, seven sites along the coast of Northern Ireland were randomly chosen and their sub-index values examined (these were based on the average of 6 selected grid squares for each area). An Excel macro program named Trixel Version 1.0b (copyright Julien Furrer, 1996) was used to create a ternary diagram to display the results of the three sub-indices for these sites. The results are shown in Figure 5.

The ternary diagram above shows the relative influence of each of the three sub-indices in the overall index score. The diagram shows a general tendency for the coastal forcing and coastal characteristics sub-indices to dominate the overall score, with the socio-economic index having the least influence. The city of Belfast for example stands out as having the greatest influence from the socio-economic index as might be expected, given its sheltered position and high level of infrastructure. Of the seven areas, Benbane Head has the highest score in the coastal forcing sub-index, followed by Fair Head, while Magilligan is dominated by the coastal characteristics sub-index as is the town of Newcastle.

The diagram also demonstrates that the overall index via its sub-indices does differentiate between areas. If all of the sites were clustered around the centre of the triangle then this would suggest that all areas studied were relatively similar in relation to their coastal characteristics, coastal forcing and socio-economic attributes. This would not be a true picture of Northern Ireland as its coastline is quite diverse with areas of high and low erosion, wave exposure and areas of high and low socio-economic activity.

Discussion

The calculated indices were tested against site assessment validation studies and correlated well at each of the 3 scales. However, a problem noted during the breakdown of the overall index scores into their component sub-indices was the under-representation of the socio-economic sub-index in its contribution to the overall index score. Belfast was the only study area tested where the socio-economic sub-index made a significant contribution to the overall index score (bearing in mind that the maximum contribution of any one of the sub-indices to the overall index is 1/3rd). There are several possible explanations why this occurred. The first and simplest explanation is that the coastline of Northern Ireland is relatively undeveloped in socio-economic terms, and that in fact the index is reflecting reality. A second possibility is that the low socio-economic sub-index scores may be an artefact of the use of dichotomous variables, i.e. variables that exist in either of two states e.g. presence or absence. The socio-economic sub-index has two

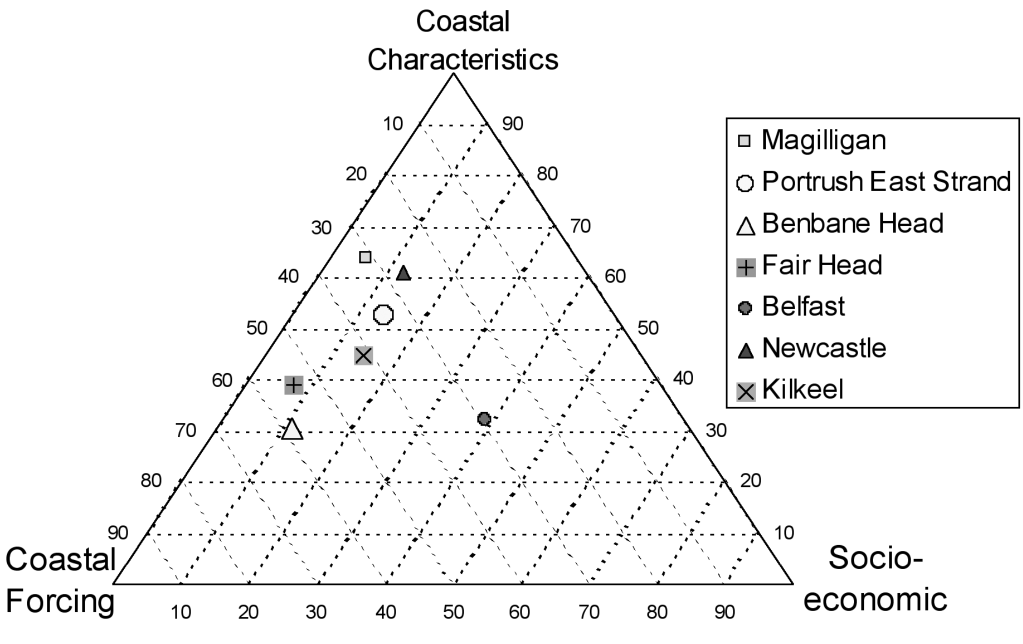

Figure 5. Triangular diagram of the relative strengths of each of the 3 sub-indices for selected sites in Northern Ireland.

dichotomous variables at each index scale, the coastal forcing sub-index has none and the coastal characteristics sub-index has only one at the local and Northern Ireland levels. Examples of dichotomous variables used are the presence or absence of railways or the presence or absence of cultural heritage features. Dichotomous variables are "coarse" variables in that they use only the extremes of the 1-5 range. Therefore, where these variables represent phenomena that occur in few locations they may skew the overall index score by giving most of the coastline low index scores. As the variables in the index are not averaged, these dichotomous variables tend to lower the overall socio-economic score.

