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Assessing the economic costs of sea level rise

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Abstract. Sea level rise is one of the potential consequences of human induced global climate change, and coastal zones, together with their inhabitants, may be becoming more susceptible and vulnerable to such external shocks and related damage impacts. Global, regional, and national scale studies have been undertaken in an attempt to assess the future threat posed by sea level rise. To date none of these studies have fully encompassed the relationship between the physical change impacts and the socioeconomic implications. The authors utilise both a 'GDP-at-risk' and an economic cost–benefit approach, in combination with biophysical analysis, to model the impacts of sea level rise along the East Anglian coastline of eastern England. The economic results indicate that for most sea-level-rise predictions the protect strategy is economically justifiable on a region-wide basis. At a more localised scale a combination of response options, including 'do nothing and retreat', may be optimal.

1 Introduction

The presence both of scientific and socioeconomic uncertainties ensures that it is not possible to predict with a high degree of confidence how present human action will induce future climate change through the enhancement of the greenhouse effect, or how geophysical, ecological, and human systems will react to such potential change. We are therefore limited to 'best guess' scenarios for climate change and the socioeconomic reactions this change may cause (Houghton et al, 1992). Sea level rise is one of the more apparent potential consequences of human induced global climate change. This rise will be due primarily to the thermal expansion of the oceans and to the melting of continental ice (that is glaciers and the Greenland ice sheet). The impact of an increase of just a few centimetres in the global mean sea level, allied to changes in the frequency and intensity of storm events, has potentially devastating damage-impact implications for coastal areas worldwide.

Best guess projections of global sea level rise are beset by uncertainties, only some of which have been addressed. The effect of global warming on the Antarctic ice mass is, for example, currently unclear and ice may accumulate, leading to reduced mean sea levels (Schneider, 1992a; 1992b). Variations in ocean 'topography' have not been properly accounted for in scenario analysis. In addition, the range of variability of the present day sea level and of the sea level during the recent geological past has not been stressed or clearly understood. Further uncertainty is related to variations in the rate of greenhouse gas emissions which depend on present and future human actions. Nevertheless it is widely accepted that sea level rise will occur, although not by the same amount globally. Indeed there is probably a considerable 'commitment' to global warming and its impacts built into the global atmospheric and oceanic systems, because of a combination of past greenhouse gas emissions, global population pressures, and energy production and consumption trends.

Thus the difference between mean sea level changes, with and without a stringent emissions-control policy, may be relatively small up to the year 2100 (Warrick, 1993; Wigley and Raper, 1992; 1993).

During the twentieth century in particular, coastal populations have been growing because of the many economic opportunities and environmental amenities that coastal zones can provide. The need to protect and enhance the wealth creation potential of coastal zones has led to widespread coastal construction and modification of physical shoreline processes, resulting in the loss of coastal habitats, changes to circulation and material flux, and to a reduction in biological productivity. Human activities can influence the sea level directly and have led to a net increase in sea levels over the past century. It has recently been estimated that a combination of groundwater withdrawal, surface water diversion, and land-use changes (wetland loss, and deforestation) have caused at least 33% of the observed sea level rise. Hence, the contributions of climate-related effects to this rise may be smaller than has previously been supposed (Sahagian et al, 1994).

Climate-related changes such as an accelerated rise in sea level (ARSL) and more frequent storm events would therefore represent potential additional stresses on systems which are already under significant and growing pressure. Furthermore, there are complex interrelationships and feedbacks between human and environmental driving forces and impacts, and climate-induced changes and effects. The process of human intervention in order to maximise the multiple use benefits provided by coastal zone environments has been characterised by failure of policy and intervention. These failures have contributed to a flux of factors which have increased the sensitivity and vulnerability of coastal zones and of their populations. The coastal zone management challenge is, consequently, to limit the impact of urbanisation and economic development on adjacent natural areas while, at the same time, protecting the coastal infrastructure and the economic and social support systems from external stress and shock.

Global, regional, and national scale studies have now been carried out in an attempt to assess the future threat of sea level rise (den Elzen and Rotmans, 1992; IPCC CZMS, 1991; Milliman et al, 1989; Titus et al, 1991). None of these studies, however, has fully encompassed the relationships between the physical changes and the socioeconomic implications. In this paper we utilise an economic cost-benefit methodology in combination with a biophysical analysis to model the impacts of sea level rise along the East Anglian coastline of eastern England. The model is a 'first cut' at comprehensive assessment of coastal-zone vulnerability and as such is limited by difficulties over the full incorporation of all nonmarket asset values (particularly ecological resources) and all possible adaptation mechanisms. The rest of this paper is organised as follows: in section 2 we examine the concept of vulnerability and relate it to Great Britain and its coastline; in section 3 we set out the models used to assess the impact of sea level rise on the East Anglian coast; in section 4 we present the results of our case study analysis; in section 5 we review the limitations of the analysis, and section 6 contains our conclusions. The results illustrate how the economic methodology is central to any assessment of vulnerability and can assist policymakers grappling with the prospect of a climate-induced sea level rise. However, policy responses depend also on institutional constraints and often require trade-offs between efficient resource allocation and precautionary action.

2 Vulnerability assessment

In May 1992 the Coastal Zone Management Subgroup (CZMS) of the Intergovernmental Panel on Climate Change (IPCC) published a technical report which laid down guidelines for the assessment of vulnerability (in biophysical and socioeconomic terms) to climate-induced sea level rise, as well as giving the formulation of potential adaptive response strategies (IPCC CZMS, 1992). The analysis in this paper broadly applies the CZMS 'Common Methodology' to the 'vulnerable' coastal zones of Great Britain. A detailed regional case study is undertaken, which utilises a conventional cost-benefit analysis to appraise policies for the control or management of the threat posed to Britain's most vulnerable stretch of coastline, the East Anglian region.

Although the CZMS Common Methodology has been used as a generic guide to our vulnerability assessment, we have departed from its recommendations in one fundamental way. The CZMS guidelines suggest different time horizons for various elements in the assessment. Thus according to IPCC, accelerated rise in sea level (ARSL) should be estimated over a 100 year time horizon; economic development in the hazard zone should be estimated over a 30 year time horizon; and response costs should be estimated in current cost terms.

In order to utilise an economic cost-benefit approach, it is necessary to run all these parameters over the same time horizon. A truncated planning horizon (that is up to the year 2050) has therefore been adopted so that the ARSL forecasts, the physical and ecological impacts assessments, and the socioeconomic implications can be put onto a common basis. The truncated time horizon has allowed us also to rely on simplifying assumptions about possible 'adaptation mechanisms' (that is population movement, industrial relocation, etc.), in addition to providing a reasonable basis for the calculation of discounted cost and benefit streams in monetary terms.

The concept of vulnerability has been defined numerous times in the climate-change literature, but not always on a consistent basis (Kasperson et al, 1990; Turner et al, 1991). It is clearly a multidimensional concept which encompasses firstly some notion of the susceptibility of a coastal area to the physical changes imposed by the ARSL, and secondly the impacts of physical changes on the relevant socioeconomic and ecological systems. The third dimension of vulnerability relates to the 'institutional' capability of a region or country to cope with or manage (by prevention and/or alleviation measures) the impacts.

