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A co-evolutionary approach to climate change impact assessment: Part I. Integrating socio-economic and climate change scenarios

Irene Lorenzoni[a,*], Andrew Jordan[a], Mike Hulme[b], R. Kerry Turner[a], Tim O'Riordan[a]

[a]*Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia, Norwich NR4 7TJ & University College London WCIE 6BT, UK*

[b]*Climatic Research Unit (CRU), School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK*

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Abstract

Climate change policies currently pay disproportionately greater attention to the mitigation of climate change through emission reductions strategies than to adaptation measures. Realising that the world is already committed to some global warming, policy makers are beginning to turn their attention to the challenge of preparing society to adapt to the unfolding impacts at the local level. This two-part article presents an integrated, or 'co-evolutionary', approach to using scenarios in adaptation and vulnerability assessment. Part I explains how climate and social scenarios can be integrated to better understand the inter-relationships between a changing climate and the dynamic evolution of social, economic and political systems. The integrated scenarios are then calibrated so that they can be applied 'bottom up' to local stakeholders in vulnerable sectors of the economy. Part I concludes that a co-evolutionary approach (1) produces a more sophisticated and dynamic account of the potential feedbacks between natural and human systems; (2) suggests that sustainability indicators are both a potentially valuable input to and an output of integrated scenario formulation and application. Part II describes how a broadly representative sample of public, private and voluntary organisations in the East Anglian region of the UK responded to the scenarios, and identifies future research priorities.

Keywords: Climate change; Co-evolution; Indicators; Socio-economic scenarios

1. Introduction

Until very recently, international and national climate policies have concentrated on the mitigation of climate change through emission reductions strategies (IPCC, 1996). However, more attention is now being paid to finding the means to allow society to *adapt* to the gradually unfolding impacts of climate change (Smithers and Smit, 1997; Rayner and Malone, 1998). Existing impact studies tend to rely upon extrapolating current or recent socio-economic trends into the future. However, the observation of past historical events suggests that future economic, social and political changes are likely to be uncertain and highly conspicuous over the timescales in which climatic changes will take effect. To complicate the task still further, changes in the climate are likely to influence the underlying economic, social and environmental contexts in which that change is experienced: the two are *inextricably* intertwined. While some manifestation of climate change is already in the pipeline because of current and recent socio-economic activities (Parry et al., 1998), the actual degree of climate change in the medium-to-long term is *not* pre-ordained; mitigation actions and patterns of adaptive behaviour now and throughout the next 30–50 yr could significantly influence the rate of future climate change, but only if society and the environment are seen as two, intimately *co-evolving* systems.

The term *co-evolution* reflects the constant and active interaction between a living organism and its environment (Norgaard, 1984, 1994). It emphasises that social structures and their processes impinge on the environment, thus modifying and changing it. Such changes in turn shape the structure of the social systems, which subsequently undergo further changes in order to be better positioned to adapt to the changing environment. The interaction between systems is constant and reciprocal.

* Corresponding author. Tel.: + 44-1603-593173; fax: + 44-1603-593739.

E-mail address: i.lorenzoni@uea.ac.uk (I. Lorenzoni).

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A 'co-evolutionary' approach highlights the complex coupling of the two systems now and into the foreseeable future (Norgaard, 1984; also used by Turner et al., 1998; Adger, in press). Mitigation and adaptation policies must be developed to reflect this. However, policy makers need some sort of visualising tool or device to capture the interdependencies between the two systems. In this article, we develop a 'co-evolutionary' approach (Norgaard, 1994) to understanding vulnerability and impact assessment, which tries to combine future climate scenarios with a series of pictures about the social, economic and environmental elements affecting specific economic sectors, in order to uncover the likely positive (i.e. exacerbating climate change impacts) and negative (i.e. attenuating climate change impacts) feedbacks between the two.

This article is subdivided into two separate parts. Part I (this paper) has three main aims: (1) to examine the utility of integrating socio-economic and climate scenarios as a means of understanding future societal responses to the unfolding impacts of climate change; (2) to produce a series of integrated scenarios; (3) to explain why these scenarios need to be re-calibrated for use in bottom-up climate impact assessments, and to provide a mechanism for doing so. By tapping the expert knowledge of the units/sectors exposed to climate change, a bottom-up approach adds local texture and a valuable input to more top-down accounts of climate impacts based on, inter alia, integrated assessment models. Part II (Lorenzoni et al., in press) describes how a broadly representative sample of public, private and voluntary organisations in the East Anglian region of the UK responded to these integrated scenarios, and identifies future research priorities. The two papers are complementary and ideally should be read together.

2. Using scenarios in climate change research

Scenarios are capable of serving multiple roles in climate assessments but until now they have tended to be used by the Intergovernmental Panel on Climate Change (IPCC) community as an aid to understanding future emission profiles. Recently, however, both climate and socio-economic scenarios have begun to be applied to investigate climate change impacts (e.g. Parry, forthcoming), vulnerabilities and adaptive responses. The forthcoming IPCC report will devote an entire chapter to describing the state of the art in this area. It is likely to underline the need for a more integrated approach to scenario development and application, linking mitigation actions right through to impacts and adaptation on the ground, and human society to the climate system.

This paper responds to the call for more 'integrated' approaches in at least three important respects. First, it attempts to link emissions scenarios to scenarios of future socio-economic change for a particular region (East Anglia) where the impacts of climate change will eventually be experienced. In short, we try to link emissions to impacts — two aspects of the climate change debate that are often addressed independently of one another. Socio-economic scenarios serve a particularly vital role in the assessment of adaptation and vulnerability because societal change in the next century is likely to be as, if not more, profound than anything brought about by climate change. Crucially, in the next 50–100 yr, units exposed to variations in the climate (Parry and Carter, 1998) will evolve *irrespective* of climate change and some may even disappear completely. Therefore, it is at best simplistic and at worst completely misguided to ignore the co-evolving dynamic development of social systems. Some way of understanding the co-evolution of the two systems needs to be found. In this paper we argue that inter-linked scenarios provide one possible tool. The scenarios we use are defined according to a series of criteria, such as the type of political governance, the stringency of environmental controls and the dominant form of economic development, *as well as* the climate impacts that the associated patterns of human behaviour are likely to produce. We devote a considerable part of the paper to explaining how we achieved this integration on account of its novelty and interdisciplinary nature. We do not present this approach as a formal model in which climate and socio-economic variables are coupled. Rather, we have crafted the scenarios to better understand the elements of human choice and behaviour in moulding the present and the future.

Second, our approach is also integrated in the sense that the scenarios themselves derive from large-scale climate models and expert judgement, but their application and interpretation takes place at a more local level. This was achieved by presenting the integrated scenarios to locally important stakeholders of climate sensitive sectors in East Anglia, who were asked to critically reflect upon their adaptive capacity under a series of interlinked climate/socio-economic conditions. In other words, our study tries to combine the 'bottom-up' knowledge of actors representing various exposure units, with the more conventional tools of integrated assessment (Parson, 1995) such as global climate models, developed 'top down'.

Finally, by asking stakeholders to think about climate- and 'non-climate' related sources of pressure on their activities, our approach begins to uncover the complicated feedbacks within and between the human and the natural systems. Whereas the standard IPCC Technical Guidelines on Assessing Climate Change Impacts and Adaptation (Parry and Carter, 1998) rely upon separating climate from non-climate futures, our approach assumes that it is practically all but impossible to construct a baseline representing the world without climate change (Parry and Carter, 1998, pp. 72–73). This is because some of the more environmentally aware actors have, albeit slowly and tentatively, *already* adopted mitigation and adaptation strategies which are built into their daily practices, even though, at the time of writing, their understanding of the challenge of adaptation lags behind that of mitigation. So, whereas top-down approaches tend to map a given level of climate change onto an essentially static social and economic system, our more co-evolutionary approach proceeds by working closely with local stakeholders to identify and explore the implications of a combination of stresses, both climate and non-climate, on locally important actors. After all, it may be that in the final analysis the climate drivers of local behaviour are far less significant in shaping adaptive responses than 'non-climate' factors.

3. Scenarios: their origins and application

According to the IPCC, a scenario is a coherent, internally consistent and plausible description of a possible future state of the world (Parry and Carter, 1998). A scenario is not a forecast because it does not attach probabilities to a particular outcome. Rather, a scenario presents a series of pictures or images of how the world *could* look like under different conditions. Scenarios were first applied by the military (Miles, 1981) and subsequently developed as a strategic management aid by oil companies, especially the Shell Group, in the early 1970s (Kassler, 1995). The underlying impetus for their development was to manage better any future surprises by forcing decision makers to 'think the unthinkable' (Hammond, 1998). Despite this effort, however, Shell has found itself in the midst of controversy over some of its activities in the North Sea (Brent Spar) and Nigeria. These 'surprises' experienced by the company serve to underline the need to continually revise a scenario approach in the light of changing circumstances. To be of maximum practical use, scenarios should also take different worldviews into account, not only the ones that currently make the most political or business sense (Elkington and Trisoglio, 1996). Good scenarios are potentially powerful vehicles for creative learning among groups of stakeholders, but only if participants are encouraged to 'think the unthinkable'.

