Katharina Helming
Marta Pérez-Soba
Paul Tabbush
(Editors)

Sustainability Impact Assessment of Land Use Changes

With 72 Figures, 55 in colour

Springer

Dr. Katharina Helming
Centre for Agricultural Landscape and Land Use Research (ZALF)
Eberswalderstr. 84, D-15374 Müncheberg,
Germany

E-Mail:
khelming@zalf.de

Dr. Marta Pérez-Soba
ALTERRA
Wageningen UR, Droevendaalsesteeg 3, 6708 PB Wageningen,
The Netherlands

E-Mail:
marta.perezsoba@wur.nl

Mr. Paul Tabbush
Forest Research, Alice Holt Lodge, Farnham Surrey, UK, GU10 4LH
United Kingdom

E-Mail:
paul.tabbush@forestry.gsi.gov.uk

Library of Congress Control Number: pending

ISBN 978-3-540-78647-4 Springer Berlin Heidelberg New York

Springer is a part of Springer Science+Business Media
Springer.com

Cover design: deblik, Berlin
Typesetting: camera-ready by the editors
Production: Agata Oelschläger

Printed on acid-free paper 30/2133/ao 5 4 3 2 1 0

Contents

Sustainability Impact Assessments: limits, thresholds and the Sustainability Choice Space

Marion Potschin and Roy Haines-Young

Centre for Environmental Management, School of Geography, University of Nottingham, UK

Abstract

Sustainability impact assessments (SIA) are inherently difficult because they often require policy advisors to compare things that are not easily compared. For example, they generally require an evaluation of policy proposals or options across the 'three pillars' of economy, society and environment. In this chapter we explore how decisions are made in relation to questions about the sustainability of policies, and show how the consideration of sustainability limits can help integrate thinking across the economic, social and environmental domains. It is argued that in relation to questions about the sustainability of actions or policies, outcomes merely need to be sufficient to maintain human well-being and that the search for optimal strategies is probably misleading. The concept of a sustainability choice space is developed as a way of helping policy advisors visualise and explore what 'room for manoeuvre' they might have in the design of a specific policy. The sustainability choice space can be used to describe the degree to which alternative policy outcomes are acceptable to stakeholders across a range of criteria. The chapter concludes with a discussion of the role that the concept of a sustainability choice space might have as part of the sustainability impact assessment toolkit being developed through SENSOR, and how it can be extended by the involvement of stakeholders in the definition of sustainability limits and the kinds of trade-offs that need to considered in a multifunctional landscape.

Keywords

Sustainability Impact Assessment, sustainability limits and thresholds, policy choices, multifunctional landscapes, Land Use Functions.

1 Introduction

Sustainability impact assessments (SIA) are inherently difficult because they often require policy advisors to compare things that are not easily compared. A core principle of sustainable development is that the 'three pillars'[1] of economy, society and environment must be respected, but how should changes in these different factors be characterised and ultimately weighed against each other?

Approaches to the problem of characterising the potential economic, social and environmental impacts of policy actions are now well established – at least conceptually if not practically. Indicators have emerged as a major tool for scientists and policy makers alike, and they are widely used to represent key elements of systems and to track trends. Increasingly models are now being employed to think about the changes that might be set in train by different policy options. The SENSOR Project[2] is firmly part of this tradition. Its goal is to develop a Sustainability Impact Assessment Tool (SIAT) that can somehow help policy advisors integrate the range of issues that need to be taken into account if the implications of policy decisions for sustainable development are to be fully evaluated.

In this chapter we examine some of the features of SIAT, and in particular reflect upon the problem of integrating information and framing decisions across the three pillars of sustainability. The discussion will focus on the concept of a 'sustainability choice space' which is proposed as a way in which policy advisors might visualise and explore what 'room for manoeuvre' they might have in the design of a specific policy. We will show how the idea of a sustainability choice space might be used to describe the

---

[1] We use the term "three pillars of Sustainability" although we agree with Kemp et al. (2005, p.3) that "the pillar-focused approaches have suffered from insufficient attention to overlaps and interdependencies and a tendency to facilitate continued separation of social, economic and ecological analyses." … and …that the overlapping circle idea comes closer to the integration of the three parts of Sustainability.

[2] "Sustainability Impact Assessment: Tools for Environmental Social and Economic Effects of Multifunctional Land Use in European Regions", Integrated Project within the EU 6th framework programme (www.sensor-ip.eu)

degree to which alternative policy outcomes are acceptable to stakeholders across a range of criteria. We also describe how such a choice space must be constructed using information derived from stakeholders to identify the dimensions of sustainability, which are important in the context of a specific policy and the limits and thresholds associated with them.

2 Sustainable Development: Ultimate vs Adequate Solutions

In order to show why the idea of a sustainability choice space is so important for those involved with SENSOR, it is worth reflecting further on the reasons why SIA (or sustainability appraisals in general) are so difficult. Not only do we face difficulties in terms of trying to resolve issues between things that are not easily compared – economy, society and environment – we also have to wrestle with the fact that 'right answers' are difficult to recognise.

Many commentators have argued that 'traditional science' is singularly ill-equipped to cope with the problems that sustainable development throws up (Holling, 1998; Kates et al., 2000; Gallopín et al., 2001). Holling (1998), for example, has attempted to contrast the features of traditional science and its analytical traditions with a more 'integrative' approach that seems more appropriate in the context of sustainability (Table 1). With its narrowly targeted, reductionist methods, that strive for ultimate but parsimonious solutions, the danger is, according to Holling (1998) that we achieve the 'right answer for the wrong question'. By contrast, it is claimed that contemporary problems, particularly those involving notions of sustainability, call for broader, more exploratory problem solving strategies that results in solutions that are essentially 'consensual'. We are witnessing, according to Gallopín et al. (2001) a 'diversification in types of knowledge production that are regarded as legitimate' and a 'democratisation of knowledge' so that the insights of lay and indigenous people are no longer regarded as in some sense inferior to that of experts.