This unrealistic influence of dichotomous variables suggests that if possible their use should be avoided. Their impact could also be lessened by combining variables into groups, for example roads and railways could be merged into a "transportation links" variable which would allow the full 1-5 vulnerability ranking to be used. In the case of cultural heritage features the problem is more complicated. As previously noted it is not easy to rank cultural features in order of their importance because of the high level of subjectivity involved.

An alternative to the production of an overall vulnerability index could be the production of a vulnerability 'profile' instead. This would mean that, instead of combining the three sub-indices into one, they would be left as three 'stand-alone'indices. These could be displayed via piecharts or barcharts beside maps of the study area. The main advantage of these profiles would be a clearer distinction of areas where one sub-index is dominant. This could possibly be viewed as an alternative to weighting the sub-indices in the creation of an overall index score. Gornitz has commented that the use of a vulnerability profile may be better than an index as the latter can conceal differences in the relative strengths of individual variables from one area to another (Gornitz, V. *pers. comm*., 1993).

Alongside these specific problems of quantifying and incorporating socio-economic data, there are more fundamental problems relating to human perceptions of vulnerability. Human actions can distort the commonly held view of vulnerability as an undesirable "state" to be avoided if at all possible. For example coastal users may deliberately encroach into inter-tidal areas or onto mobile and unstable dune systems. This problem is highlighted with the positioning of the 5th green at Royal Portrush Golf Club, Co. Antrim. The green is deliberately positioned on the crest of the highest seaward dune for reasons of its scenic view; inevitably this places the green in a vulnerable area. Paradoxically if the green was located in a safer, less vulnerable position it would be perceived as less attractive and therefore less "valuable". The green has been defended by rock armour in an attempt to hold the dune in a static position against its natural tendency to behave in a dynamic manner. Figure 6 attempts to highlight the complex relationship between vulnerability and perceived value on an eroding coast.

Although the diagram is schematic, actual values could be added to the graph in terms of property value and actual distances to the coast. The numbers (1-5) on the diagram illustrate how perceived value changes with increasing perception of vulnerability. For example a house at location 1, e.g. 500m from the shoreline, has a certain baseline value. This value increases at location 2 as it is closer to the shoreline and then increases again significantly at location 3. Location 4 is where the house reaches its maximum value as it is now close to the shore with excellent views of the sea. At location 5, however, awareness of the vulnerability of the area causes the property value to fall away steeply. The box at point 4 therefore indicates the point of maximum value at which the owner ideally wants to maintain the house-to-shore distance. As this distance decreases, the value of the property declines due to perception of risk. Further seaward comes the point of 'terminal'vulnerability i.e. loss of land area. A recent example of this "vulnerability = value" phenomenon can be found in the case of the Mussenden Temple at Downhill, Co. Derry. Much of its character comes from its spectacular cliff-edge location (Figure 3.1.4). However, it was vulnerable because of cliff erosion. Rather than lose one of its prime possessions or risk moving it inland, the National Trust in 1998 spent £250,000 in strengthening the cliff (BELFAST TELEGRAPH, 23 May, 1998). In doing this the Trust explicitly went against its normal policy of allowing natural processes to proceed uninterrupted. Similarily in 1999 at Beachy Head in Sussex, England, the Belle Tout Lighthouse was moved back 55ft (16.8m) from the eroding cliff edge at a cost of £250,000 (THE INDEPENDENT, 18th MARCH, 1999).

The dotted line on the vulnerability curve in Figure 6 is linked with the placement of coastal defences, i.e. with defences in position the value peak is located further seaward as defences both reduce "real" risk and delay the perception of risk (although in the majority of cases there must have been some perception of risk to "generate" the defences). Even with coastal defences, continuing wave attack eventually raises the economic costs of defending the site to exceed the actual value of the land and therefore the site is abandoned and its value declines rapidly. It should be noted that in the index developed here, coastal defence structures were considered to be indicators of erosion either actual or threatened. However, there are cases where defence structures can actually be the cause of erosion (PILKEY and DIXON, 1996). "Defence" structures such as seawalls are not always built to protect against erosion as they may be built to create promenades or to improve access to beaches. CARTER and BARTLETT (1990) noted how coastal engineering structures caused spectacular changes at