A growing body of research work explores the applicability of scenario-based 'futures studies' as a means of obtaining a better understanding of the potential for societal adaptation to future environmental change (Gallopin and Raskin, 1998). Crucially scenarios can be used to inform present choices in the light of future alternatives, an aspect pursued in this paper. "A longer-term perspective can provide a framework within which to evaluate short-term decisions" (Patterson, 1999, p. 95) and also to examine more systematically the implications of unexpected events or 'side-swipes'. Scenario approaches have been applied in Europe, for instance, to urban transport patterns in the Netherlands in order to identify more sustainable systems that meet prescribed CO_2 emissions arising from transport in the year 2030. Nijkamp et al. (1997) surveyed Dutch transport experts asking them which factors would be expected or desired from a sustainable transport system. Their opinions were then used to formulate two scenarios, namely 'expected' and 'desired', the intention being to highlight the uncertainties faced when designing and planning future transport arrangements. Interestingly, these two scenarios lead to very different transport futures. The authors conclude that policy targets of CO_2 reductions would only be met by implementing the 'desired' scenario. Socio-economic and climate scenarios have also been used to outline social, economic and political future conditions in Western Europe between 2020 and 2080 (Parry, forthcoming) with the aim of identifying policy relevant impacts and sensitive sectors. However, the scenarios used are not formally integrated to produce a co-evolutionary view of the future.

In this paper, socio-economic and climate scenarios are combined to provide an opportunity for assessing social as well as environmental variations on compatible timescales. There is often a huge discrepancy between the timescales used for modelling social and economic systems (a few years or decades at the very most) and those used to make environmental and climate change projections (decades to many centuries), despite their inherent complexity and unpredictability. Our scenarios attempt to integrate the two systems by presenting them on commensurate timescales. Interestingly, Working Group 2 of the IPCC is currently investigating the need to formally combine climate with 'non-climate' scenarios, including the scenarios developed in the Special Report on Emissions Scenarios (SRES, due for publication in 2000). However, the preliminary SRES98 scenarios describe different 'non-intervention' worlds, that is, possible global futures (in terms of societal, political, technological and environmental characteristics of different parts of the world), without taking into account the effects of climate change or explicit climate change policies.

4. Existing climate change scenarios

Anthropogenically induced climate change is caused by, and has damaging impacts upon, societies and economies. Therefore, the first step in our analysis was to develop a set of socio-economic scenarios. Several reputable candidates are already in existence. For instance, global scenarios for the years 2000–2050 have been developed by the World Business Council for Sustainable Development (WBCSD) to illustrate possible future challenges to a business audience (WBCSD, 1997). They have been compiled on the basis of different potential future response strategies to the challenges set by sustainable development objectives. These are expressed in terms of questions such as "how resilient is the global ecosystem?" and "what human systems can best respond to the challenge of sustainable development?". The three WBCSD scenarios, namely FROG!, GEOpolity and Jazz, unfold in the following ways:

1. In the *FROG!* scenario, sustainable development is difficult to achieve, as the social systems are inadequate and vulnerability of natural systems increases. Local economic growth and technological innovations are given more importance; economic growth objectives retain their primacy in policy-making circles.
2. *GEOpolity* represents a world relying on more co-ordinated international governance based on innovative infrastructure systems and new global institutions enforcing global societal and environmental standards.
3. The *Jazz* world combines economic growth objectives and strategies with environmental and social values in transparent structures and new possibilities. The idea is to use market forces and novel structures to achieve sustainable development. Conflicts are resolved through mediation. Self-interest spurs businesses to be transparent and accountable to the public; 'green' behaviours are not necessary but are actively rewarded.

The scenarios formulated for the Natural Resources and Environment Panel of the UK Foresight Programme (OST, 1999), hereafter OST scenarios, were deemed more appropriate to our task as they were developed in an UK context. Their main aim is to cast light on future social, economic, environmental trends for the UK in the period 2010–2040. They are meant to be malleable and can be tailored to specific UK sectors. The scenarios may also be used as a basis on which to develop sustainability indicators at the national and regional levels (OST, 1999).

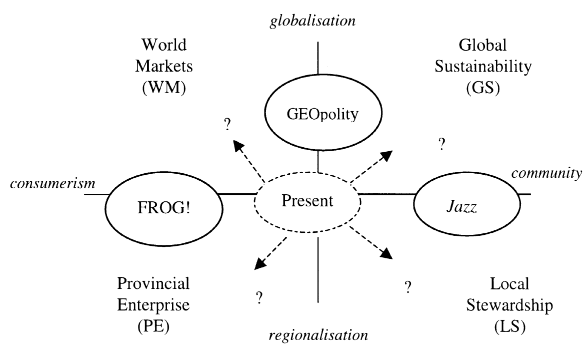

Fig. 1. A comparison of the WBCSD and OST futures scenarios showing possible paths of future development (adapted from OST, 1999).

They are framed by two orthogonal axes, representing societal values (ranging from consumerist to conservationist) and level of governance (ranging from local to global) respectively. These produce four quadrants representing four possible future worlds: world markets, provincial enterprise, global sustainability and local stewardship. For simplicity's sake the four 'futures' appear in Fig. 1 as independent possible states of the world. In reality, the boundaries are fuzzy and the different states are differentiated because certain trends and characteristics become more or less dominant across government, business and public contexts. The similarities with the WBCSD scenarios are obvious even if they have different origins.

5. Re-calibrating the scenarios for climate change in East Anglia

Our work entailed re-configuring the essentially 'macro' socio-economic OST scenarios to reflect the challenges of climate change. This work was partly undertaken for the UK Department of the Environment, Transport and the Regions (DETR) (Berkhout et al., 1999) to inform its ongoing Climate Impacts Programme (UKCIP). Following on from this research and with ESRC funding, the Centre for Social and Economic Research on the Global Environment (CSERGE) and the Climatic Research Unit (CRU) set out to test the ability of these national-level socio-economic scenarios to uncover the adaptation and vulnerability issues that arise at the local level in East Anglia.

The work in East Anglia was carried out in three distinctive parts. The first involved re-calibrating the national-level OST scenarios to make them more pertinent local needs and circumstances (covered in this paper). Secondly, a suite of regional level scenarios for the 2020s and the 2050s was produced and these were in turn combined with possible climate outcomes related to each of the four future worlds (this paper). Finally, these East Anglian futures scenarios were presented to locally important stakeholders, via a series of individual interviews and two group discussions (see Part II: Lorenzoni et al., in press). The stakeholders involved represented the main economic, governmental and social sectors of the East Anglian economy. Particular attention was paid in the selection process to those sectors which the existing literature on climate impacts identifies as being especially sensitive to climate change (e.g. CCIRG, 1996; Palutikof et al., 1997).

An important part of this process was to develop a suite of impact indicators for East Anglia using the Pressure–State–Impact–Response Framework, the aim being to obtain a set that could be deployed at both regional and national scales. The formulation and refinement of the indicator set was both an integral component of the scenario building and an output of the whole exercise (see Box 1).

Box 1: Using indicators in futures scenarios
In recent years there has been a drive towards establishing indicators at national and regional levels for the monitoring of sustainability in different areas of the economy. These processes emerged to satisfy the need of establishing some parameters against which to measure change of present conditions into the future. In some instances the approach has been coherent; in other cases indicators have been formulated in a piecemeal fashion by different institutions and organisations. Concern has been expressed that the use and applicability of indicators may be limited if they are not linked to the context of the possible future changes (in social, political and economic systems) which they attempt to quantify. Future states are not set in stone; they can develop and evolve very differently according to the forces, drivers and circumstances that take place and contribute to altering the present situation. In order to have a more focused understanding of what the future might hold, quantified indicators of future change can be coupled with descriptions of that change.

Our study in the East Anglian region revealed a strong desire among stakeholders for a qualitative explanation of what future worlds may look like, in addition to a set of quantified impacts. Consequently, the research team collaborated with local organisations (e.g. the Environment Agency) and individuals to derive a minimum set of climate change indicators. These illustrate the range and severity of possible impacts. Stakeholders said they found them useful as an aid to identifying the areas that may be affected by climate change (‘impact indicators’) or to related pressures that may affect those impacts (‘pressure indicators’ to use the same definitions as adopted by the Environment Agency). In order to be policy relevant, these indicators should reflect regional- and national-level trends (DETR, 1999).