Table 1. Two traditions of science (after: Gallopín et al. 2001, and Holling, 1998)

Attribute	**Analytical**	**Integrative**
Philosophy	Narrow and targeted Disproof by experiment Parsimony the rule	Broad and exploratory Multiple lines of converging evidence Requisite simplicity the goal
Perceived organisation	Biotic interactions Fixed environment Single scale	Biophysical interactions Self organisation Multiple scales with cross scale interactions
Causation Hypotheses	Single and separable Hypotheses and null rejection of hypotheses	Multiple and only partially separable Multiple, competing hypotheses Separation among competing hypotheses
Uncertainty	Eliminate uncertainty Standard statistics Experimental Concern with Type I error (in hypothesis testing, rejecting the proposition when it is true	Incorporate uncertainty Non-standard statistics Concern with Type II error (failing to reject the proposition when it is false)
Evaluation goal	Peer assessment to reach ultimate unanimous agreement	Peer assessment, judgement to reach a partial consensus
The danger	Exactly right answer for the wrong question	Exactly right question but useless answer

While arguing for the integrative approach, Holling (1998) acknowledges that it is not without its dangers. These include the possibility that wide consultation and discussion may result in formulating the right question, but that ultimately the methods may not guarantee an appropriate or satisfactory answer. However, while it is certainly the case that science increasingly has to take account of the interaction between experts, decision makers and the public (Figure 1) it does not follow that traditional science and the methods of conjecture and refutation have no place in current debates. What these critiques of traditional science lack is any recognition that there is a fundamental difference between the sorts of problems we face in the scientific and policy realms.

The differences between the problems encountered in the scientific and policy realms can best be seen in terms of how solutions are regarded. For the scientist, theories (= solutions) stand or fall according to whether they are supported or refuted by evidence about how the world works. The guiding principle is that there is only one true explanation and that through trial and error, or conjecture and refutation, that answer might ultimately be discovered. Solutions to questions involving sustainable development are not usually like this, for here - while solutions must not ignore bio-physical, economic or social constraints - many different organisational strategies or policies can deliver outcomes, which have the capacity to ensure social justice, well-being and inter-generational equity. Solutions to the problems of sustainability merely have to be sufficient or adequate, not ultimate, and so we may be presented with a choice of many ways forward. We do not, in other words, need to find 'a best' or 'optimal' solution. Indeed there may not be one. 'Success' ultimately depends on finding an adequate solution.

The difference between 'ultimate' and 'adequate' solutions is well illustrated by different ways of thinking about land use patterns and sustainable development – the type of problem that is a central concern to projects such as SENSOR.

Forman (1995), for example, has hypothesised that for any landscape, or major portion of the landscape, there exists an optimal spatial arrangement of ecosystems and land uses to maximise ecological integrity. He argues that the same is true for achieving basic human needs and for creating a sustainable environment. As he looks to the future, he argues that 'the major but tractable challenge' is to discover what those arrangements are.

The view that the search for optimal spatial arrangements are the major challenge confronting land use science can be contrasted with an alternative vision, which envisages that if our goals include ecological integrity or continued human well-being, then many different spatial arrangements of land cover and use are likely to be able to achieve such ends (cf. Potschin and Haines-Young, 2006). Thus while we might acknowledge that a certain level of woodland cover is necessary to maintain biodiversity, and that a certain degree of fragmentation should not be exceeded, those criteria can be met by many different arrangements of woodland parcels across a landscape.

It is now widely acknowledged that whatever sustainable development involves, it certainly embodies the idea that the output of ecosystem goods and services from landscapes or ecosystems should be maintained (MA, 2005). 'Sustainability' is, we suggest, assessed more in terms of the ability to maintain functional outputs than by structural properties *per se*. Thus we would argue, in contradistinction to Forman (1995), that the major challenge confronting land use science is to understand what possible spatial arrangements are sufficient to maintain the outputs of goods and services that people value, and what types of arrangement are unlikely to achieve such ends, and thus to identify the ***range of planning choices*** that are available to us (cf. Haines-Young, 2000; Potschin and Haines-Young, 2006).

An understanding of the difference between 'ultimate' or 'optimal' and 'adequate' solutions in the context of sustainability is of fundamental importance for anyone attempting to design impact assessment tools. In searching for appropriate problem solving strategies we need to look no further than the example of the process of evolution by natural selection, which also operates on the basis that at any one time, new forms do not need to be optimal, but simply sufficient to improve survival over other varieties (cf. Sartorius, 2006). The difference between the two processes is merely that under sustainability planning, the strategy that 'survives' is determined more by social negotiation than competition. Sustainability impact assessment is essentially normative rather than prescriptive, and is based on an understanding of the ways in which economic, social and environmental considerations constrain our planning choices.

The search for adequate or sufficient solutions, rather than ultimate answers is, in fact, implicit in the 'adaptive' and 'flexible' approaches espoused by the champions of so-called 'sustainability science' (e.g. Kates et al., 2000, 2001). Indeed, as Kemp et al. (2005) have pointed out sustainability is best approached as an open-ended process, and that the notion of sustainable 'landing places' that is sometimes used by the European Commission is probably misleading. As Kemp et al. (2005) note, such ideas suggest that the problem of sustainable development can be 'solved' whereas in reality only specific issues can be resolved and managed.

3 Constraining Choices: Limits and Thresholds

Questions about environmental limits, and their implications for policies related to sustainable development have recently emerged as an important focus of debate in the scientific and policy literature (e.g., Sagoff, 1995; Lomborg, 1998; Davidson (2000)[3]. These discussions are, in fact, part of a much longer and wide-ranging discussion about the extent to which human development can be maintained in the light of supposed environmental constraints. Going back to the late eighteenth century, for example, Malthus (1798) considered the limiting relationships between population growth and food supply. In the twentieth century discussion of resource constraints was stimulated by the publication of *Limits to Growth* (Meadows et al., 1972) which argued that in a finite world, economic expansion could not be sustained indefinitely. In the contemporary literature, the recent notions of limits have been framed around the ideas of 'ecological

[3] See also Bertrand et al. (2008)

footprints' and 'sustainable patterns of consumption and production', both of which imply that there are limits beyond which certain types of growth and development are not sustainable. Such ideas are also now actively being discussed in the political arena, for example, in relation to ideas of 'one planet living'[4].