Figure 1 illustrates the coastal areas of Great Britain which are potentially vulnerable to ARSL on this basis. Much of Britain's coastal lowlands are at risk since they lie well below the present day high-tide levels. This risk will increase if, in the future, the sea level rises, or if ground altitudes fall, or if there is an increase in storminess, which results in extreme water levels. Published 'best guess' predictions of global sea level rise are in the range of 17 cm to 26 cm by the year 2030, and 33 cm to 39 cm by the year 2050 (Wigely and Raper, 1992). The most recent results (mid 1994) from the MAGICC model at the Climatic Research Unit, University of East Anglia, predict an East Anglian regional rise of 18.5 cm by 2050 and 45 cm by 2100. Our case study area is the stretch of coast, in the East Anglia Region, bordering the North Sea from Hunstanton to Felixstowe (figure 2, see over). This coastal zone contains a range of urban/industrial and ecological (recreation, landscape and amenity) type assets.

IPCC's CZMS recommends the assessment of three broad types of policy response:

Retreat	abandon the land and structures in vulnerable areas and resettle the population; this option can also include managed retreat which in turn can be linked to specific measures aimed at restoring or creating desirable habitat, landscape, or amenity features (ecological sustainability);
Accommodate	continue occupancy and use of vulnerable areas;

Protect continue full defence of vulnerable areas (especially population centres), economic activities, and natural resources.

In our case study analysis, we have utilised response options that are broadly compatible with the CZMS classification.

It is possible to approach the problem of assessing the economic implications of sea level rise and the policy responses either from a 'top down' or a 'bottom up' perspective. Both approaches have been applied at a global level (for the former see Houghton et al, 1990; 1992; and for the latter see den Elzen and Rotmans, 1992, and Milliman et al, 1989). The top down assessment necessarily has to rely on aggregated data. Fankhauser (1994) has recently produced such an assessment. In his model, the rule of thumb used to estimate the socially optimal degree of coastal protection is the ratio of costs under full protection against those under full retreat. The larger the costs of protection, or the lower the damage under full retreat, the lower will be the degree of protection.

Fankhauser's (1994) model predicts that, for Great Britain, the optimal degree of protection varies between 92% and 98% (for a predicted sea level rise of between 20 cm and 1 m over the next 100 years) for open coasts and beaches, and between 98% and 99% for urban/industrial/port areas. The policy message is that it will

Figure 1. Areas of Great Britain potentially vulnerable to ARSL. Source: National Audit Office, 1992 (December 1991 data); and Institute of Terrestrial Ecology, 1989.

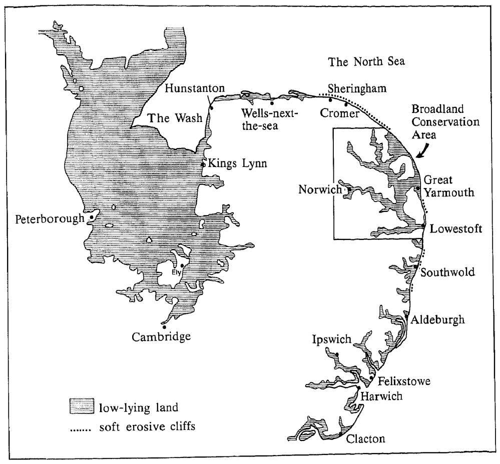

Figure 2. Tidal flood areas and soft, erosive cliffs in East Anglia. Flood risk areas comprise low-lying land below the level of the highest recorded tide.

probably be economically optimal for Great Britain to protect most of its vulnerable coastline. The combined protection and damage cost estimate for Great Britain varies between £48 billion and £283 billion, or £1.9 billion and £10.3 billion, depending on which discount rate (1.5% or 3.0%) is used (Fankhauser, 1994).

The aggregated nature of the data and the top down type model may, however, mask important regional-local differences. Determining the optimal policy response to sea level rise is really a problem of regional coastal zone management. Thus the optimal protection strategy may be different for different coastlines. We set out to test this proposition by formulating and testing a bottom up type model, using East Anglian coastal zone data.

3 East Anglian coastal zone: A case study

Methodology

The basic approach adopted in the study is to combine information about the physical hazard posed by ARSL with data on assets at risk, to produce a physical and then an economic estimation of the impacts of ARSL. The analysis is ordered in a stepwise manner, in accordance with the approach recommended in the CZMS vulnerability assessment guide (figure 3, see over).

The study area comprises the East Anglian coast between Hunstanton and Felixstowe (see figures 1 and 2). The main risks posed by ARSL in this hazard zone would result from increased flooding and coastal erosion. The output of global climatological models and their predictions of the RSL were used as baselines for the estimation of the future potential physical hazard.

The vulnerability of this stretch of coastline derived partly from the existence of large areas of low-lying land, both immediately adjacent to the shoreline and inland of Great Yarmouth, and partly from the existence of stretches of soft erosive cliffs. Coastal defences (mainly engineered hard structures), built largely after the very destructive surge-flood caused by the 1953 North Sea storm, and river flood embankment defences play a crucial role in the maintenance of the current shoreline, of the levels of economic activity, and of environmental resources in the immediate hinterland. Maintenance and replacement costs for sea defences and coastal protection works are likely to be very substantial in the future.

The case study methodology contained the following sequential stages:

1. development of regional scenarios of ARSL;
2. development of an analysis linking ARSL with zone-specific physical hazards—flooding, inundation, and erosion;
3. subdivision of the hazard zone into separate physiographic units, based on the risk of flooding and erosion;
4. collection of asset data for the hazard zone, in order to establish an inventory of natural and artifically constructed capital assets;

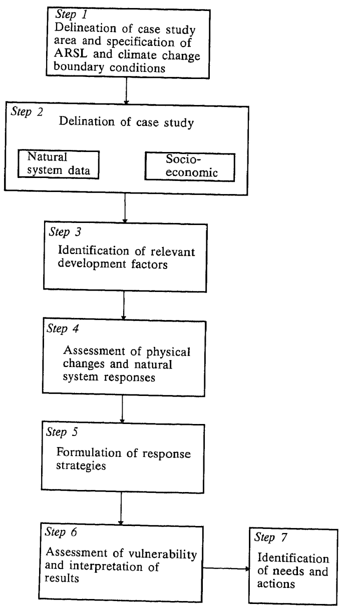

Figure 3. Stepwise approach for vulnerability analyses. Source: Adapted from IPCC, CZMS.

5. quantification and evaluation of the in-place sea defence and coastal protection system in the hazard zone;
6. definition of ARSL response options and an assessment of their impact on coastal hazards and assets in the zone;
7. economic valuation of the costs and benefits of the various response options, including the do nothing option.

The coastline of England and Wales is approximately 4500 km long, and over one third, mainly in the East Anglian case study region, is protected by artificial and/or seminatural defences. In 1992 the National Rivers Authority published the results of a survey of existing sea defences and their condition. On average about 16% of the defences were in need of significant or moderate renovation, and some 17% of defences were judged to have a residual life of five years or less, including our study region where some 363 km of defences were requiring attention.