6. Integrating climate and ‘non-climate’ scenarios

The project team produced two sets of user-friendly futures scenarios to use in further face-to-face interviews with stakeholders. They were based around a set of simple themes pertinent to the East Anglian region and made more intelligible to people who may have had little experience of using scenarios.

The East Anglian scenarios combine socio-economic and climate information. They derive directly from a combination of the *OST Scenarios*, the *SRES98 emissions scenarios* and the *UKCIP98 climate scenarios*. For the purposes of this research, two different timeframes, the years 2025 (2020s) and 2055 + (2050s and beyond), were chosen as basic chronological points for analysis on the ground that they were broadly commensurate with those employed in the OST Futures Scenarios study and the preliminary SRES98 emissions scenarios (the OST scenarios use a 2010–2040 timeframe, whereas SRES98 scenarios currently concentrate on the periods up to 2020 and 2050). The latter timescale (2055 +) may seem quite short in climatic terms, but it reflects the difficulty of predicting future socio-economic trends more than 5–10 yr into the future. The characteristics of each scenario were displayed using the same four-quadrant format. We hoped this would provide a value-neutral representation of the four worldviews and help overcome the potential problem of maintaining consistency between respondents and possible futures, which is a characteristic of open-ended interview-based research.

The OST scenarios were coupled with consistent climate change scenarios in the following manner. First, the OST scenario storylines were compared with the four storylines in the still to be formally approved IPCC Special Report on Emissions Scenarios (SRES98; http://sres.ciesin.org/). While they are not exactly the same, they both share a similar underlying structure and comparative logic. The SRES98 marker emissions scenarios are, of course, mainly concerned with the sectors and societal choices that primarily affect climate change issues (and particularly the emission of greenhouse gases) in the IPCC process, whereas the OST scenarios have a somewhat wider purview, encompassing many more ‘non-climate’ sectors and environmental changes. As discussed above, these ‘non-climate’ factors have to be taken fully into account, since they may be vital determinants of local level vulnerability and adaptive capacity.

The four OST scenarios storylines were found to be similar to those underlying the unapproved SRES98 marker emissions scenarios (http://www.ipcc-ddc.cru.uea.ac.uk/). The World Markets (WM) OST scenario was taken to correspond to the A1 SRES storyline, Local Stewardship (LS) to B2, Provincial Enterprise (PE) to A2 and Global Sustainability (GS) to B1. On this basis, we proceeded by comparing the global greenhouse gas emissions related to each scenario. Three steps were followed.

Firstly, the preliminary SRES98 carbon (C) emissions (expressed in giga-tonnes of carbon (GtC) from energy sources rounded to nearest GtC) were taken as a starting point and emissions for each scenario were calculated (see Table 1).

Table 1
Preliminary SRES98 global fossil carbon (C) emissions (in Gt)

Story/year	WM/A1	PE/A2	GS/B1	LS/B2
1990	6	6	6	6
2000	7	7	7	7
2025	11	12	8	10
2055	15	19	9	12

Table 2
Preliminary SRES98 global fossil C emissions (in Gt) re-interpreted to allow for different climate policy regimes

Story/year	WM/A1	PE/A2	GS/B1	LS/B2
1990	6	6	6	6
2000	7	7	7	7
2025	10	12	7	9
2055	13	19	7	10

Table 3
Preliminary SRES98 global fossil C emissions (in Gt) re-interpreted in qualitative terms to allow for different climate policy regimes under each scenario (based on Table 2). Note — in *all* cases C emissions are still higher than the 1990s, even in the 'Low' case

Story/year	WM/A1	PE/A2	GS/B1	LS/B2
2025	10	12	7	9
2025	Medium	High	Low	Medium–low
2055	13	19	7	10
2055	High	Very high	Low	Medium

However, SRES make no allowance for explicit climate policy interventions (e.g. Kyoto targets, etc.): "in 1996, the plenary session of the Intergovernmental Panel on Climate Change (IPCC) charged Working Group III of the Panel to develop a Special Report on Emissions Scenarios (SRES), including a new set of scenarios for the emissions of greenhouse gases. The scenarios are 'non-intervention scenarios', implying that no explicit additional climate policies are to be assumed". (http://sres.ciesin.org/)

Secondly, it was necessary that all the carbon emissions calculated for the scenarios should be adjusted downward on the basis of how effective the global climate policy regimes under each of the four worldviews might be (for example, see Table 2).

These latter estimates are of course somewhat arbitrary and go some way beyond what the IPCC were asked to consider. But we agreed that it was important to *start* with the Table 1 (unapproved IPCC thinking), then do some thinking of our own (Table 2) which considers the likely climate regimes that will emerge in our futures and how effective these climate policy regimes will be in reducing emissions *in those specific worlds*. A note of caution is expressed with regards to these calculations, as there is a danger of some circular reasoning. Under GS the preliminary SRES98 emissions are low anyway (because of de-materialisation, de-carbonisation, improved efficiencies, etc.). In this future world, it will be a lot harder to get *further* emissions reductions on the basis of specific climate policies.

This reasoning provided a quantification of likely outcomes for carbon emissions in relation to the different world scenarios for the two timeframes involved (Table 2). However, the research team thought it more appropriate to present the global carbon emission indications in the four world views, both for 2025 and 2055, in qualitative rather than quantitative terms, as this was deemed to be more understandable to the interviewees. Thirdly, under this re-interpretation, the figures obtained and shown in Table 2 were expressed in words (see Table 3). The global carbon emissions with respect to 1990 levels for each of the four world scenarios were denoted as: medium increase in WM, low increase in GS, high increase in PE, and medium–low increase in LS. These re-interpretations were then incorporated into the scenario sheets for East Anglia presented to the interviewees.

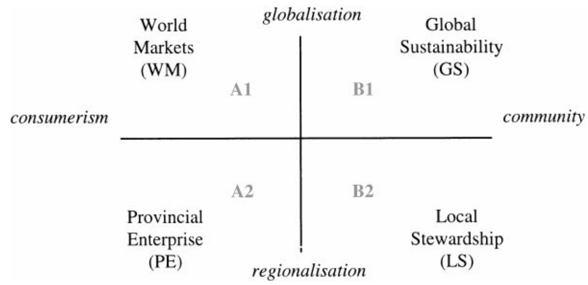

Fig. 2. The preliminary SRES98 storylines (A1–B2) compared to OST scenarios (adapted from OST, 1999).

After additional consideration and comparison of the storylines underlying the OST and preliminary SRES98 scenarios, it was concluded that each of the four OST scenarios could be matched to one of the SRES scenarios, as illustrated below (Fig. 2), in terms of storylines and emission figures.

Once the comparability between the OST scenarios and the preliminary SRES98 scenarios had been established, the four OST scenarios were compared to the four UKCIP98 climate scenarios modelled for the UK by Hulme and Jenkins (1998). These are termed low, medium–low, medium–high and high with reference to the respective global warming rates underlying each climate future. They also cover a range of UK future climates. By relating emissions from the OST scenarios with the global warming rates of the UKCIP98 scenarios (and hence the climate outcomes), it was possible to associate different warming rates, and therefore different UK climates, to the different socio-economic scenarios devised by OST.

The WM/A1 scenario was related to a medium–high warming rate; GS/B1 to a low warming rate; PE/A2 to a high warming rate and LS/B2 to a medium–low warming rate. Each of these four UKCIP98 climate scenarios was then re-interpreted to design possible future climates for East Anglia in the 2020s and the 2050s. This coupling of OST/SRES futures with the UKCIP98 climate scenarios is not precise, but approximate. Future work is

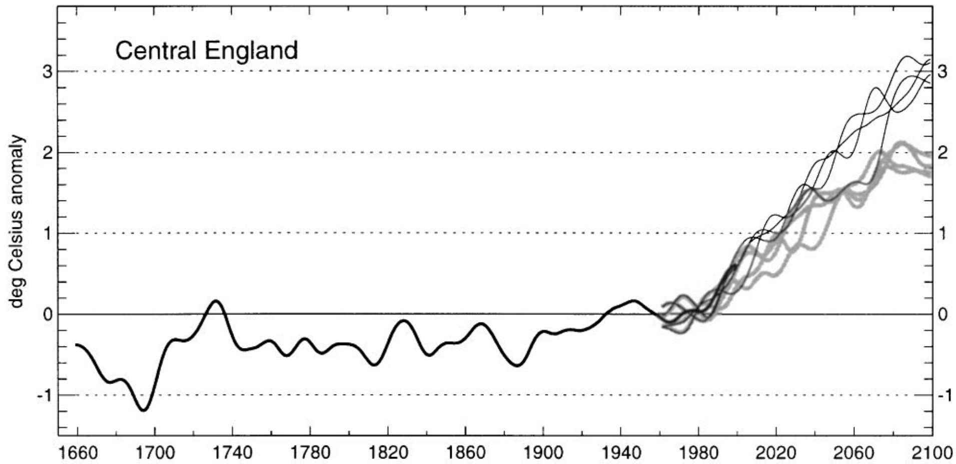

Fig. 3. The observed temperature trend from 1659 to 1997 for the UK, smoothed to emphasise variations on 30 yr time-scales, and simulated temperature trends for the UK from 1960 to 2100. The higher trend curves (thin black lines) result from a high greenhouse gas emissions scenario; the lower trend curves (represented in grey colour) result from a low emissions scenario. These curves are smoothed to emphasise decadal variations in temperature (source: Hulme and Jenkins, 1998).

likely to make this coupling more explicit, on the basis of the finally approved SRES futures.