If, in the context of making sustainability assessments, economic, social and environmental limits or thresholds constrain or frame the choices that we can make, how do we go about defining them? Unfortunately the task is not an easy one, because different discipline areas have approached the problem in different ways. We thus begin with some clarification of terminology (see Bertrand et al., 2008).

A review of the ecological literature suggests that although the terms 'limit' and 'threshold' tend to be used interchangeably, it is useful to distinguish between them because they highlight important features about system behaviour that ought to be considered when developing policy or management strategies. Ecosystems are, for example, important to people because of the benefits they actually or potentially deliver and the contribution they make to human well being (MA, 2005). However, external pressures may progressively undermine the capacity of these systems to continue to deliver those benefits at the level required. As a result, society may judge that a 'critical point' has been reached, beyond which further change is unacceptable. This critical point denotes what most commentators call a limit (Figure 1a).

The term threshold, by contrast, is probably best used to describe situations where a sudden regime shift occurs, because the system can exist in alternative stable states. In this case, the 'threshold' is that point at which systems become vulnerable to such behaviour.

The study of thresholds has recently become the focus of attention in the environmental literature, largely because of the dramatic nature of the change that can be triggered once a threshold has been crossed (Scheffer et al., 2001; Scheffer et al., 2003; Scheffer and Carpenter, 2003). Such behaviour is well known in aquatic systems impacted by eutrophication, for example, where increased nutrient loading may cause the sudden loss of ecological integrity, which cannot simply be restored by reducing pollution loads due to hysteresis effects (Figure 1a). However, while there have recently been some attempts to document such behaviour (Walker and Meyers, 2004), and explore the extent to which it may be exhibited by 'coupled ecological-social systems', it seems that such dynamics are by no

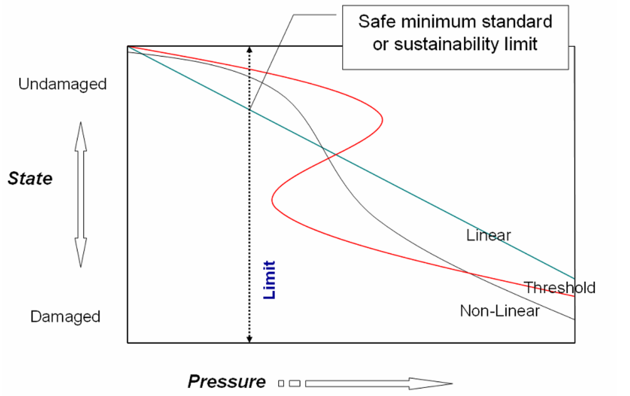
[4] international http://www.oneplanetliving.org/ , also recently promoted by the UK Government http://www.defra.gov.uk/news/latest/2006/defra-1013.htm, http://www.cpi.cam.ac.uk /bep/downloads/one%20planet%20living.pdf

means universal and that the existence of threshold effects are difficult to predict before they are observed.

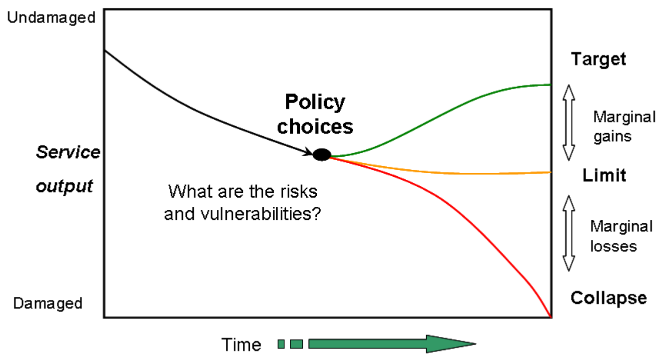
Without denying the possibility that systems may exhibit threshold responses, we would argue that when making sustainability assessments, the more general idea of a limit is probably more useful – and certainly less ambiguous. Limits can be defined for all types of system, whether they exhibit a progressive linear decline in the face of external pressures, whether change is progressive but non-linear, or whether there may ultimately be some collapse if the system experiences a 'regime shift' or threshold response (Figure 1a). The idea of a limit can be used to deal with the dangers of sudden collapse (due to threshold-type responses), but at the same time can focus attention on possibly the more widespread situation where there is a chronic or gradual loss of the functionality as a result of increasing economic, social or environmental pressures on resource systems. A limit can be defined whether the system shows a threshold response or not.

In fact, as Figure 1b suggests, different types of limit can be envisaged, depending on how society wants to cope with the risks associated with loss of function or benefit. Thus while absolute limits might be recognised, management might aim to keep the system above some 'safe minimum standard', or 'precautionary limit' that ensures that the danger of collapse or significant damage is not extreme, given the presence of uncertainty and environmental variability[5]. Although the idea of a limit is a simple one, there is a hidden complexity in the way they are defined, which must be discussed if we are to make successful sustainability assessments. This complexity arises from the fact that the identification of a limit ultimately hinges on the judgment made by individuals or groups 'that a critical point has been reached'. How, we might ask, is that judgment made and justified? We would argue that is mainly in terms of the perceived or predicted consequences or implications of exceeding a given limit that those judgments are made.