Four different ARSL values were employed in the analysis (20, 40, 60, and 80 cm by the year 2050), which reflects the uncertainty inherent in the climate models and in the related policy responses in the climate change problem. The 80 cm values is a 'worst case' figure [not based on the best guess climate (model predictions)] but it allows for unrealised and unpredicted impacts or feedbacks (see Lashof, 1989; Schneider, 1992a). The historical return periods of water levels and rates of coastal retreat were then adjusted upwards to account for the predicted changes in sea level.

The next task was to establish what assets were actually at risk. The flood hazard zone was defined as all coastal areas less than 5 m above the ordinance survey datum. Areas at risk because of coastal erosion were assumed to be limited to land adjacent to an eroding coastline. These zones were found to contain many different types of assets, both natural and fabricated (figure 4, see over). A detailed survey was therefore carried out to establish the number and location of properties, the total population, the area and type of agricultural land, the transport infrastructure, the number of waste sites and nature conservation sites, together with the number of historical sites, landscape resources, and recreation resources (Bateman et al, 1991).

The East Anglian hazard zone has at its heart an internationally important wetland complex known as Broadland. This multiple-use area is recognised as providing a wide range of functional and structural values (Gren et al, 1994). Environmental economists have made considerable progress in terms of placing meaningful monetary valuations on some components of wetland and other ecosystems, but such assessments still underestimate the full value of these natural assets. The recreation and amenity value of Broadland has recently been estimated and we used this data as a proxy and partial indicator of the environmental asset value at risk in the zone.

Broadland is under continued threat from flooding, with some 20000 ha of the complex lying below surge-tide level. The area is protected by over 200 km of tidal embankments, many of which are old and in a deteriorating condition. The current standard of flood protection provided by the river walls in Broadland is frequently below a one in ten (or even a one in five) year flood return. In section 4 we outline the economic method used to value Broadland recreation and amenity services.

The impact of ARSL on the hazard zone depends greatly on how the coastline is managed. Three different stylised management approaches, representing a range of possible responses to ARSL, were therefore produced. The management responses were: retreat, that is, abandon defences (do nothing); accommodate, which means maintain defences at their current physical height (viz. status quo protection

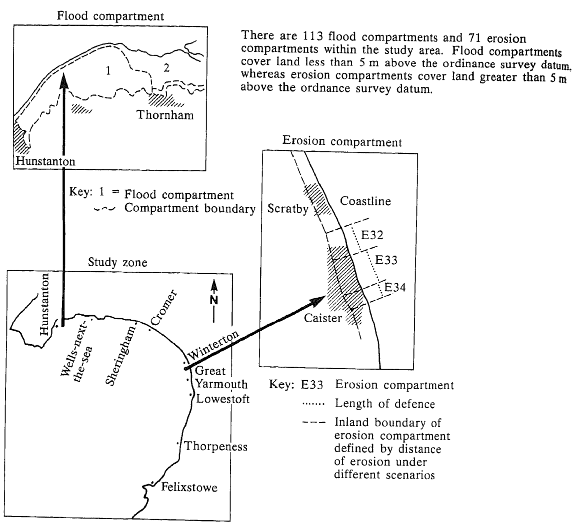

Figure 4. Examples of flood and erosion compartments.

standard which declines as and when ARSL occurs); protect, that is, improve defences (and retain a given level of protection despite ARSL). These responses were defined in terms of the extent and effectiveness of defences that they represented. Efforts were then made to model actual feasible changes in flood return periods and coastal erosion rates up to 2050.

Having established the change in risk faced by coastal assets as a result of estimated future ARSL, our final analytical step was to express the consequences of such changes in economic terms.

4 Economic impact assessment

In the first approach tested we used readily available national/regional income statistics. With the use of this rapid assessment method it is possible to identify the financial asset values under threat from rise in sea level, this being achieved by calculating the proportion of the national gross domestic product (GDP) represented by the assets within the hazard zone. It must be stressed that this is an indicator of what is at risk rather than a measure of the economic damage cost or lost social value due to RSL.

The Regional (East Anglia) Income Accounts identify those GDP activities associated with three broad categories—agriculture, population, and industry. Data from the physical assets inventory for the hazard zone (defined by the 5 m contour) allow calculation of the percentages of the total East Anglian population living in the zone; the total amount of the region's agricultural land found in the zone; and finally the total regional industrial activity located in the zone. These percentages converted into equivalent GDP financial percentages via the services, agriculture, and industrial GDP account estimates. This number (£GDP) for the total affected assets/economic activity in the zone is converted into present value terms via an appropriate rate of discount.

For each ARSL scenario an equal annual incremental rise in RSL (with 1989/90 as the base year) is assumed up to 2050, that is 1/60th of the potentially affected activity (total £GDP) would be at risk in the first year, 2/60ths in the second year, etc. The present value is obviously sensitive to the assumed rate of economic growth, and hence a range of economic growth rates over the period to 2050 is incorporated in the analysis.

Thus the real value of economic activity potentially at risk in the hazard zone, t years in the future, is:

$$M_{\text{ev}} = (t/60) \times (\text{total GDP 1989/90 £}) \times (1+g)^t$$

where

M_{ev} is the economic vulnerability measure,

g is the GDP growth rate,

and the present value of V_{pev} is given by

$$V_{\text{pev}} = \text{real value} \times (1+r)^{-t},$$

where r is the discount rate.

The results of the GDP-at-risk analysis are shown in table 1. They represent the total present value of real GDP at risk of loss from permanent flooding and erosion over the period 1990–2050. The sensitivity of the results is presented for a range of RSLs, GDP growth rates, and discount rates. As would be expected, the greatest losses occur in the retreat response strategy. This reflects the abandonment of the flood hazard zone and the high rates of erosion that are assumed to occur because of this response. The losses are relatively insensitive to changes in RSL predictions. For the flood hazard zone the assumed pattern of abandonment is identical under all RSL scenarios and hence the difference in the estimated loss is due to the increasing rates of erosion.

Table 1. The total present value of real GDP at risk from permanent flooding and erosion, 1990–2050 (£ million).

GDP growth rate pa (%)	RSL scenario							
	3% discount rate				6% discount rate			
	20 cm	40 cm	60 cm	80 cm	20 cm	40 cm	60 cm	80 cm
(a) Permanent flooding								
1	3872	4003	4139	4409	1558	1610	4665	1773
3	8359	8641	8936	9517	2955	3045	3159	3364
5	19178	19824	20502	21835	6039	6243	6457	6876
(b) Erosion								
1	295	448	1142	1214	119	180	459	488
3	637	967	2466	2620	225	342	872	926
5	1462	2217	5657	6012	460	698	1781	1893

In contrast to the retreat strategy, in the accommodate response strategy it is assumed that a defence line is maintained, and this is reflected in the significantly lower loss estimates. Nevertheless, some abandonment of land and property within the flood hazard zone is assumed to occur as flood frequency thresholds are exceeded. Similarly erosion is also assumed to take place. Compared with losses in the retreat response, the losses in the accommodate response are more sensitive to changes in the RSL prediction because, as the RSL increases, the number of flood compartments assumed to be abandoned increases (that is 34% for a 20 cm RSL climbing to 62% for a 80 cm RSL). In addition, at higher predicted values of RSL, we have assumed that the effectiveness of erosion defences decreases and the rate of erosion increases.