For the year 2025, a single climate future is assumed (the medium–high climate in the UKCIP98 climate scenarios) and this is propagated through each of the four socio-economic scenarios. The underlying rationale for this is that climate change by 2025 is largely independent of actions occurring today and in the near future, being mostly dependent on historic emissions and on the inertia of the climate system. By 2025, for example, there is relatively little variation in the global warming curves of the four UKCIP98 climate scenarios developed by Hulme and Jenkins (1998) (see Fig. 3). The effects and consequences of the greenhouse gases already released into the atmosphere will be felt within the next 25 yr almost regardless of the mitigation strategies adopted in the meantime (Parry et al., 1998).

The climate for the period 2055 + is conditioned to a greater (but by no means exclusive) extent on the evolution of the socio-economic system and on decisions taken with regard to mitigation. Each of the four re-calibrated OST scenarios linked to one of the UKCIP98 climate scenarios, allows to differentiate between ‘low’ and ‘high’ climate change signals. The time-scales adopted represent the furthermost time horizon (50 yr) which social scientists use in describing future changes.

Climate change was described in each of the four worldviews in 2025 and 2055 in terms of the following variables (based on the UKCIP98 climate scenarios): temperature, precipitation, sea level rise, and the likelihood of more high-tide events. In addition, it was thought necessary to characterise the ‘climate’ sheets of the scenarios with indications of extreme variability in the climate. These were expressed in terms of how much shorter winter would be if a certain degree of warming occurred and the percentage frequency of warmer years (see Figs. 4–10, in particular Figs. 5 and 8).

The final scenario sheets formulated for 2025 and 2055 + and presented to the regional stakeholders contained: (1) a characterisation of each world in terms of growing and declining economic sectors, climate policy and strategy; (2) climate change with respect to today associated with each of the four world views; (3) a summary sheet with the key points of the information presented in the other two sheets. The scenarios for the 2050s (2055 +) were enriched with an additional sheet indicating the possible effects on illustrative sectors of the East Anglian economy, namely, the natural environment, the coastal zone, water services, agriculture and tourism. These were derived via an assessment of the sectoral consequences of the socio-economic and climate characteristics in each scenario. These characterisations were not intended to be prescriptive, but were devised simply as a means of prompting responses from the interviewees to think about their vulnerability and adaptive capacity (see Figs. 4–10).

The advantage of displaying the information in this way was thought to be two-fold. First, emissions could be linked to impacts in an integrated manner. In other words, respondents could be presented with four possible worlds or development ‘paths’ which society could choose to follow, with the resulting emissions and climate impacts. Second, the respondents could then be left to deduce their adaptive capacity to the combination of pressures represented in each of the four quadrants for themselves. We hoped that the climate expertise of the researchers could be fruitfully combined with the local-level expertise of the stakeholders representing particular exposure units. Ideally, the process of ‘thinking through’ the indicators would take place during the interviews,

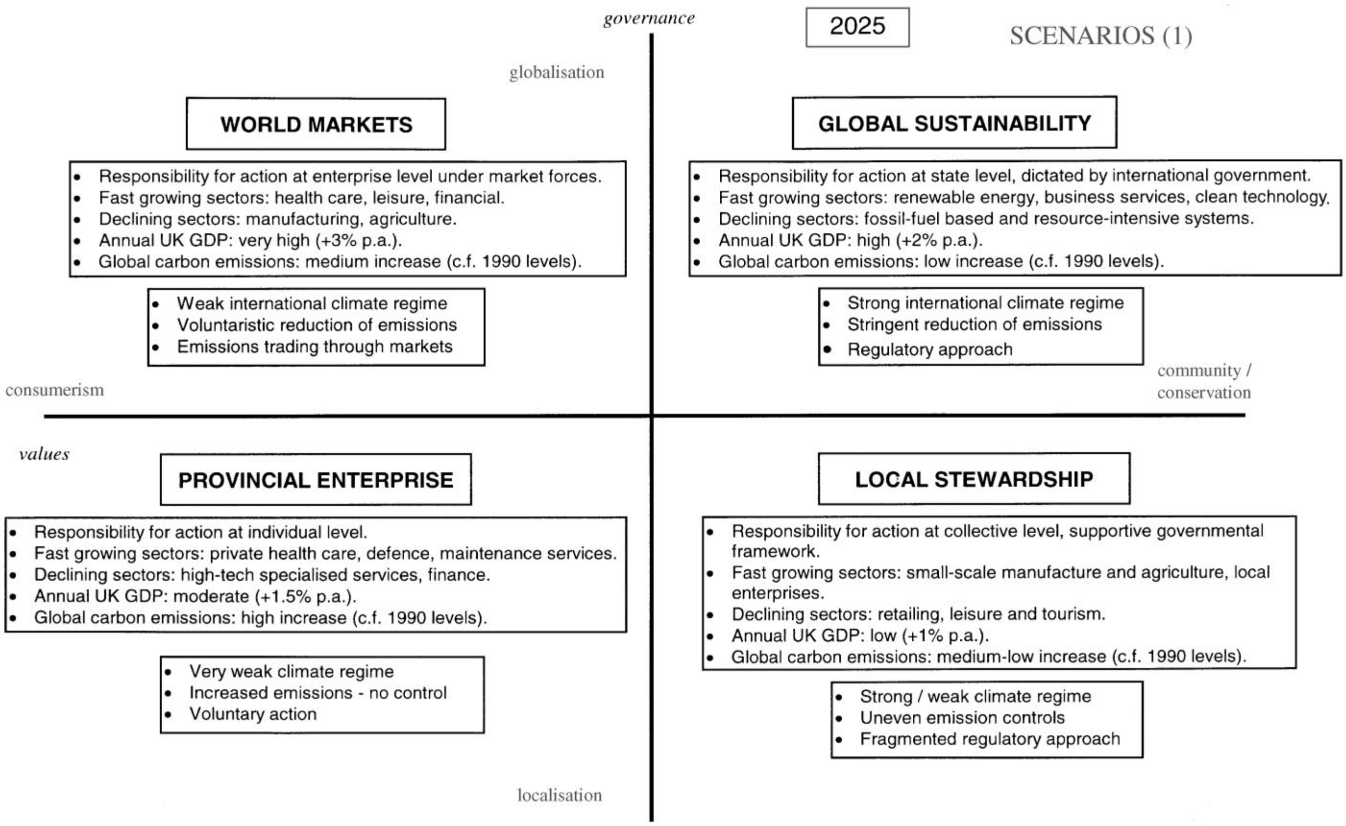
governance
2025
SCENARIOS (1)
globalisation
WORLD MARKETS
• Responsibility for action at enterprise level under market forces.
• Fast growing sectors: health care, leisure, financial.
• Declining sectors: manufacturing, agriculture.
• Annual UK GDP: very high (+3% p.a.).
• Global carbon emissions: medium increase (c.f. 1990 levels).
• Weak international climate regime
• Voluntaristic reduction of emissions
• Emissions trading through markets
GLOBAL SUSTAINABILITY
• Responsibility for action at state level, dictated by international government.
• Fast growing sectors: renewable energy, business services, clean technology.
• Declining sectors: fossil-fuel based and resource-intensive systems.
• Annual UK GDP: high (+2% p.a.).
• Global carbon emissions: low increase (c.f. 1990 levels).
• Strong international climate regime
• Stringent reduction of emissions
• Regulatory approach
consumerism
community / conservation
values
PROVINCIAL ENTERPRISE
• Responsibility for action at individual level.
• Fast growing sectors: private health care, defence, maintenance services.
• Declining sectors: high-tech specialised services, finance.
• Annual UK GDP: moderate (+1.5% p.a.).
• Global carbon emissions: high increase (c.f. 1990 levels).
• Very weak climate regime
• Increased emissions - no control
• Voluntary action
LOCAL STEWARDSHIP
• Responsibility for action at collective level, supportive governmental framework.
• Fast growing sectors: small-scale manufacture and agriculture, local enterprises.
• Declining sectors: retailing, leisure and tourism.
• Annual UK GDP: low (+1% p.a.).
• Global carbon emissions: medium-low increase (c.f. 1990 levels).
• Strong / weak climate regime
• Uneven emission controls
• Fragmented regulatory approach
localisation

Fig. 4.