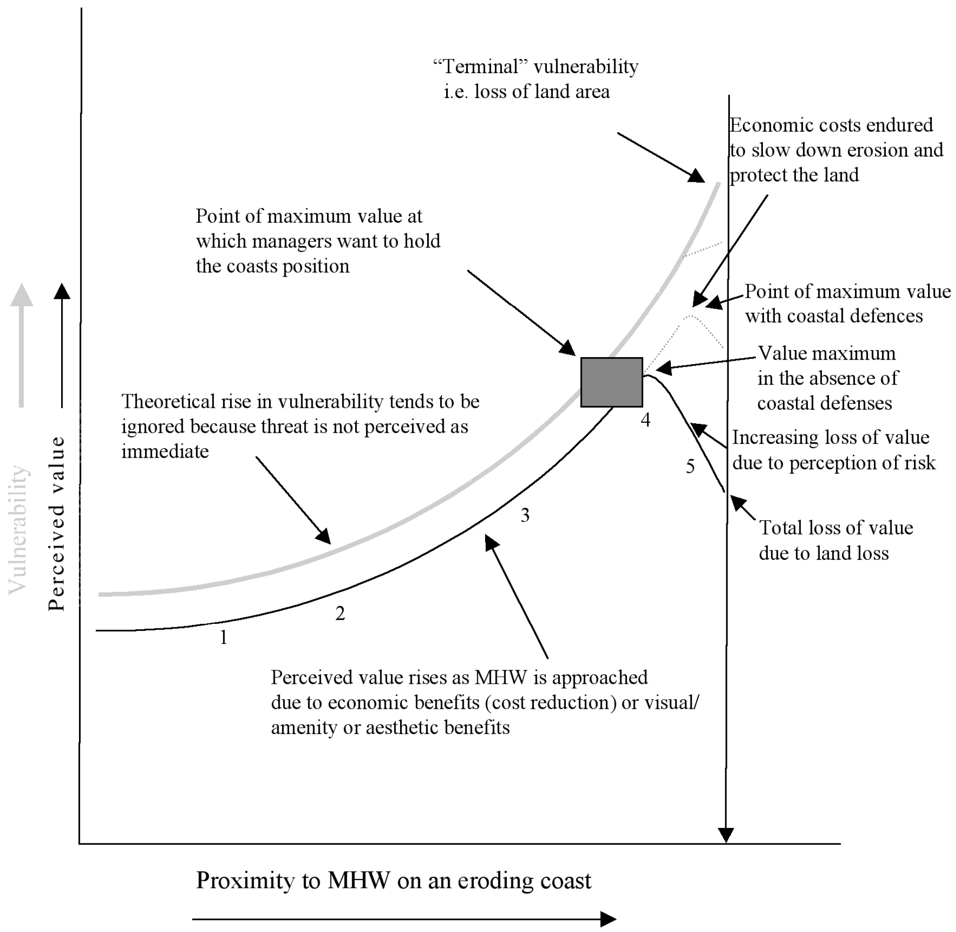

Figure 6. Schematic model of the relationship between vulnerability and perceived value on an eroding coast.

Portballintrae, Portrush and Carnlough beaches in Co. Antrim. At Portrush West Bay the level of the beach has dropped by over 1.5m since the building of a seawall and promenade at the back of the beach in the 1960's (CARTER and BARTLETT, 1990). Further complexity is added if coastal defences are considered not just as indicators of erosion but as the cause of erosion down-drift of the areas they were placed to protect.

There are inherent problems in trying to keep the shoreline static, as it is a dynamic environment with dynamic processes operating on it. Human interference in these processes can distort definitions of vulnerability. Many people seem to want the quality-of-life experiences associated with vulnerable coastal locations, such as spectacular views, without the negative reality of catastrophic erosion, cliff collapse, prohibitive insurance costs and ultimately the total loss of property.

Conclusion

"Vulnerability" is a human value judgement, so ultimately the perceived value of coastal areas will strongly influence management decisions. Consequently the socio-economic element of coastal vulnerability is at the very heart of management practice. The inclusion of socio-economic variables in coastal vulnerability indices is extremely important albeit not without difficulties. The socio-economic aspect is usually omitted from published indices, probably due to the difficulties in obtaining and ranking the data. The incorporation of a socio-economic sub-index in an overall index to assess vulnerability to wave-induced erosion for Northern Ireland proved to be a useful exercise in examining the problems involved in the compilation of such indices.

LITERATURE CITED

BELFAST TELEGRAPH, 1998. *Artworks*. 23rd May, Johnston, N., Belfast.

CAMBERS, G. 1998. Coping With Beach Erosion. UNESCO Publishing, Paris.