Losses have not been calculated for the protect response strategy. Although this response maintains the status quo, permanent flooding and erosion losses still occur. For example, 2.8% of agricultural land and 0.4% of property are assumed to be abandoned if present day flood frequencies continue to be experienced and acceptable 'tolerance' thresholds are therefore exceeded. Similarly erosion is still assumed to occur. Overall, however, the losses would be insignificant compared with those in the retreat and accommodate response strategies.

In the second approach to economic evaluation, direct damage and loss are estimated via a partial social cost–benefit (SCB) model. The model is restricted to a consideration of the two 'active' management response options (namely accommodate and protect). The social cost–benefit analysis (SCBA) is 'partial' because it considers only the economic benefit (damage cost avoided) of protection to properties, agriculture, and one aspect (recreation and amenity) of Broadland environmental service value. These asset categories were the most amenable to monetary evaluation.

The economic cost–benefit decision is to accept the response strategy that maximises the present value of net benefit V_{pn}:

$$\text{maximise } V_{\text{pn}} = \sum_{t=0}^{T} \frac{1}{(1+r)^t}(B_t - C_{c,t})$$

where
B_t is the total benefit (damage costs and losses avoided),
$C_{c,t}$ is the capital and operating costs of the defence system,
r is the discount rate,
V_{pn} is the net present value.
On the costs side:

$$C_t^{\text{sq}} = \sum_{t=0}^{T} \frac{1}{(1+r)^t}\left[l(C_{\text{M},t}^{\text{sq}} + C_{\text{R},t}^{\text{sq}}) + C_{\text{Br},t}^{\text{sq}} + C_{\text{Bn},t}^{\text{sq}}\right],$$

and

$$C_t^{\text{imp}} = \sum_{t=0}^{T} \frac{1}{(1+\text{r})^{\text{t}}}\{l[C_{\text{D},t} + (C_{\text{M},t}^{\text{imp}} + C_{\text{R},t}^{\text{imp}})] + C_{\text{Br},t}^{\text{imp}} + C_{\text{Bn},t}^{\text{imp}}\},$$

where
C_t is the present value of total cost at time t (£ million),
sq is the maintain (status quo) option,
imp is the improve option,
l is the length of defence (km),
$C_{\text{M},t}$ is the hard and soft engineering defence maintenance cost at time t (£ km^{-1}),
$C_{\text{R},t}$ is the replacement cost of defences at time t (£ km^{-1}),
$C_{\text{Br},t}$ is the cost of repairing breaches in defence at time t (£),

$C_{\text{Bn},t}$ is the beach nourishment cost at time t (£),
$C_{\text{D},t}$ is the cost of improving defences at time t (£ km^{-1}),
t is the time,
r is the discount rate,
T represents time horizon.
On the benefits side:

$$V_{\text{B}} = \sum_{t=0}^{T} \frac{1}{(1+r)^t}(L_t^{\text{prop}} + L_t^{\text{agr}} + L_t^{\text{env}})$$

where
V_{B} is the present value of benefits (£),
L_t^{agr} is the losses (erosion and flooding) at time t (£),
L_t^{prop} is the built property losses at time t (£),
L_t^{env} is the assets lost at time t (£).

The erosion and permanent inundation losses were assumed to be irreversible, whereas other losses were assumed to be temporary flooding damage costs. Hence agriculture losses are given by

$$L^{\text{agr(per)}} = \sum_{t=T_n}^{T} \frac{1}{(1+r)^t} Y_t^{\text{per}} A_t^{\text{per}}, \quad \text{and} \quad L^{\text{agr(tem)}} = \sum_{t=0}^{T_n} \frac{1}{(1+r)^t} Y_t^{\text{tem}} A_t^{\text{tem}},$$

where
$L^{\text{agr(per)}}$ is the present value of permanent losses,
$L^{\text{agr(tem)}}$ is the present value of temporary losses,
Y_t is the annual income from agricultural land at time t (£/ha),
A_t is the area affected (ha) at time t,
T_n is the threshold time at which permanent loss occurs.

Built property losses are given by

$$L^{\text{prop(per)}} = \sum_{t=T_n}^{T} \frac{1}{(1+r)^t} L_{t(\text{ann})}^{\text{prop(per)}} N_t^{\text{per}},$$

and

$$L^{\text{prop(tem)}} = \sum_{t=0}^{T_n} \frac{1}{(1+r)^t} L_{t(\text{ann})}^{\text{prop(tem)}} N_t^{\text{tem}},$$

where
$L^{\text{prop(per)}}$ is the present value permanent losses,
$L^{\text{prop(tem)}}$ is the present value temporary losses,
$L_{t(\text{ann})}^{\text{prop}}$ is the annualised value of built property loss at time t,
N_t is the number of built property affected at time t.

In the context of environmental assets valuation (E_t), a contingent valuation study (CVM) has been completed which estimated the monetary value (willingness to pay [WTP]) of conserving Broadland via a protection strategy designed to mitigate the increasing risk of salt water flooding (Bateman et al, 1993). The CVM is a questionnaire-based method supported by a rigorous testing protocol, though more specifically it aimed at assessing the value of conserving the recreation and amenity values provided by Broadland. A do nothing scenario was constructed and translated into a pictorial display to enable survey respondents to judge for themselves the relative merits of the current wetland asset structure and the change in environment that would result if frequent flooding was to occur. Survey respondents were asked for their WTP to conserve Broadland in its present condition.

Various payment methods and elicitation methods were tested. The results of an open-ended elicitation method test and of an iterative bidding method test are summarised in table 2. All the results refer to user values and range from £67 to £140 per household per annum. The total use (recreation and amenity) value of Broadland was thus estimated to be within the range of £5 million – £15.5 million per annum depending on the visitation rate data chosen. The lower bound estimate of £5 million is used in the cost–benefit analysis.

Table 2. Broadland recreation and amenity, use value estimates [source: Bateman et al (1993a)].

N	Mean WTP[a] (£)	Median WTP (£)	SD	SE Mean	Minimum Bid (£)	Maximum Bid (£)	Lower quartile	Upper quartile
Open ended WTP study								
846[b]	67.19[c]	30.0	113.58	3.91	0.0	1 250.0	5.0	100.0
Iterative bidding WTP study								
2051[d]	74.91[e]	25.0	130.1	2.87	0.0	2 500.0	10.0	100.0
Dichotomous choice WTP study								
2070	140[f]	139	NApp	NApp	NApp	NApp	NApp	NApp

Note: WTP refers to the willingness to pay.
[a] Includes as zeros, those who refused to pay anything at all.
[b] Total sample of 862 interviews include 16 incomplete questionnaires which were omitted from the calculation of the mean.
[c] 95% confidence interval = £59.53; £74.86.
[d] Total sample of 2070 of which 19 incomplete questionnaires were omitted from the calculation of the mean.
[e] 95% confidence interval = £69.27; £80.55.
[f] 95% confidence interval = £75; £261.

The total benefit of adopting either the maintain defences strategy or the improve defences strategy is given by the size of the damage costs and losses avoided, that is the difference between the damage costs and losses incurred in an abandon defences situation and those incurred in either of the two 'defend' responses. The net benefit of each response strategy can be calculated by subtracting the capital and maintenance of defence system costs from the value of the total benefit (damage costs avoided).