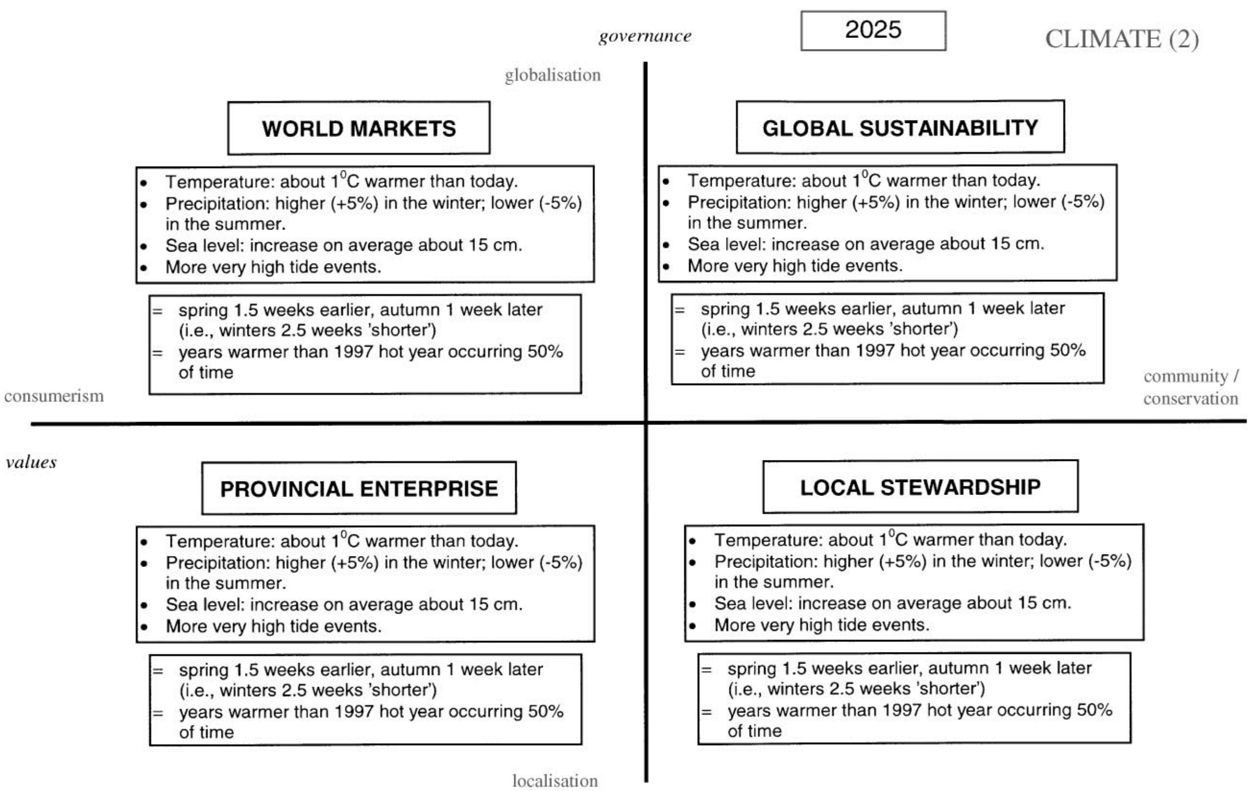
governance
2025
CLIMATE (2)
globalisation
WORLD MARKETS
• Temperature: about 1°C warmer than today.
• Precipitation: higher (+5%) in the winter; lower (-5%) in the summer.
• Sea level: increase on average about 15 cm.
• More very high tide events.
= spring 1.5 weeks earlier, autumn 1 week later (i.e., winters 2.5 weeks 'shorter')
= years warmer than 1997 hot year occurring 50% of time
GLOBAL SUSTAINABILITY
• Temperature: about 1°C warmer than today.
• Precipitation: higher (+5%) in the winter; lower (-5%) in the summer.
• Sea level: increase on average about 15 cm.
• More very high tide events.
= spring 1.5 weeks earlier, autumn 1 week later (i.e., winters 2.5 weeks 'shorter')
= years warmer than 1997 hot year occurring 50% of time
consumerism
community / conservation
values
PROVINCIAL ENTERPRISE
• Temperature: about 1°C warmer than today.
• Precipitation: higher (+5%) in the winter; lower (-5%) in the summer.
• Sea level: increase on average about 15 cm.
• More very high tide events.
= spring 1.5 weeks earlier, autumn 1 week later (i.e., winters 2.5 weeks 'shorter')
= years warmer than 1997 hot year occurring 50% of time
LOCAL STEWARDSHIP
• Temperature: about 1°C warmer than today.
• Precipitation: higher (+5%) in the winter; lower (-5%) in the summer.
• Sea level: increase on average about 15 cm.
• More very high tide events.
= spring 1.5 weeks earlier, autumn 1 week later (i.e., winters 2.5 weeks 'shorter')
= years warmer than 1997 hot year occurring 50% of time
localisation

Fig. 5.

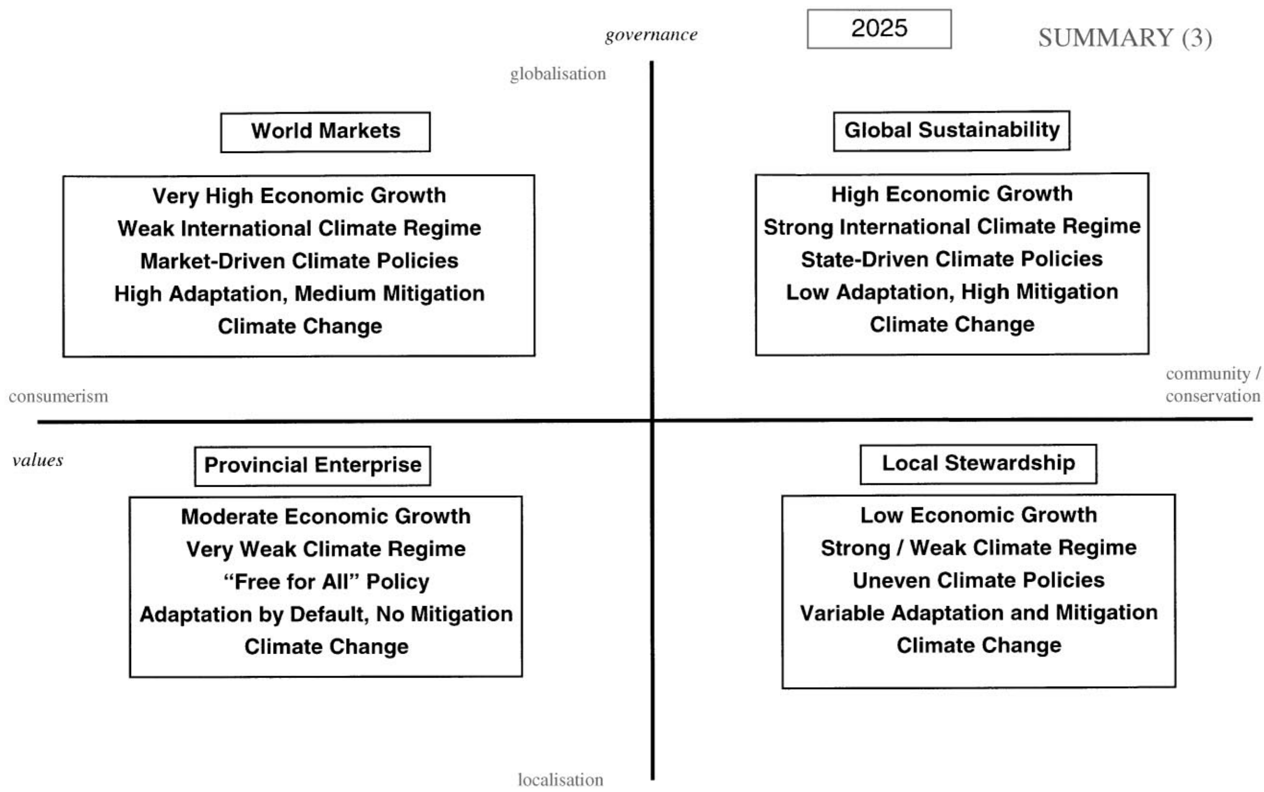
governance
2025
SUMMARY (3)
globalisation
World Markets
Very High Economic Growth
Weak International Climate Regime
Market-Driven Climate Policies
High Adaptation, Medium Mitigation
Climate Change
Global Sustainability
High Economic Growth
Strong International Climate Regime
State-Driven Climate Policies
Low Adaptation, High Mitigation
Climate Change
consumerism
community / conservation
values
Provincial Enterprise
Moderate Economic Growth
Very Weak Climate Regime
"Free for All" Policy
Adaptation by Default, No Mitigation
Climate Change
Local Stewardship
Low Economic Growth
Strong / Weak Climate Regime
Uneven Climate Policies
Variable Adaptation and Mitigation
Climate Change
localisation

Fig. 6.