CARTER, R.W.G. and BARTLETT, D.J. 1990. Coastal erosion in northeast Ireland – Part 1: Sand beaches, dunes and river mouths. *Irish Geography*, 23, 1-16.

CARTER, B. 1993. Retreat to the future. *The National Trust Magazine*, 70, 28-29.

CENDRERO, A. and FISCHER, D. W. 1997. A procedure for assessing the environmental quality of coastal areas for planning and management. *Journal of Coastal Research*, 13, (3), 732-744.

COOPER, J. A. G. and McLAUGHLIN, S. 1998. Contemporary multidisciplinary approaches to coastal classification and environmental risk analysis. *Journal of Coastal Research*, 14, (2), 512-524.

DEVOY, R. J. N. 1992. Questions of coastal protection and the human response to sea-level rise in Ireland and Britain. *Irish Geography*, 25, (1), 1-22.

DILLEY, R. S. and RASID, H. 1990. Human response to coastal erosion: Thunder Bay, Lake Superior. *Journal of Coastal Research*, 6, (4), 779-788.

DOORNKAMP, J. C. 1990. Policy, planning and engineering reactions to sea level rise. *In*: Doornkamp, J. C. (ed.), *The Greenhouse Effect and Rising Sea Levels*. M1 Press Limited, Nottingham, 135-145.

FLEMMING, C. A. and TOWNEND, I. H. 1989. A coastal management database for East Anglia. *Coastal Zone'89*, 4092-4107.

GORNITZ, V. 1990. Vulnerability of the East Coast, USA to future sea level rise. *Journal of Coastal Research*, 1, (Special Issue No. 9), 201-237.

GORNITZ, V., DANIELS, R. C., WHITE, T. W. and BIRDWELL, K. R. 1993. The development of a coastal risk assessment database: vulnerability to sea-level rise in the U.S. southeast. DE-AC05-84OR21400, *U.S. Government Report*, Oak Ridge National Laboratory, Tennessee.

HOPLEY, D. 1992. Global change and the coastline: assessment and mitigation planning. *Journal of Southeast Asian Earth Sciences*, 7, (1), 5-15.

HUGHES, P. and BRUNDRIT, G. B. 1992. An index to assess South Africa's vulnerability to sea-level rise. *South African Journal of Science*, 88, (June 1992), 308-311.

INDEPENDENT (The), 1999. Gently does it…850 ton lighthouse is rescued. March 18th, Clare Garner, London.

LEE, J. K., PARK, R., MAUSEL, P. W. and HOWE, R. C. 1991. GIS-related modeling of impacts of sea level rise on coastal areas. *GIS/LIS'91*, V1.002, 356-367.

LEGGETT, D.J. and JONES, A. 1996. The application of GIS for flood defence in the Anglian Region: developing for the future. *International Journal of Geographical Information Systems*. 19, (1), 103-116.

MARSHALL, J. D. C. 1991. *Forgotten Places of the North Coast*. Clegnagh Publishing, Coleraine.

McCUE, J. and DEAKIN, R. 1995. Using geographical information systems in shoreline management planning. *Proceedings of Management Techniques in the Coastal Zone*, University of Portsmouth, 163-177.

McKENNA, J., MACLEOD, M., POWER, J. and COOPER, J.A.G. 2000. *Rural Beach Management: A Good Practice Guide*. Donegal County Council, Lifford, Ireland.

McLAUGHLIN, S. 2001. *Assessment and Development of a Coastal Vulnerability Index for Northern Ireland Employing GIS Techniques*. Unpublished D.Phil. Thesis, University of Ulster, Coleraine.

O' RIAIN, G. 1996. *The Development of Indices to Coastal Erosion Utilising a Geographical Information System*, MSc Thesis, Trinity College , Dublin.

OPENSHAW, S. 1983. *The Modifiable Areal Unit Problem*. GeoBooks, Norwich.

PILKEY, O.H. and DIXON, K.L., (1996). *The Corps and the Shore*. Island Press, Washington.

RIVAS, V. and CENDRERO, A. 1994. Human influence in a low-hazard coastal area: an approach to risk assessment and proposal of mitigation strategies. *In*: Finkl, C. W. (ed.), *Coastal Hazards: Perception, Susceptibility and Mitigation*. The Coastal Education and Research Foundation, Fort Lauderdale, Florida, 289-298.

TOWNEND, I. H. and FLEMMING, C. A. 1994. Classification techniques for coastal interpretation. *Littoral'94*, Lisbon, Portugal, (September 26-29), 965-979.

WILSON, P. and CARTER, B. 1990. Portrush to Millstrand. *Irish Association for Quaternary Studies (IQUA), Field Guide no*. 13: North Antrim and Londonderry.