[5] In context of sustainable fisheries, the safe minimum standard is often referred to as a 'precautionary reference point'.



a) Systems can show a range of responses to some external driver. The responses may be linear or non-linear, or show 'threshold' behaviour, involving a regime shift. The concept of a limit can be used to specify the extent of acceptable change in terms of the levels of benefit the system can generate or the risks and uncertainties involved in approaching some threshold.



b) Faced with increasing levels of damage, there may come a point at which society looks at the policy options, ranging from maintaining the status quo (i.e. deciding that some limit of acceptable change has been reached), restoration or enhancement of function, or of allowing collapse. The choice between options depends on weighing the marginal gains and losses in relation to some limit.

Fig. 1. Relationship between thresholds and limits and different types of system response to environmental pressures (adapted from Haines-Young et al., 2006

Consider, for example, the problem of climate change, and the recent argument put forward that unless the level of emissions of green house gasses are curtailed, then *unacceptable* levels of damage to the economy may result. The limit being discussed is a warming of no more than 2°C. The interesting thing to note about this debate is that while physical scientists can point to a range of consequences that different levels of warming might have[6], ultimately the particular limits that will be agreed will emerge as a result of a socially negotiated process. This process will be conditioned, to a large measure, by different views people take about levels of risk, possible costs and ideas about the speed at which societies and economies can adjust to long term climate change.

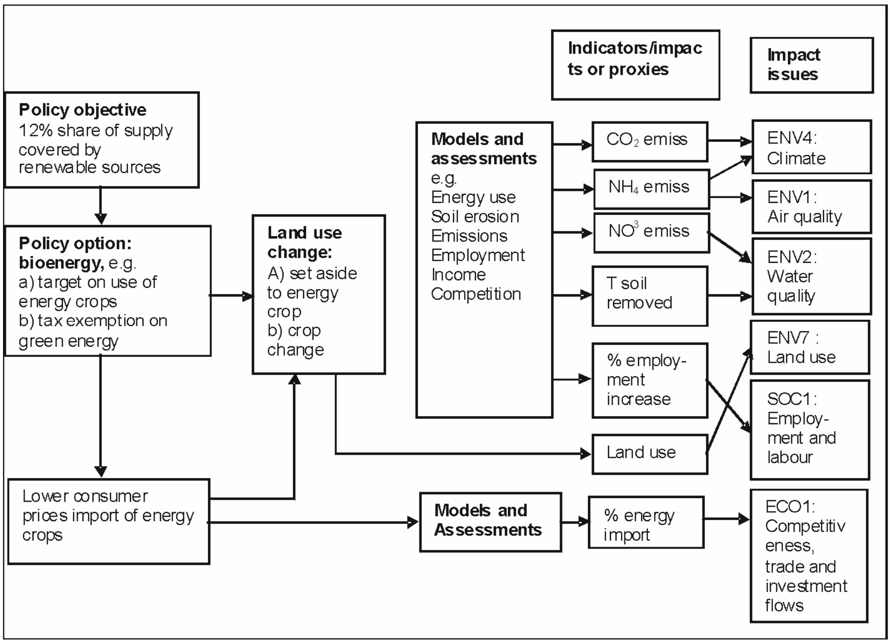


Fig. 2. Simple cause-effect model describing the potential impacts of biofuel policy options on a range of indicators and impact issues (after Frederiksen and Kristensen, 2008).

Alternatively, consider the scenario that significant land areas in Europe might be turned over to the production of biofuels. The consequences of different policy options can potentially be modelled[7], and outcomes char-

---

[6] Including the existence of possible threshold responses, such as the disruption of the north Atlantic conveyor, or the melting of the Greenland Ice Sheet.

[7] See also Kuhlman et al. (2008), and SENSOR indicator framework, and methods for aggregation/dis-aggregation – a guideline,

acterised and compared in terms of the implications that different levels of biofuel production might have for a range of economic, social and environmental indicators (Figure 2). Faced with different scenarios - what factors constrain our possible policy choices? Once again it is the judgements we make in partnership with experts and stakeholder groups, about whether, for particular indicators, critical limits are breached and how we might prioritise issues if trade-offs between costs and benefits have to be considered.

Sustainability impact assessments are difficult not only because they force us to compare things that are not easily compared, but also because they are multi-dimensional. In making assessments we have to take account of many different types of limit, most of which cannot be fixed *a priori*. The discussion, identification and setting of limits is, it seems, part of the 'democratisation of the knowledge' that many now see as an essential element of contemporary scientific and policy debates.

4 Multi-dimensional decision making: The Sustainability Choice Space

The identification of limits across the three pillars of sustainability is important because these limits constrain our policy choices. In the context of projects like SENSOR, the goal of comparing policy options through sustainability assessment is not to discover some optimal solution, but to find strategies that are sufficient or adequate, in terms of maintaining over time the benefits that land use systems can provide. We can visualise the process in terms of the model described in Figure 3, which illustrates the idea of a sustainability choice space in relation to different trajectories of land use change.

The goal of SENSOR is to provide a set of tools that can be used to evaluate the impacts of policy decisions as they are expressed through changes in land use.

The approach adopted involves identifying a set of economic, social and environmental indicators linked to land use, which allow us to trace the consequences of different policy options. The fundamental assumption is that land use change is the key driver.

---

http://lis4.zalf.de/home_sensor/upload/modul1/Reporting%20Deliverables/Deliverables%20Module%205/SENSOR_del_5.2.2_with_annexcomplete.pdf