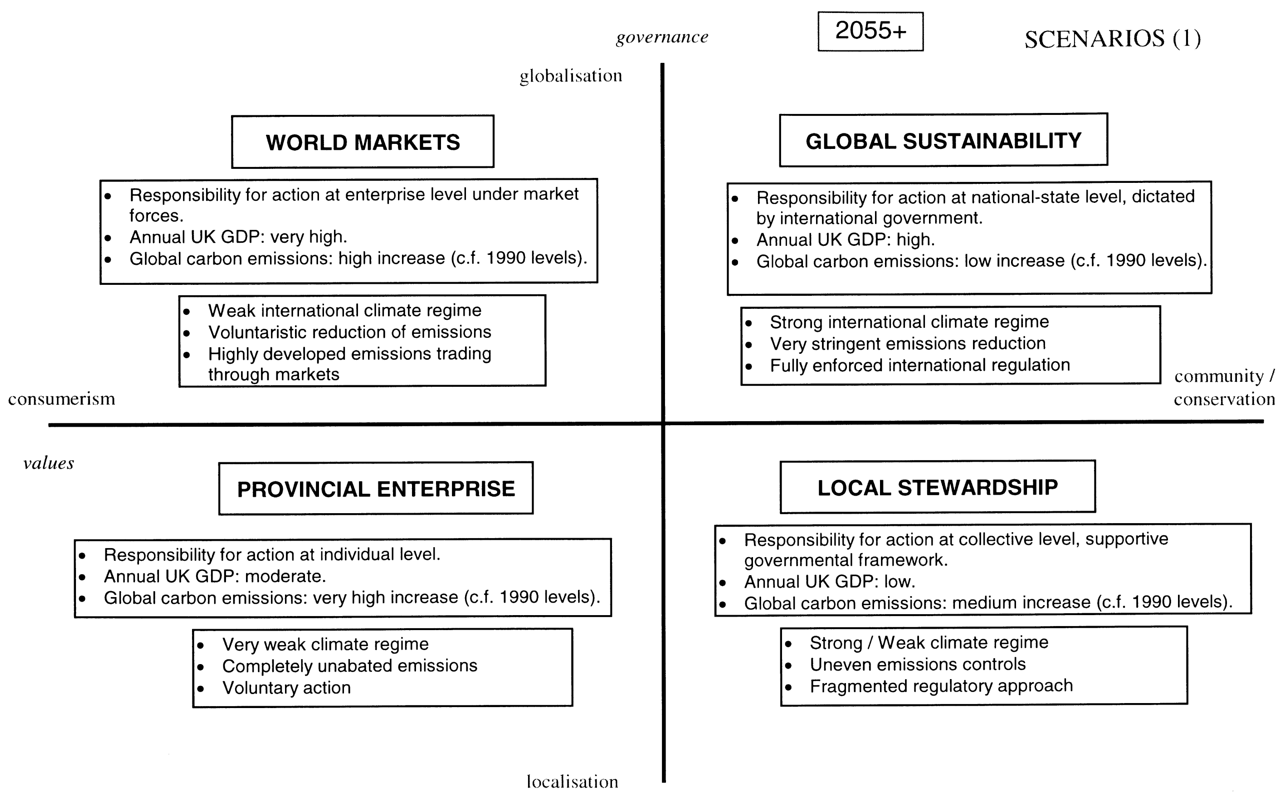
governance
2055+
SCENARIOS (1)
globalisation
WORLD MARKETS
Responsibility for action at enterprise level under market forces.
Annual UK GDP: very high.
Global carbon emissions: high increase (c.f. 1990 levels).
Weak international climate regime
Voluntaristic reduction of emissions
Highly developed emissions trading through markets
GLOBAL SUSTAINABILITY
Responsibility for action at national-state level, dictated by international government.
Annual UK GDP: high.
Global carbon emissions: low increase (c.f. 1990 levels).
Strong international climate regime
Very stringent emissions reduction
Fully enforced international regulation
consumerism
community / conservation
values
PROVINCIAL ENTERPRISE
Responsibility for action at individual level.
Annual UK GDP: moderate.
Global carbon emissions: very high increase (c.f. 1990 levels).
Very weak climate regime
Completely unabated emissions
Voluntary action
LOCAL STEWARDSHIP
Responsibility for action at collective level, supportive governmental framework.
Annual UK GDP: low.
Global carbon emissions: medium increase (c.f. 1990 levels).
Strong / Weak climate regime
Uneven emissions controls
Fragmented regulatory approach
localisation

Fig. 7.

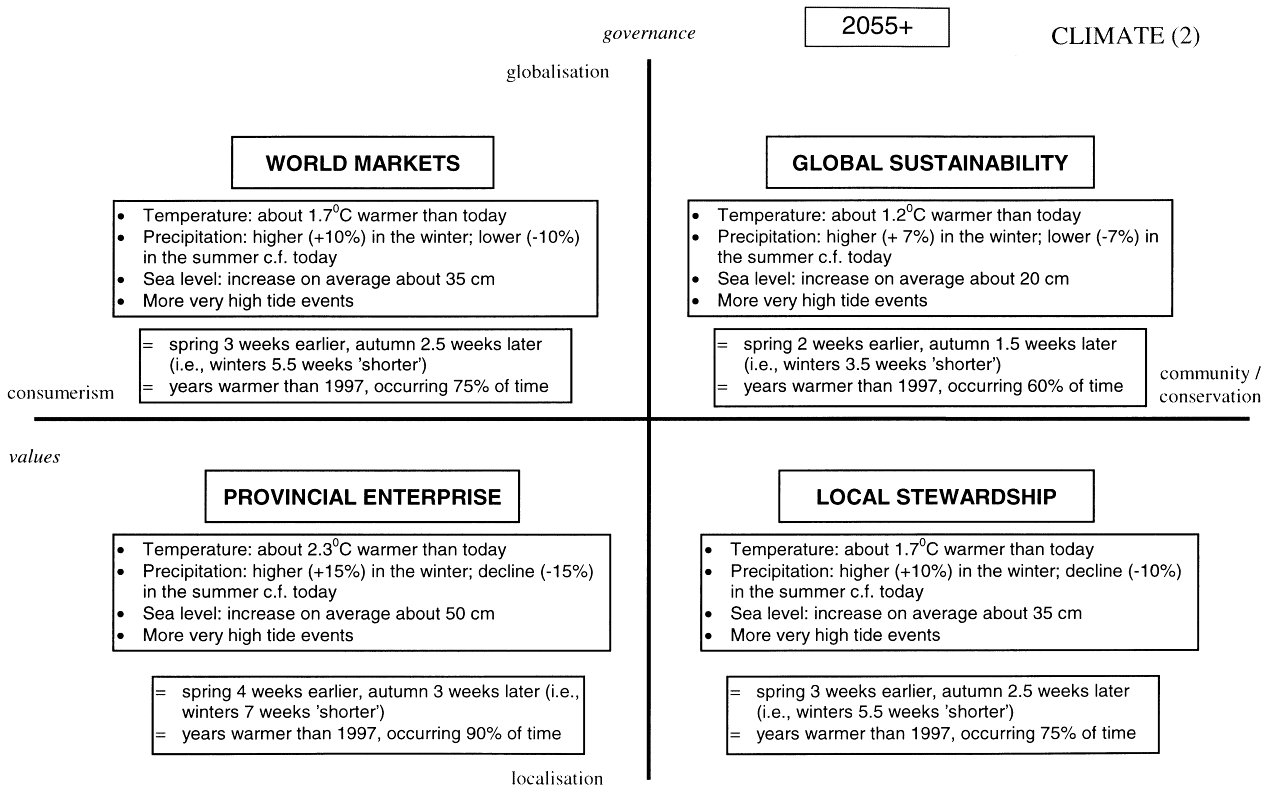
governance
2055+
CLIMATE (2)
globalisation
WORLD MARKETS
• Temperature: about 1.7°C warmer than today
• Precipitation: higher (+10%) in the winter; lower (-10%) in the summer c.f. today
• Sea level: increase on average about 35 cm
• More very high tide events
= spring 3 weeks earlier, autumn 2.5 weeks later (i.e., winters 5.5 weeks 'shorter')
= years warmer than 1997, occurring 75% of time
GLOBAL SUSTAINABILITY
• Temperature: about 1.2°C warmer than today
• Precipitation: higher (+ 7%) in the winter; lower (-7%) in the summer c.f. today
• Sea level: increase on average about 20 cm
• More very high tide events
= spring 2 weeks earlier, autumn 1.5 weeks later (i.e., winters 3.5 weeks 'shorter')
= years warmer than 1997, occurring 60% of time
consumerism
community / conservation
values
PROVINCIAL ENTERPRISE
• Temperature: about 2.3°C warmer than today
• Precipitation: higher (+15%) in the winter; decline (-15%) in the summer c.f. today
• Sea level: increase on average about 50 cm
• More very high tide events
= spring 4 weeks earlier, autumn 3 weeks later (i.e., winters 7 weeks 'shorter')
= years warmer than 1997, occurring 90% of time
LOCAL STEWARDSHIP
• Temperature: about 1.7°C warmer than today
• Precipitation: higher (+10%) in the winter; decline (-10%) in the summer c.f. today
• Sea level: increase on average about 35 cm
• More very high tide events
= spring 3 weeks earlier, autumn 2.5 weeks later (i.e., winters 5.5 weeks 'shorter')
= years warmer than 1997, occurring 75% of time
localisation