The total economic cost of the abandon defences option would be given as:

$$C^{\mathrm{dn}} = \sum_{t=0}^{T} \frac{1}{(1+\mathrm{r})^{\mathrm{t}}}(Y_t^{\mathrm{tem}} A_t^{\mathrm{tem}}) + (Y_t^{\mathrm{per}} A_t^{\mathrm{per}}) + [L_{t(\mathrm{ann})}^{\mathrm{prop(tem)}} N_t^{\mathrm{tem}}] + [L_{t(\mathrm{ann})}^{\mathrm{prop(per)}} N_t^{\mathrm{per}}] ,$$

where C^{dn} represents the total present value cost of do-nothing.

This basic economic analysis will be more complicated in hazard zones which are already 'defended' from erosion and/or flooding by various sea defence and coastal protection structures and systems. These defences will not collapse immediately but will be subject to progressive failure over an uncertain period of time. Other complications include also the current status of the asset inventory in the zone, namely the quality, age and condition of property, vintages of plant and equipment in industrial enterprises, and the quality and carrying capacities of natural ecosystems.

The economic value of property, plant and equipment, for example, will vary with their replacement date and consequent residual economic lifetimes. For assets which will be fully depreciated by 2050 we need to estimate (given the RSL) what, if any, accelerated depreciation cost (due to an earlier than expected replacement date) is applicable. It is also important to try and distinguish between marginal and nonmarginal asset changes. Thus the threat (let alone the actual loss) of extensive loss of land or property and/or the loss of unique irreplaceable structures and natural systems may stimulate macroeconomic effects within the national economy. There may also be an indirect cost, in the form of psychological damage (increased stress and anxiety, and related illnesses), incurred by people who suffer flooding or inundation. Environmental goods and services pose special valuation problems. A minimum estimate of the likely costs of environmental damage to the Broadland unique complex has been included in the cost–benefit model.

4 Results

Tables 1, (a) and (b), give the range of estimates produced by using the 'GDP-at-risk' approach for the do nothing and maintain status quo response strategies under the four ARSL scenarios and for two different rates of discount.

The results of the cost–benefit analysis are summarised in table 3. The present values of flood and erosion defence costs for each response strategy are set out first. These are the accumulated costs of defence over the period 1990–2050, discounted at the UK Treasury's 6% discount rate. The first observation to make is that there are no protection costs associated with the retreat response strategy. This is because the retreat option considered involves a complete abandonment of the coastal zone. For the two remaining proactive response strategies the costs shown combined both flood and erosion defence costs. Of these two cost components the latter is always the smaller, accounting for around 20% to 30% of the total defence cost. Although in the accommodate response strategy it is assumed that the physical scale of the defences remains the same, there is still a gradual rise in defence costs with increasing RSL, because we assume an increased frequency of flooding events and consequent defence repair costs. In the case of the protect response strategy, there is a gradual rise in defence costs which reflects the need for progressively higher defences and increased volumes of beach nourishment to counter RSL and enhanced erosion. The highest RSL prediction (80 cm) causes a significant jump in

Table 3. Costs and benefits of RSL and policy responses in East Anglia (1990–2050).

Response strategy	RSL (6% discount rate, £ million 1991)			
	20 cm	40 cm	60 cm	80 cm
Protection costs				
Retreat	–	–	–	–
Accommodate	132	137	151	157
Protect	187	232	292	485
Flood and erosion damage costs				
Retreat	1325–1333	1347–1355	1396–1405	1426–1436
Accommodate	184–194	239–257	298–320	368–397
Protect	66–77	63–74	70–81	74–85
Benefits of defence (relative to do nothing 'retreat')				
Accommodate	1139–1141	1098–1108	1085–1098	1039–1058
Protect	1256–1259	1281–1284	1324–1326	1351–1352
Net benefits				
Accommodate	1007–1009	961–971	934–947	882–901
Protect	1069–1072	1049–1052	1032–1034	866–867

costs because the required standard of defence would necessitate the use of new, more expensive engineering methods.

We next present the accumulated flood and erosion damage costs for each response option over the period 1990–2050. Unlike the 'GDP-at-risk' approach, this analysis includes the losses resulting from future flooding (temporary and permanent), as well as from erosion. A range of values is given in each case, reflecting the degree of uncertainty surrounding the nature of future flooding conditions. The contribution that erosion makes to the total loss varies greatly. For example, in the retreat response strategy it accounts for around 10% to 15% of the loss, whereas in the protect response strategy it accounts for around 7% to 30%.

We include also an environmental damage cost both in the retreat and in the accommodate response strategies. As outlined in the previous section, a conservative estimate of £5 million per annum is assigned to cover the value of the conservation of the whole of Broadland in its present-day condition. In practice, however, both the retreat and accommodate strategies would, over time, result in a deteriorating wetland environment. The annual conservation value is therefore subject to a depreciation rate which is incorporated crudely into the cost–benefit analysis. Overall, the highest losses, not unexpectedly, occur under the retreat option, although the accommodate option costs are the most sensitive to changing RSL predictions.

The next stage of the analysis is to establish benefits against which defence costs are compared; benefits in this case being the benefits of defence. Such values are determined by comparing flood and erosion losses under a given response strategy with those that would have occurred under a do nothing situation. The difference between the two figures is the 'avoided loss', hence it is a benefit of defence. In this study the retreat response strategy is considered equivalent to the do nothing situation. Therefore the losses under this strategy are compared with the losses under the accommodate and protect response strategies, in order to produce the estimates shown in the table. The protect response strategy produces the greatest benefits across all RSL categories.

The final stage of the analysis is the subtraction of the cost of defence from the benefit of defence to produce the new present value (NPV) of defence. The first point to make is that if the NPV is positive, then the response strategy under consideration is economically more efficient that the baseline retreat response strategy. Similarly a negative NPV would indicate that a retreat response is the economically efficient option. In fact, all the NPVs are positive, indicating that on a regional scale an active response strategy is preferable to immediate abandonment.

As far as the two active response strategies are concerned, the protect response has the highest NPV, which indicates that this would be the preferred approach to coastal management for all RSL scenarios, with the exception of the 80 cm rise case. In this latter "extreme' case the high cost of maintaining a protect style defence line means that an accommodate response strategy becomes more efficient. It is important to remember that the above results are for a combined flood and erosion hazard situation. Owing to the nature of the study area, the analysis is dominated by the flood hazard. In contrast to the overall results, when the erosion hazard alone is considered, the NPV is negative in almost all cases in the accommodate and protect response strategy simulations.

Both the 'GDP-at-risk' and the cost–benefit analyses indicate that, although physical parameters such as the assumed rate of RSL do have an effect on the results, socioeconomic parameters are equally significant. Thus the extent and value of property at risk in the hazard zone dominates the damage cost calculations, although the environmental asset valuation we use is only a proxy variable and

undoubtedly underestimates the full costs involved. Similarly the assumed discount rate has a major influence on the results; the effect of changing it from the UK Treasury rate of 6% to 3% and to 9% was approximately to double and to halve the original NPVs, respectively.

The results of the analysis described above indicate which of the response strategies is the most economically efficient when applied on a region-wide basis. The study area, however, is comprised of 184 individual flood and erosion compartments, which are diverse in nature and in the distribution of assets and defences they encompass. At this disaggregated compartmental scale, it may well be that the most efficient response strategy is not the same as at the regional scale.