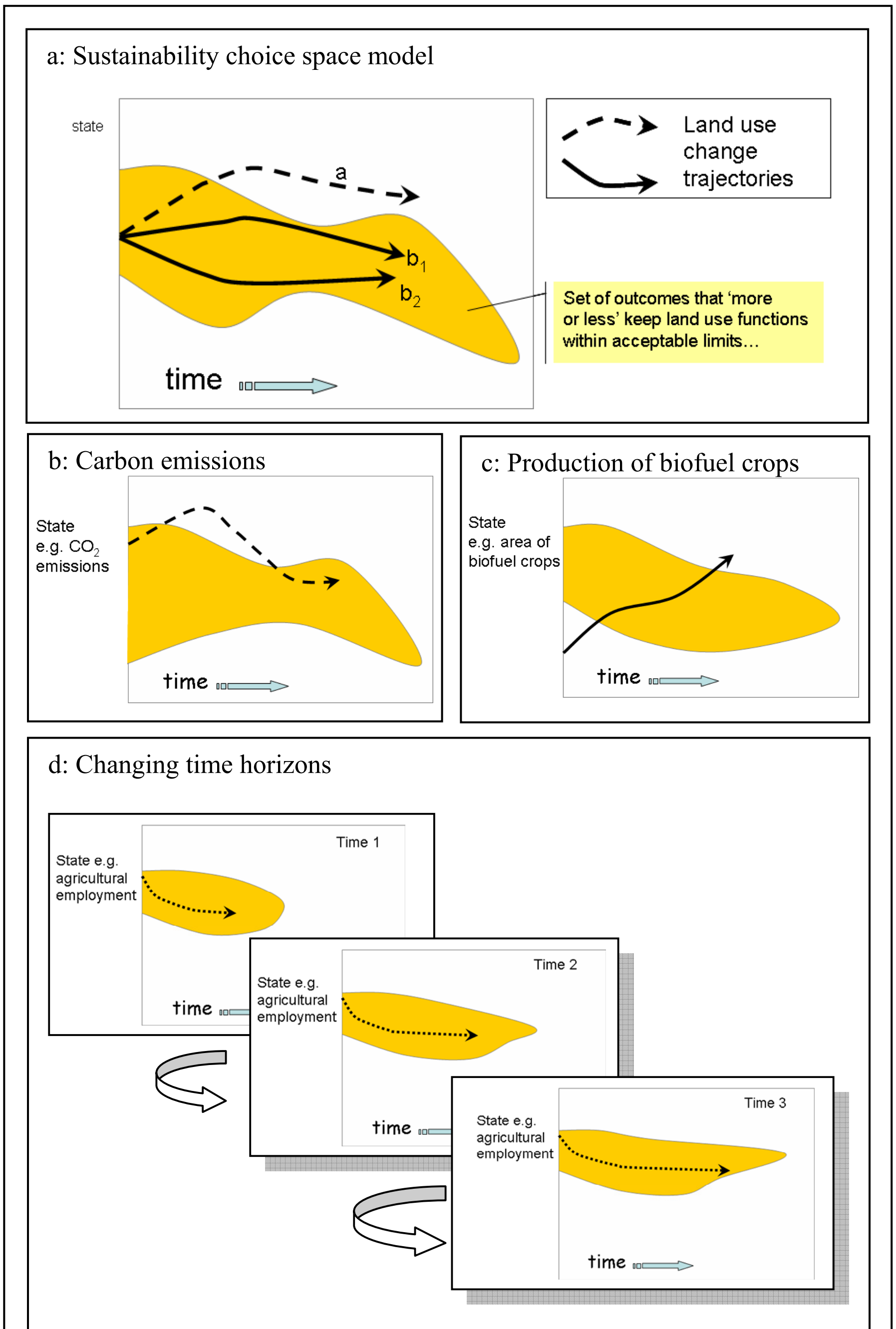


Fig. 3. The Concept of the Sustainability Choice Space

Thus in the simplest case we could characterise the dynamics of the system that we are interested in by a single indicator[8] that reflects these land use changes, such as ‘CO_2 emissions or ‘the area of biofuel crops’.

For those concerned with assessing the implications of some policy measure the key question is whether the land use trajectory is likely to take us out of the region beyond which some critical limit is reached for the indicator that we are interested in. We suggest that this critical region can profitably been seen as the ***sustainability choice space***, in that it expresses the room that we have for manoeuvre in designing our different policy options. If current land use trajectories are likely to take us outside the critical region then we can ask questions about what types or level of policy intervention might bring us back within limits (Figure 3, trajectory a). If we perceive that in the future our views of limits might need to be changed, then we might ask what options there are for ensuring that future trajectories continue to sustain the level of benefits we currently enjoy (Figure 3, trajectory b_1 and b_2). In Figure 3, since trajectories b_1 and b_2 are likely to keep us within acceptable limits then both can be regarded as ‘adequate’ or ‘sufficient’ in sustainability terms. The decision between them is essentially a matter of social or political choice, and it is within this space that trade-offs between various types of benefits can be discussed.

The model shown in Figure 3a is simplistic, however, and several important features should be noted to see what insights it has for understanding real world situations.

First, the shape of the choice space can change over time. A sustainable trajectory of land use is one which maintains the output of the goods and services that are important to well-being. That is, it remains within the limits that society has identified, or agreed on, as significant. This is the issue that is being captured by the indicator. However, clearly the view that society has about limits can change, and so a trajectory that was once thought of as unproblematic can become so. The problem of CO_2 emission is a case in point (Figure 3b). Improved scientific knowledge now suggests that emission loads need to be significantly reduced - thus over time we can see that the choice space has been reduced in terms of the upper limits of emissions that are considered allowable. At the same time, there is probably a lower level of emission, below which the costs or risks of further carbon emission controls would probably outweigh the benefits. Again this may change with, say, changes in technology such as carbon storage. The

[8] In the case of SENSOR, a set of high level, aggregated indicators known as ‘land use functions’ (see Perez Soba et al., 2008), will be used to summarise the affects of different policy. The argument presented here applies whether we use a single indicator or an aggregated land use function.

point is, however, that there is scope for policy choices between these limits, and any informative sustainability assessment has to be framed around notions of where these limits lie.

The same point can be illustrated by reference to the biofuel case shown in Figure 3c. Here we start from the position that biofuel output is probably below what Society requires, given the need to reduce the consumption of fossil fuels. Thus while policy changes may stimulate the expansion of such crops, there is likely to be an upper limit to such an expansion in particular areas, beyond which the wider impacts of the new land use patterns become unacceptable. For example, given the need to sustain and enhance farmland bird populations, the replacement of traditional forms of arable farming with short rotation coppice, may conflict with this aim. Moreover, the expansion of large areas of woody crops may also impact on the visual and aesthetic qualities of landscapes. Once again views about what constitutes the upper and lower limits may change over time, and crucially may be contingent on the character of the particular landscape or set of landscape types that we are dealing with.