Fig. 8.

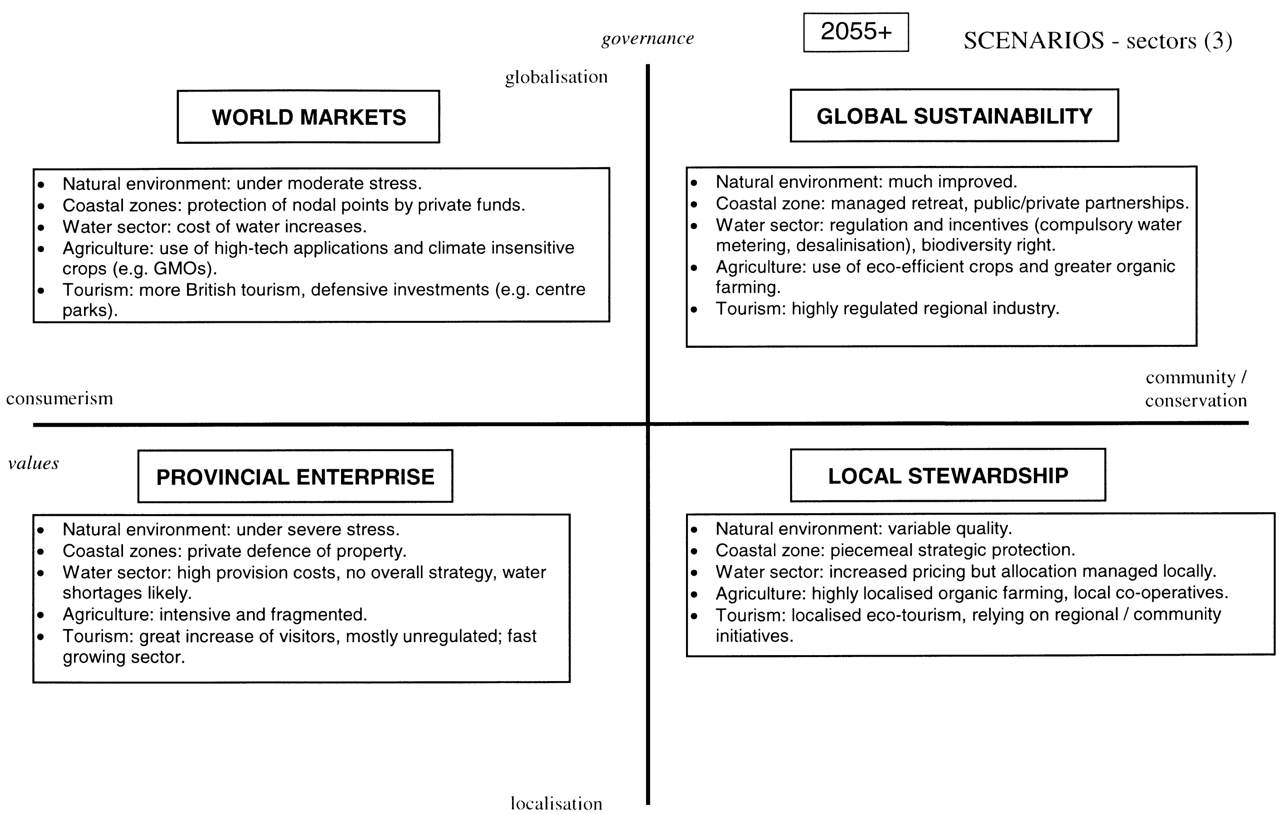
governance
2055+
SCENARIOS - sectors (3)
globalisation
WORLD MARKETS
• Natural environment: under moderate stress.
• Coastal zones: protection of nodal points by private funds.
• Water sector: cost of water increases.
• Agriculture: use of high-tech applications and climate insensitive crops (e.g. GMOs).
• Tourism: more British tourism, defensive investments (e.g. centre parks).
GLOBAL SUSTAINABILITY
• Natural environment: much improved.
• Coastal zone: managed retreat, public/private partnerships.
• Water sector: regulation and incentives (compulsory water metering, desalinisation), biodiversity right.
• Agriculture: use of eco-efficient crops and greater organic farming.
• Tourism: highly regulated regional industry.
consumerism
community / conservation
values
PROVINCIAL ENTERPRISE
• Natural environment: under severe stress.
• Coastal zones: private defence of property.
• Water sector: high provision costs, no overall strategy, water shortages likely.
• Agriculture: intensive and fragmented.
• Tourism: great increase of visitors, mostly unregulated; fast growing sector.
LOCAL STEWARDSHIP
• Natural environment: variable quality.
• Coastal zone: piecemeal strategic protection.
• Water sector: increased pricing but allocation managed locally.
• Agriculture: highly localised organic farming, local co-operatives.
• Tourism: localised eco-tourism, relying on regional / community initiatives.
localisation

Fig. 9.