A partial testing of this proposition was undertaken by repeating the cost–benefit analysis for the 113 flood hazard compartments and looking at the results on this compartmental level. The testing was carried out prior to the incorporation of the environmental damage costs into the analysis. For each compartment the most economically efficient response strategy was identified. The results of this disaggregated analysis are shown in figure 5. In some cases the NPVs of the accommodate and the protect strategies were identical and in some cases the NPVs of both these active responses were zero, indicating that none of the response strategies were dominant. From figure 5 it can be seen that while protect is the most efficient response strategy in a significant number of compartments, it is not the dominant one. In particular, with higher values for RSL, the number of compartments for which retreat is the most efficient strategy increases as well. Overall, the results highlight the fact that for any region the optimal situation will comprise a variety of localised response strategies.

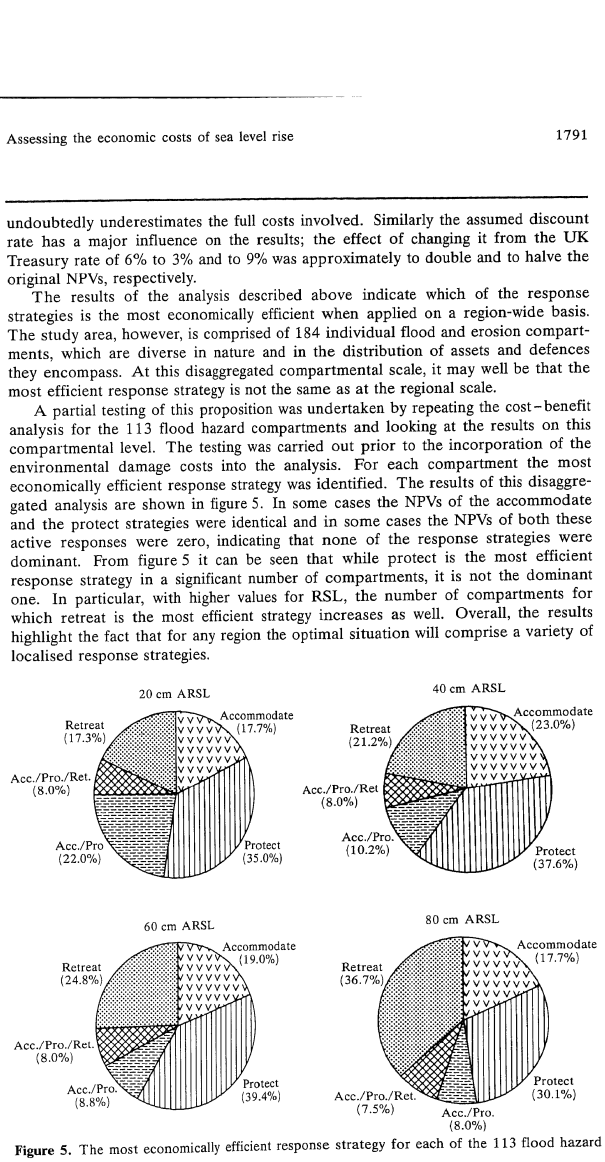

Figure 5. The most economically efficient response strategy for each of the 113 flood hazard compartments.

5 Limitations of the analysis

In the assessment of the physical hazard of ARSL, because the erosion-sedimentation budget of the separate compartments is unknown, it is assumed that each compartment of coastline (defined in terms of their *economic* assets in this study) is effectively independent of the others. Thus the cost-benefit analysis ignores the secondary impact of the preferred policy response option that one section of coast has on its neighbouring coastline compartments. It cannot even be assumed that the 'external' impact of protecting compartment n from RSL wil be greatest in compartments $(n-1)$ or $(n+1)$: the external impact of each proactive solution requires site-specific modelling of the erosion-sedimentation process. In that respect the present analysis is a grossly simplified model of the actual physical process.

The second limitation of the present study lies in the assessment of human adaptation to RSL. Adaptation effects are not incorporated in the GDP-at-risk methodology, where only an estimate based on geographic location is obtained and there is no time dimension effect except for a varying discount rate and an economic growth rate. The approach to the modelling of adaptation in the cost-benefit analysis has been outlined above: essentially the future streams of income from an industrial, commercial, or agricultural asset are lost when the probability of permanent loss through flooding or erosion reaches a threshold. This is analogous to an 'adaptive expectations' model in standard neoclassical economic analysis, where decisions are made based on adapting to past experiences and implies an inability to avoid impacts in a 'rational expectations' mode. Further discussions on this theme can be found in Yohe (1991).

But the greatest area of uncertainty in the economic analyses is in the estimation of losses or gains of economic well-being and in their interpretation in the context of socially desirable resource allocation decisions. This problem has been discussed in the general environmental economics and management literature by Pearce and Turner (1990) and by Turner (1993), among many others. In the RSL context, the economic analysis is limited in its ability to capture the contribution to the well-being of economic assets in the coastal zone. A number of these assets are public goods which are difficult to value in monetary terms. There is also the perennial question of the appropriate discount rate which ought to apply in situations where long-run environmental impacts are or may be experienced.

Our sensitivity analysis highlights the importance of the discount rate used. Although most economists who have studied impacts of climate change accept the need for discounting, there is little consensus on what positive discount rate should be used, or whether a zero rate is most appropriate (see Birdsall and Steer, 1993; Broome, 1992; Cline, 1992; 1993; Fankhauser, 1993). The argument in support of a zero rate maintains that, for a phenomenon such as global warming with potentially catastrophic consequences, intergenerational equity dictates that it would be inappropriate to weight the costs to future generations any less heavily than those to the present generation.

In general, those who advocate a positive rate of discount appeal to the empirical observation of historical savings and interest rates (for example, Nordhaus, 1992). In addition to this, a 'pure time preference rate' reflecting the myopia of society is often discussed as a possible addition to the rate reflecting growing real income over time. A pure time preference addition of 1.5% is sometimes used (Cline, 1992). Whatever rate is employed, and in this study results have been presented on the basis of two rates, 3% and 6%, the nature and estimation of the long-term costs and benefits are critical. Discount rates lower than the UK government's public discount rate of 6% are normally favoured in climate change studies. However, as Markandya and Pearce (1991) have argued, the safest way to ensure that complex environmental issues are incorporated into economic analysis is to include a full assessment of the value of the assets, rather than to worry overmuch about adjusting the discount rate to encourage conservation of resources.

A managed retreat policy option introduces complicating factors into the analysis of RSL coping strategies. In general, the analytical information requirements are larger, and the costs of management and the potential environmental benefits are both higher. The potentially enhanced environment, in terms of coastal saline habitats and recreational facilities, explains the demand made by conservation bodies and others (Radley, 1993) for this option. The management costs for such an option will be higher, as a piecemeal approach to each part of the coast is necessary; the advantages of such a strategy are in the potentially enhanced coastal environment (Reid and Trexler, 1991).