The second point to make about Figure 3 is that while the shape of the sustainability choice space may change over time, it is generally impossible to identify some 'ideal' or 'final' state. Thus in the figure, the choice space is 'closed off' – since the future is hidden. As time passes, however, the corridor defined by that we perceive limits 'opens up', as the future 'reveals' itself. This is illustrated by the example in Figure 3d, which has been constructed around the issue of 'agricultural abandonment'.

In many areas of Europe, agriculture is economically marginal, and land abandonment has become an important driver of land use change in these areas (Swaffield and Primdahl, 2006). In Figure 3d, the indicator used as a proxy for this process is the level of agricultural employment, which is shown to be declining slowly over time. At each time step, however, our view of the future may be different as our perspectives and understanding of economic, social and biophysical limits change. Thus a trajectory that was thought initially to be 'within tolerance limits' may eventually be judged to be 'unsustainable' if, for example, our notion of what constituted a minimum level of employment changed. This might arise, for example, as our views about the levels of rural population needed to maintain rural services changed, or as the result of increased concern about the risk of fires in landscapes that are undergoing succession back to woodland as a result of land abandonment.

The third point to note about the idea of a sustainability choice space is that although we may plot the state of the system in terms of a single indicator that reflects some aspect of the economic, social or environmental characteristics of the land use system, the notion of a limit helps us integrate thinking across the three pillars of sustainability in ways not easily achieved by current indicator approaches. The level of agricultural employment in rural areas (Figure 3d), for example, could be viewed as an economic indicator, but it clearly has environmental consequences, since it can affect a range of physical characteristics of an area. Withdrawal of farming may not only change risks associated with fires, for example, but also the visual properties of a landscape, which once gave it its 'sense of place'[9]. Similarly the limits associated with an environmental indicator such as CO_2 emissions are ultimately also determined by social and economic considerations that include the costs and risks associated with the sorts of investment that might need to be made to trigger particular land use changes (e.g. reduced input agriculture) on a sufficient scale to make a difference.

The final point to make about the model shown in Figure 3 is that in reality the choice space is multi-dimensional. Sustainability assessments need to take account of many factors, and these can be expressed in different ways. As we have seen, some aspects of 'multi-dimensionality' can be accommodated in the way limits are expressed. We have argued that judgements about what constitutes a limit generally bring together a range of economic, social and environmental issues. Thus the model shown in Figure 3 is in some sense already multi-dimensional - even though it focuses on a single indicator. The representation could be further enriched and extended by using some aggregated, or 'high level' indicator, such as the land use functions proposed by the SENSOR team. However, clearly the representation of the choice space could also be made even more comprehensive by including other indicators and the limits that apply to them as extra dimensions to the graph. Such multi-dimensional thinking is, of course difficult to represent, and we will consider the problems this poses for the design of policy assessment tools in the final section of this paper. At this stage it is important to note that in principle, thinking about limits in relation to some set of indicators can help policy customers understand how policy choices might be constrained, and ultimately what options are available, given the goals of sustainable development.

[9] What qualities for example make 'The English Lake District' or the 'Black Forest' so distinctive? What is the essence of 'Tuscanyshire' that makes it such a focus for recreation and holiday home development amongst the British?

5 Sustainability Choice Space: Case Studies

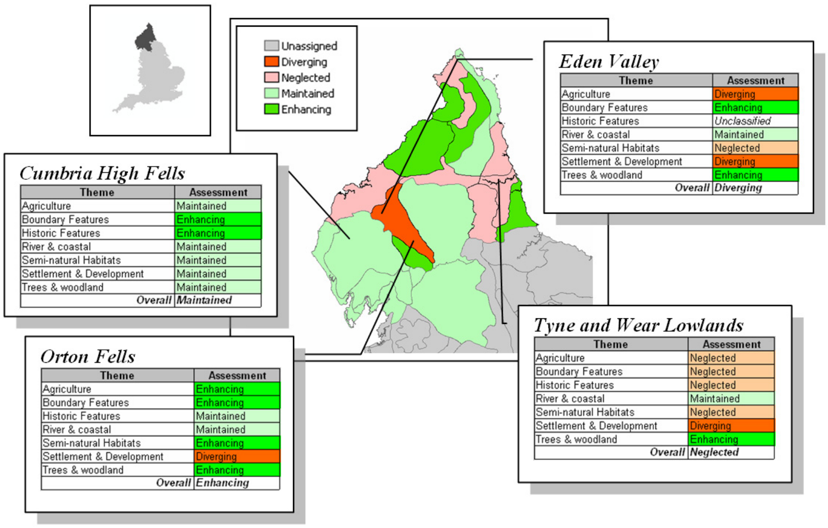
The idea of a sustainability choice space in relation to issues of land use change is relatively new, and has mainly been discussed in conceptual rather than practical terms (Potschin and Haines-Young, 2006). As an emerging idea, however, it has resonance with thinking in other discipline areas. In addition to the general debate about the need to live within limits noted in our introduction, the idea is analogous with concepts discussed in the literature on sustainable consumption and production, where concepts such as 'sustainability spaces' (Binder and Wiek, 2001), 'solution spaces for decision-making (Wiek and Binder, 2005), and 'sustainability corridors' (Bringezu, 2006), have been proposed as a way of looking at indicators and the messages they convey. In the more ecologically orientated literature, Kaine and Tozer (2005) have in the context of agricultural systems, attempted to conceptualise sustainability as a set of boundary conditions. These workers develop a 'pasture envelope' concept in the form of phase diagram in which the trajectories over time of key biophysical variables such as pasture biomass and composition are graphed against critical thresholds established on the basis of pasture growth rates and livestock growth requirements.