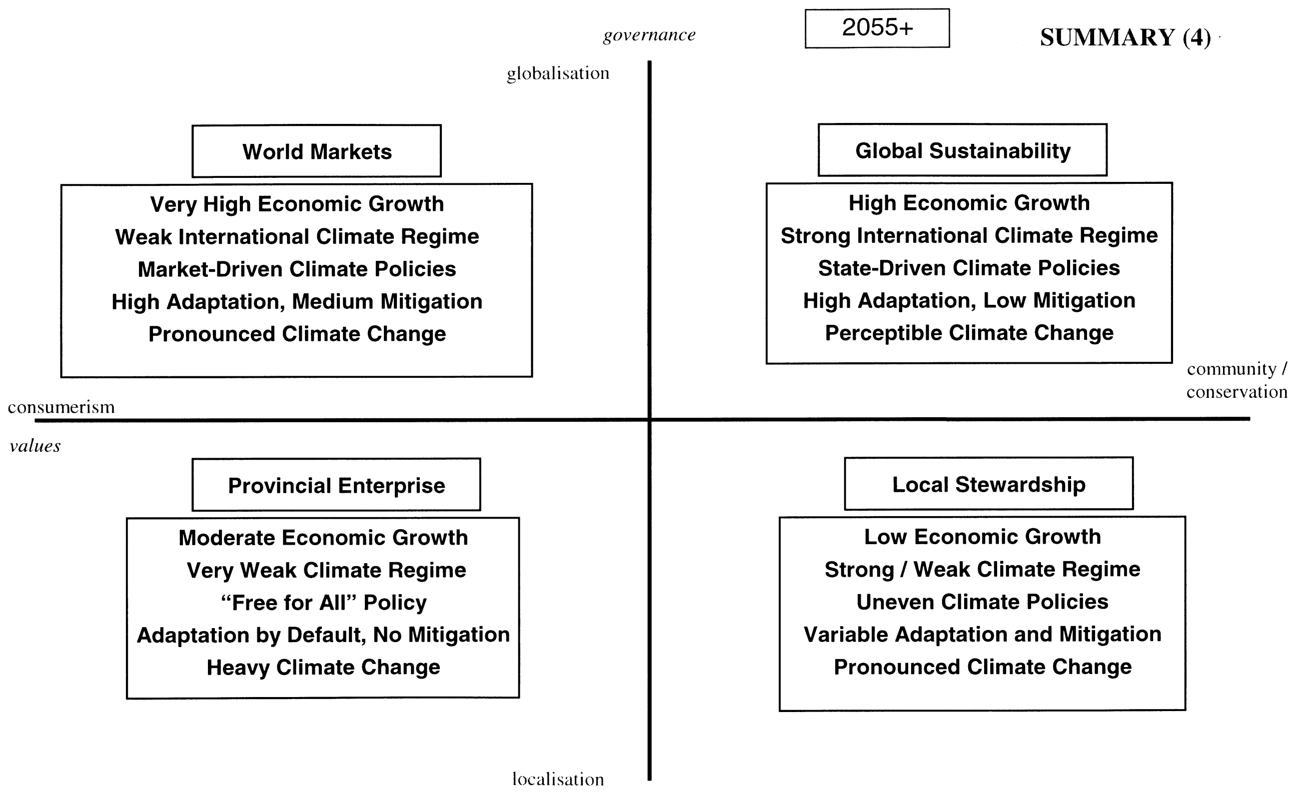

Fig. 10.

though it was hoped that the stakeholders could then be persuaded to do more detailed work for themselves after the interview.

7. Conclusions

In this paper we have set out to explore the potential benefit of integrating socio-economic and climate scenarios, by applying them 'bottom up' to tap the expertise and perspectives of locally important stakeholders in potentially sensitive sectors. The scenarios that we have developed combine elements of the preliminary SRES98 scenarios, which do not make allowance for explicit climate policy interventions, the OST scenarios and UKCIP98 scenarios. The combination is enriched with our own characterisation of possible future worlds, which includes mitigation options linked to climate changes. We regard this approach as justified up to the extent that our endeavour is to present a set of scenarios not solely focused on climatic changes, but including the interactions between socio-economic (including mitigation and adaptation options) and natural systems. In Part II we test these assertions by applying the scenarios in the East Anglian region of the UK.

The conclusions of this part of the paper are two-fold. First, our approach tries to offer a more sophisticated and dynamic account of the potential feedbacks between natural and human systems than top-down assessments. Crucially, by combining socio-economic and climate scenarios we have tried to present a more dynamic image of the future to the very people who will have to enact key adaptive responses to changes in the climate within the next two to three decades. In particular, our scenarios provide a useful tool that works across different disciplines and different sectors of society, merging different temporal and spatial scales. The scenario framework in this paper illustrates how mitigation and adaptation can be presented and perceived as connected/co-evolving systems. This in turn allows stakeholders to envision the changes possible within their own sectors and their specific responses to the issues presented. Our approach involves stakeholders and builds upon the need expressed by IPCC to have consistent bases for emissions and adaptation studies. In all these senses, our approach seeks to be genuinely integrative.

Second, we argue that sustainability indicators are a potentially valuable input to and an output of integrated scenario formulation. As an input, they can be used to flesh out and give added specificity and concreteness to scenario storylines expressed in more qualitative terms. The respondents to our survey thought they worked especially well as 'prompts', encouraging them to think in a more focused way about potential impacts and adaptive responses. After some pre-testing, we discovered that indicators which had been designed to meet the *practical* needs of stakeholders in East Anglia worked best of all, although it is also important to retain some consistency for the purposes of making comparisons between and within sectors. As an output, indicators are a potential valuable means of communicating information about climate impacts in one sector/region to audience in other sectors/regions. In order to make the findings as policy relevant as possible, the indicators should not be simply 'dreamed up' by researchers but should reflect as accurately as possible current regional- and national-level trends/predictions (DETR, 1999). In Part II of this article we explore the practical utility of the scenarios by subjecting them to case study test in the East Anglian region of the UK.

References

Adger, W.N., 1999. Evolution of economy and environment: an application to land use in lowland Vietnam. Ecological Economics 31 (3), 365–379.

Berkhout, F., Hertin, J., Lorenzoni, I., Jordan, A., Turner, R.K., O'Riordan, T., Cobb, D., Ledoux, L., Tinch, R., Hulme, M., Palutikof, J., Skea, J., 1999. Socio-economic scenarios for climate impact assessment. Final Report submitted to the DETR by SPRU, CSERGE, CRU and the PSI. SPRU, University of Sussex, Brighton, UK.

Climate Change Impacts Review Group (CCIRG), 1996. Review of the potential effects of Climate Change in the United Kingdom. Second Report, HMSO, Norwich, UK.

Department of the Environment, Trade and the Regions (DETR), 1999. A better quality of life. A strategy for sustainable development for the UK. The Stationery Office Ltd., London, UK, 1999.

Elkington, J., Trisoglio, A., 1996. Developing realistic scenarios for the environment: lessons from Brent Spar. Long Range Planning 29 (6), 762–769.

Gallopin, G.C., Raskin, P., 1998. Windows on the future: global scenarios and sustainability. Environment 40 (3), 7–11, 26–31.

Hammond, A., 1998. Which World? Scenarios for the 21st century. Global Destinies, Regional Choices. Earthscan Publications Ltd., London, UK.

Hulme, M., Jenkins, G.J., 1998. Climate Change Scenarios for the UK: scientific report. UKCIP Technical Report no. 1, Climatic Research Unit, Norwich, UK.

Intergovernmental Panel on Climate Change (IPCC), 1996. Climate Change 1996. Impacts, Adaptation and Mitigation of Climate Change: Scientific — Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

Kassler, P., 1995. Scenarios for world energy: barricades or new frontiers? Long Range Planning 28 (6), 38–47.

Lorenzoni, I., Jordan, A., O'Riordan, T., Turner, R.K., Hulme, M., A co-evolutionary approach to climate change impact assessment Part II — a scenario-based case study in East Anglia (UK). Global Environmental Change, in press.

Miles, I., 1981. Scenario analysis: identifying ideologies and issues. In: Methods for Development Planning: Scenarios, Models and Micro-studies. UNESCO Press, Paris, France, pp. 31–54.

Nijkamp, P., Rienstra, S.A., Vleugel, J.M., 1997. Long-term scenarios for surface transport. International Journal of Environment and Pollution 7 (3), 305–326.

Norgaard, R.B., 1984. Coevolutionary development potential. Land Economics 60 (2), 160–173.

Norgaard, R.B., 1994. Development Betrayed. The End of Progress and a Coevolutionary Revisioning of the Future. Routledge, London, UK.

Office of Science and Technology (OST), 1999. Environmental futures. Report for the UK's National Technology Foresight Programme, Department of Trade and Industry, DTI/Pub 4015/1k/3/99/NP. URN 99/647, UK.

Palutikof, J.P., Subak, S., Agnew, M.D. (Eds.), 1997. Economic Impacts of the Hot Summer and Unusually Warm Year of 1995. University of East Anglia, Norwich and HMSO, London, UK.

Parry, M. (Ed.), Assessment of the potential effects of climate change in Europe (ACACIA Project), Jackson Environment Institute, UEA, Norwich, UK, forthcoming.

Parry, M., Carter, T., 1998. Climate Impact and Adaptation Assessment. Earthscan Publications Ltd., London, UK.

Parry, M., Arnell, N., Hulme, M., Nicholls, R., Livermore, M., 1998. Adapting to the inevitable. Nature 395, 741.

Parson, E.A., 1995. Integrated assessment and environmental policy making. In pursuit of usefulness. Energy Policy 23 (45), 463–475.

Patterson, W.C., 1999. Transforming Electricity: the Coming Generation of Change. Earthscan Publications Ltd., London, UK.

Rayner, S., Malone, E.L., 1998. Human Choice and Climate Change. Batelle Press, Columbus, OH, USA.

Smithers, J., Smit, B., 1997. Human adaptation to climate variability. Global Environmental Change 7 (2), 129–146.

Turner, R.K., Lorenzoni, I., Beaumont, N., Bateman, I.J., Langford, I.H., McDonald, A.L., 1998. Coastal Management for Sustainable Development: analysing environmental and socio-economic changes on the UK coast. The Geographical Journal 164 (3), 269–281.

World Business Council for Sustainable Development (WBCSD), 1997. Global Scenarios 2000–2050. Summary Brochure, WBCSD, London, UK.