The costs of a managed retreat option may include property losses, but the coastal structures, such as saline wetlands, created by such an option will possibly be permanent assets and will not require further capital cost inputs. However, the ecological benefits of allowing inundation have to be set against the loss of the existing in-place coastal assets, and the potential loss of protected areas behind the coast. This is a familiar theme. For example, Daniels et al (1993) identify major potential species loss in the zone at risk from climate induced RSL in the study area of South Carolina. The species loss potential occurs due to habitat loss and due to the concurrent climatic impacts of shifting ecological zones, all leading to localised or even regional extinction both of plant species and land-bound animal species, such as the bald eagle and the woodpecker. But it is important to realise that many of these impacts would not be ameliorated through a managed retreat or coastal enhancement policy, though the conservation of other species would be enhanced.

Pethick (1993) presents evidence that managed retreat sites may have *net* negative impacts on intertidal habitat. Thus managed retreat sites in estuaries tend to be divorced from the dynamic forces of sedimentation and erosion, and increase the tidal prison and possibly reduce the extent of intertidal habitat. The managed retreat option is therefore complex and difficult to assess in terms of net impact if it were to be comprehensively utilised in the coastal zone.

The problem of the economic valuation of environmental assets has already been extensively discussed in the literature, but managed retreat would introduce an added difficulty in terms of the need to derive preferences for complex trade-offs due to changes in habitats and ecological assets. The two new elements in the analysis would then be: the extra cost of restoring saltmarshes, which could involve additional breakwaters to protect the new saltmarsh area, and the benefits in economic terms (that is, the preferences expressed) of the habitat created net of the loss of existing habitat, which may be sand dunes or other desirable environmental asset. Also, in the case of managed retreat, greater attention would have to be paid to possible interrelationships between the coastline compartments.

In the British context, managed retreat would be an option primarily designed to reinstate saltmarshes and tidal flats. It has been suggested that, in order to compensate for anticipated losses of all types of coastal habitats over the next twenty years, an area of around 13500 ha should be recreated (Pye and French, 1993). This figure, however, is insignificant compared with the estimated 800000 ha of land thought to be vulnerable to flooding.

The institutional arrangements necessary for managed retreat are, in large part, in place in Great Britain, as the major authorities with responsibility in the coastal zone have discretionary powers which would enable them to compensate landowners and undertake such projects. Table 4 contains a summary of the authority of the particular bodies, based on the interpretation by Gibson (1993). Private landowners have no legal obligation to defend the coast and could undertake managed retreat for conservation or other objectives, providing no risk of flooding ensues to neighbouring private properties.

Table 4. Areas of responsibility and authority to enact managed retreat of the major British agencies [source: based on Gibson (1993)].

Body	Responsibility	Authority to enforce managed retreat
National Rivers Authority	All matters relating to flood defence, primarily on unbuilt land, under the Water Resources Act, 1991.	Discretionary authority
Coastal port authorities	Part of local authorities with responsibility mainly for built environment under the Coastal Protection Act, 1949	Discretionary authority but could be liable for maintaining protection to which private owners contributed before 1962
Internal drainage boards	Mainly agricultural land behind coastal defences under the Land Drainage Act, 1991	Discretionary authority but also liable for sewage discharge duties which could potentially conflict with managed retreat

In general, compensation would not be obligatory where the relevant bodies undertook discretionary action, because natural forces would be causing the property loss. However, where conservation bodies, which have used land purchase increasingly as a conservation strategy, operated a retreat policy, they would be liable for any increased flood risk to neighbouring properties. Positive financing of managed retreat for enhanced conservation interest is available to the national agencies under their statutory powers, and environmental enhancement has potential EC funding.

Clearly, managed retreat has been considered only recently and at present potentially involves only a small area of the British coastline. The enhanced environmental benefit in particular compartments of coastline could be assessed by considering the present value of the additional costs and the net environmental enhancement. However, it would form only part of a larger overall strategy to manage the coastline in the face of RSL induced by climate change.

6 Conclusions

This case study has shown that the CZMS 'Common Methodology' does provide a valuable approach to vulnerability assessment in coastal zones. It has proved possible to determine a hazard zone and associated ARSL risk, albeit on the basis of a range of simplifying assumptions. The data requirements even for this simplified modelling approach have, however, been formidable.

The case study analysis has departed from the CZMS guidelines in one important way. A somewhat truncated planning horizon (up to the year 2050) has been adopted to put the forecasts of the RSL, the physical and ecological impacts assessments, and the socioeconomic implications onto a common basis. This constraint has facilitated the formulation and calibration of a partial social cost-benefit model [encompassing discounted (present value) costs and benefits streams]. The cost-benefit model has, together with the rapid assessment GDP-at-risk method, in turn proved to be a useful decisionmaking aid in the context of the choice between alternative options of policy response to RSL.

The results of our 'bottom up' model and analysis indicate that the East Anglian coastal zone is a vulnerable area at risk from RSL. The active response options proved to be economically efficient strategies under all RSL scenarios. But the disaggregated (flood compartment level) analysis showed also that the full range of response options would need to be deployed as a package of measures (and include for some stretches of coast the do nothing or managed retreat strategies) in order to ensure the most economically efficient response.

Given the multiple uncertainties (scientific and socioeconomic), sensitivity analysis was fundamentally important. The study results proved sensitive not only to changes in the physical parameters but also to changes in socioeconomic parameters such as the discount rate applied within the cost-benefit analysis.

References

Adger N, Fankhauser S, 1993, "Economic analysis of the greenhouse effect: optimal abatement level and strategies for mitigation" *International Journal of Environment and Pollution* 3(1-3) 104-119

Bateman I J, Bateman S, Brown D, Doktor P, Karas J, Maher A, Turner R K, 1991, "Economic appraisal of the consequences of climate-induced sea level rise: a case study of East Anglia", final report to Ministry of Agriculture, Fisheries, and Food, London, April

Bateman I J, Langford I H, Willis K G, Turner R K, Garrod G G, 1993a, "The impacts of changing willingness to pay, question formats in CVM", CSERGE WP GEC 93-05, CSERGE University of East Anglia, Norwich and University College London

Bateman I J, Willis K, Garrod G, 1993b, "Consistency between contingent valuation estimates: a comparison of two studies of UK national parks", Countryside Change WP-40, Countryside Change Unit, University of Newcastle Upon Tyne

Birdsall N, Steer A, 1993, "Act now on global warming—but don't cook the books" *Finance and Development* **30**(1) 6-8

Broome J, 1992 *Counting the Cost of Global Warming* (White Horse Press, Cambridge)

Cline W R, 1992 *The Economics of Global Warming* (Institute for International Economics, 11 Dupont Circle, Washington, DC)

Cline W R, 1993, "Give greenhouse abatement a fair chance" *Finance and Development* **30**(1) 3-5

Daniels R C, White T W, Chapman K K, 1993, "Sea-level rise: destruction of threatened and endangered species habitat in South Carolina" *Environmental Management* **17** 373-385

den Elzen M G J, Rotmans J, 1992, "The socio-economic impact of sea level rise on the Netherlands: a study of possible scenarios" *Climatic Change* **20** 169-195

Fankhauser S, 1993, "Global warming economics: issues and state of the art", Global Environmental Change WP 93-28, Centre for Social and Economic Research on the Global Environment, University of East Anglia and University College, London

Fankhauser S, 1994, "Protection vs. retreat: estimating the costs of sea level rise", CSERGE WP GEC 94-02, University College London and University of East Anglia