The idea of a 'sustainable trajectory' through some kind of choice space is also echoed by recent discussions in the sustainable development literature on 'transition management' (Wiek et al., 2006; Tukker and Binder, 2007; Kemp et al., 2005). Transition management is a general term that deals with issues of governance related to sustainability, and is proposed in the Netherlands as a way of replacing outcome-based planning with more adaptive and reflexive approaches. The concept represents sustainability as a process or journey, rather than some end point, and stresses the fact that strategies should 'not aim to realise a particular path at all costs' but rather to explore all promising paths 'in an adaptive manner' (Kemp et al. 2005, p. 25).

In terms of providing a practical example of the application of the idea of a choice space, the concept can be partly illustrated by reference to a recent study undertaken in the UK, which has dealt with the problem of land cover change and its impact on landscape character (Haines-Young et al., 2008) (Figure 4). This study, known as *Countryside Quality Counts* (CQC)[10], considered landscape character in terms of seven key themes: woodland, boundary features, agriculture, settlement, semi-natural cover, historic features and river and coastal elements. For each of the major landscapes in England, data showing how these elements were changing

[10] Project homepage: http://www.cqc.org.uk/

were compared to the visions which stakeholders had for these areas. The visions were used to identify the desired direction and scale of change for each of these elements, and a judgment was made about whether overall landscape character (i.e. local distinctiveness) was being maintained.



Notes:
This is an extract of the CQC Second Phase Assessment which has considered the impact of change on countryside character in England between 1998 and 2003. The spatial units are Joint Character Areas (JCAs) of England, which describe the major cultural landscapes at the mesoscale. The nature of change across the seven themes that define countryside character have been assessed in terms of whether those changes are maintaining or enhancing local distinctiveness, whether the changes are transforming the area, so that character is diverging from traditional patterns, or whether, if past change had eroded character, the area is stable but neglected. Although all of the JCAs in England have been assessed, only four contrasting areas from the north of England are shown here. The overall assessment for each JCA takes account of stakeholder views about countryside change and its implications for countryside character, and which of the seven themes are most important in terms of what defines the area's 'sense of place'.

Fig. 4. Representing change in countryside character in terms of a 'choice space'

Figure 4 shows the major landscapes of England that can be identified at the national scale. For each spatial unit an analysis has been made of how, for example, recent changes in woodland cover and woodland management, and patterns of agricultural land use relate to targets that local stakeholders have identified as appropriate in terms of sustaining the landscape character of each area. An expert-led judgment has been made about the scale and direction of change in relation to the information supplied by stakeholders. Thus each landscape area has been assigned to one of a number of categories depending on how they are changing across all seven landscape themes considered. If the landscape character of an area is largely intact, then depending on the magnitude of change, each area is classified as being maintained or restored (enhanced). Alternatively, if in the past the character of the area had been eroded, and there is little recent evidence of change that would tend to restore it, then the area is described as neglected. Finally, if the area is changing in ways that are inconsistent with its traditional character, then the area is classified as diverging.

The analysis made in *Countryside Quality Counts* differs from that which will be attempted in SENSOR, in that it has not been designed to model the possible consequences of different policy options. Rather the purpose of *CQC* was to trace the outcomes of existing policy measures that have impacted on the rural landscapes of England. Nevertheless, the study does illustrate something of the sustainability choice space concept, in that it shows how, through consultation with stakeholders, the issues that matter in terms of sustaining the quality of different landscapes can be identified, and sustainability limits defined. These limits have been used to assess patterns of change for each of the seven landscape themes, represented by a set of indicators, such as ‘woodland cover’, or ‘area under agri-environment agreements’, and to determine whether certain critical limits have been crossed. These limits have then been used to make a judgment about whether changes in a set of indicators describing the characteristics of specific geographical areas lie outside this ‘socially negotiated’ suite of boundary conditions.In this way the project has been able to answer the type of question that eventually SENSOR will have to consider, namely ‘where is land cover change occurring?’ and ‘do those changes matter?’

6 SIAT and the Sustainability Choice Space

In the final part of this chapter we turn from the general issues surrounding the sustainability choice space concept to look at the specific problems associated with implementing it as part of SENSOR’s sustainability impact assessment toolkit.

In terms of providing information that can be used by policy customers, the practical problem faced in designing SIAT is how to move from a set of spatially disaggregated indicators describing the modelled consequences of land use change, to some integrated view that can help users to make a sustainability assessment. In order to ensure the greatest flexibility of the interface, it is likely that a range of information handling tools will be provided.

The early SIAT prototypes[11] have shown how users can be given access to real and modelled trajectories for a range of individual social, economic and environmental indicators at 'NUTSx' level (Petit et al., 2008). In addition to providing metadata for each indicator, the system will be designed to inform users about any limits that are associated with particular indicators, and thus begin to provide them with the types of information that can help them explore the implications of a particular policy case or option. As a general principle, users should clearly have access to the most disaggregated information that is available. However, for such a potentially large and diverse body of information to be useful in decision-making, tools to help users summarise the information would also be valuable.

The proposal that individual indicators can be grouped into a set of nine broad 'land use functions' (see Perez-Soba et al., 2008) is a first step in this data aggregation process. These functions can be used to see how in a more integrated sense, the changes in individual indicators might impact on the wider aspects of human well-being and the environment. In order to interpret what changes in these functions mean, it is recognised that some understanding of context is important. Thus work has been initiated using expert-based knowledge to identify limits for both the individual indicators and the aggregated land use functions for a set of 30 'Cluster Regions' across Europe (see Renetzeder et al., 2008), and to construct profiles describing the sustainability issues that are important within each region.