Gibson J, 1993, "Managed retreat: incentives and legal issues", paper presented at Managed Retreat: Putting Theory into Practice Conference, London, March

Gren I-M, Folke C, Turner R K, Bateman I J, 1994, "Primary and secondary values of wetland ecosystems" *Environment and Resource Economics* **4** 55-74

Houghton J T, Callander B A, Varney S K, 1992, "Climate change 1992: the supplementary report to the IPCC scientific assessment", report for the World Meteorological Organisation and the United Nations Environment Programme (Cambridge University Press, Cambridge)

IPCC CZMS, 1992 *Global Climate Change and the Rising Challenge of the Sea* Intergovernmental Panel on Climate Change, Coastal Zone Management Group, World Meterological Organisation and United Nations Environment Programme, Geneva

Kasperson R E, Dow K, Golding D, Kasperson J X, 1990 *Understanding Global Environmental Change: The Contribution of Risk Analysis and Management* Centre for Technology, Environment and Development, Clark University, Worcester, MA
Lashof D A, 1989, "The dynamic greenhouse: feedback processes that may influence future concentrations of atmospheric trace gases and climate change" *Climate Change* **14** 213-242
Markandya A, Pearce D W, 1991, "Development, the environment and the social rate of discount" *World Bank Research Observer* **6** 137-152
Milliman J D, Broadus J M, Gable F, 1989, "Environmental and economic implications of rising sea level and subsiding deltas: the Nile and Bengal examples" *Ambio* **18** 340-345
National Audit Office, 1992 *Coastal Defences in England* (HMSO, London)
Nordhaus W D, 1992, "An optimal transition path for controlling greenhouse gases" *Science* **258** 1315-1319
Pearce D W, Markandya A, Barbier E, 1989 *Blueprint for a Green Economy* (Earthscan, London)
Pearce D W, Turner R K, 1990 *Economics of Natural Resources and the Environment* (Harvester Wheatsheaf, Hemel Hempstead)
Pernetta J C, Elder D L, 1992, "Climate, sea level rise and the coastal zone: management and planning for global change" *Ocean and Coastal Management* **18** 113-160
Peters R I, Lovejoy T E (Eds), 1992 *Global Warming and Biological Diversity* (Yale University Press, New Haven, CT)
Pethick J, 1993, "Shoreline adjustments and coastal management: physical and biological processes under accelerated sea-level rise" *Geographic Journal* **159** 162-168
Pye K, French P W, 1993 "Targets for coastal habitat re-creation", English Nature Science No. 13, English Nature, Peterborough
Radley G P, 1993, "The environmental objectives of managed retreat", paper presented at Managed Retreat: Putting Theory into Practice Conference, London, March
Reid W V, Trexler M C, 1991 *Drowning the National Heritage: Climate Change and US Coastal Biodiversity* World Resources Institute, Washington, DC
Sahagian D L, Schwartz F W, Jacobs D K, 1994, "Direct anthropogenic contributions to sea level rise in the twentieth century" *Nature (London)* **367** 54-57
Schneider S H, 1992a, "Global climate change: ecosystem effects" *Interdisciplinary Science Reviews* **17** 142-148
Schneider S H, 1992b, "Will sea level rise or fall?" *Nature (London)* **356** 11-12
Titus J G, Park R A, Leatherman S P, Weggel J R, Greene M S, Mansel P W, Brown S, Gaunt C, Trehan M, Yohe G, 1991, "Greenhouse effect and sea level rise: the cost of holding back the sea" *Coastal Zone Management* **19** 172-204
Turner R K (Ed.), 1993 *Sustainable Environmental Economics and Management: Principles and Practice* (Belhaven Press, London)
Turner R K, Kelly M, Kay R, 1990 *Cities at Risk* BNA International, London
Turner R K, O'Riordan T, Kemp R, 1991, "Climate change and risk management", in *Climate Change: Science, Impacts and Policy: Proceedings of the Second World Climate Conference* Eds J Jager, H L Ferguson (Cambridge University Press, Cambridge) pp 397-408
Warrick R A, 1993, "Slowing global warming and sea-level rise: the rough road from Rio" *Transactions of the Institute of British Geographers* **18** 140-148
Wigley T M L, Raper S C B, 1992, "Implications for climate and sea level rise of revised IPCC emission scenarios" *Nature* **357** 293-300
Wigley T M L, Raper S C B, 1993, "Global mean temperature and sea level projections under the IPCC emissions scenarios", in *Climate and Sea Level Change: Observations, Projections and Implications* Eds R A Warrick, E M Barrow, T M L Wigley (Cambridge University Press, Cambridge) pp 401-404
Yohe G W, 1991, "Uncertainty, climate change and the economic value of information: an economic methodology for evaluating the timing and relative efficacy of alternative responses to climate change with application to protecting developed property from greenhouse induced sea level rise" *Policy Sciences* **24** 245-269

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Sustainability and the rural economy: an evolutionary perspective

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Abstract. The authors define the rural economy not as a functional entity but as a complex, open system, the analysis of which requires an interdisciplinary approach oriented to the study of processes and interactions. This evolutionary perspective is illustrated by two generic studies of rural issues: the role played by the postwar planning regime in the definition and management of rural space in Britain; and the connection between agricultural development and the reproduction of farm structures. The understanding of sustainable development which emerges calls for a holistic and responsive approach to rural policy formulation.

Introduction

Any discussion of the 'rural economy' immediately raises a series of questions. What is meant by the term 'rural'? Is there a distinct 'rural economy'? And, more recently, what might constitute a 'sustainable rural economy'? In this paper we seek to address these issues, though the main concern is to develop a coherent approach to the study of the rural economy and to consider the implications for the design of sustainable development policies. The approach is ambitious because it attempts to inform various social science perspectives on the 'rural'; particularly those of agricultural economics and rural sociology. This is not to deny the distinctive methodological and substantive interests of the individual subdisciplines, but the term 'rural economy' does echo the holistic traditions of classical 'political economy' where the economic, social, and political were treated in the round.

Everyday usage of the term 'rural' typically reflects the distinctive spatial pattern of land use in rural areas. Nevertheless, the definition of rural areas has itself become increasingly difficult in advanced industrial economies with the blurring of the distinction between urban and rural space (Murdoch, 1993), and this has led to various attempts to 'capture' the rural by using quantitative methodologies. Examples include: simple population densities (Walford and Hockey, 1991); rurality indices combining population densities, rates of population change, age structure, occupancy rates, and so on (Cloke, 1977; Cloke and Edwards, 1986); and multivariate classification systems based on the main constituents of local economies, such as population, employment structure, house prices, and location (Hodge and Monk, 1991).

Although these studies are valuable in identifying key components of rurality, they are potentially misleading inasmuch as the 'rural' is represented as a static and coherent category. This gives rise to a number of problems when it comes to considering economic activity in rural areas. First, the nature of such activity is highly diverse, so the 'rural' cannot simply be equated with particular sectors, certainly not just farming, forestry, and raw materials. "Some rural areas have an employment structure which is more akin to that of successful urban areas" (DoE, 1992, page 4). Second, the economic structure of rural areas is dynamic as is illustrated by the urban-rural shift in manufacturing industry and the growth of