Implementation of the sustainability choice space concept will add a further dimension to this 'layering' of information in SIAT. As things stand by working with individual indicators and aggregated land use functions, the policy customer will gain insights into the potential impacts of particular policy options. A more rounded sustainability impact assessment will require a systematic comparison between various policy scenarios. In particular, users will need to develop an understanding of the ***sensitivity*** of the outcomes to different input assumptions, and the key points where different policy options may deliver different results. It is proposed that this type of analysis can best be provided using the sustainability choice space concept.

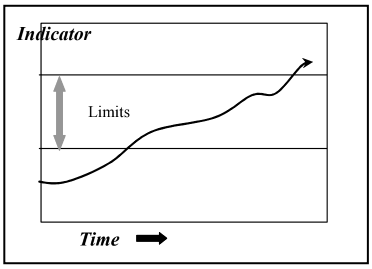
---

[11] See www.sensor-ip.eu

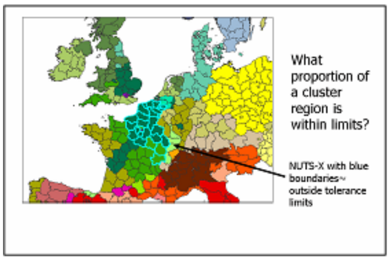
Figure 5 provides an illustration of how the idea of a sustainability choice space can be implemented as part of SIAT. Although the ideas have been framed around the specific needs of SENSOR, the issues are sufficiently generic to be of interest to those building other types of decision support system. The most important design requirements are that SIAT should:

- Allow users to identify those geographical areas that are most sensitive to particular policy scenarios, in the sense that projected policy outcomes potentially lie beyond specified economic, social and environmental limits, and to understand how outcomes differ ***between*** different policy scenarios. In this way the policy customer would be able to build up an understanding of the 'core' areas which might be impacted under any of the different policy options, and those where outcomes were more dependent on the policy choices made. The contextual information provided at Cluster Region level should be designed to help users understand what the key sustainability issues are in different areas, at least at the land use function level. For example, users should be able to compare the outcomes of the run of SIAT for the biofuel policy case, with assumptions of different world oil prices, and identify which areas are most likely to impacted under any circumstances, and which areas are more 'marginal', being sensitive to only particular sets of modelled assumptions.
- Allow users to identify how and where the broad impacts of different policy scenarios differ in terms of which indicator subsets or land use functions are affected and potentially driven outside specified limits. For example, it may be the case that under a given scenario one geographical region may mainly be affected by rising unemployment, while in another environmental damage might be an issue. The policy customer will need to understand where the 'pressure' points are for a particular scenario across the 'three pillars' and what policy choices are potentially available to resolve them.
- Allow users to look at any potential 'trade-offs' that appear to exist in a given geographical area or set of areas, in the sense that one particular policy scenario might affect the suite of indicators or land use functions in one way, while a second policy scenario might affect them in another. For example, users should be able to consider the outcomes of the biofuel policy case under assumptions of different levels of economic growth, and identify those situations where, say, growth in jobs might be offset by greater environmental damage, and those other areas where the reverse might occur.
- Finally, the system should allow the user to undertake all of the analyses suggested above 'dynamically', so that the trajectories of different

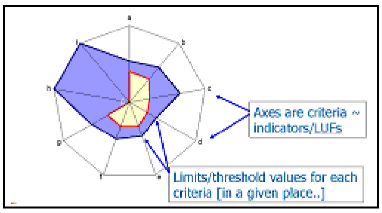
policy assumptions can be compared over ***time*** and space. For example, policy customers should be able to explore how differences between policy scenarios build up over time. If differences mainly only develop in the long term because of non-linearities, say, then given uncertainties the initial choice of policy option may not be so significant. Given the need to support decision making that is adaptive in character, policy customers should also be able to look at the effect of relaxing or changing particular constraints at some time in the future, to see if ‘corrective’ measures might be available should assumed trajectories not be realised.



The trajectories of individual indicators and/or land use functions can be plotted under different policy scenarios to determine the sensitivity of outcomes to different policy assumptions



At the NUTSx level, units where sustainability limits are exceeded for a given indicator or land use function can be highlighted. Limits may vary by cluster region (as indicated by the groups of coloured NUTSx unit). The proportion of units within a region that are sensitive to a given policy case can be used as a measure of the impact of a policy



Radar or spider diagrams can be used to show how outcomes impact across the set of land use functions (LUFs) for a given region and how limits differ for each of the elements. These diagrams can be animated to show how the situation changes over time.

Fig. 5. Implementing the Sustainability Choice Space Concept

The overall design requirement for SIAT, however, is that while the system attempts to map out the consequences of different policy assumptions, the user must not be misled into thinking there are ‘optimal solutions’ that can be identified by working with the system. The primary goal is to enable users to review the possible consequences of different policy assumptions and to understand how sensitive outcomes are on the basis of current knowledge. This issue is particularly acute in terms of the ways that ideas about economic, social and environmental limits are implemented and used within SIAT, and consideration of it brings us back once again to the question of how 'stakeholder knowledge' might be handled in SENSOR.

As Bertrand et al. (2008) have argued the specification of limits across the range of economic, social and environmental indicators that are included within SENSOR is a major task, involving many different types of uncertainty. While we have argued in this chapter that ultimately decisions about individual limits need to take account of all 'three pillars' and be grounded on an understanding of stakeholder values, practically this would be difficult to accomplish at European scales. Thus SENSOR may need to take an incremental approach.

The current work programme envisages that the specification of limits for indicators and land use functions will be based on 'expert knowledge'. This is a good starting point, but clearly the user must not be misled into believing these limits are 'definitive'. Thus at the most basic level SIAT users should be able to review what might happen if particular limits varied up or down by some margin - how would choices between policy options be affected? At the more sophisticated level, the policy customer would need to know how stakeholders might regard such limits and how their values might change them or affect the weighting between the different dimensions of well-being and environment captured by the land use functions. SENSOR is uniquely placed to explore this particularly important 'research frontier'.

A significant proportion of the resources supporting SENSOR have been given over to the analysis of stakeholder views and values (see Morris, 2008). This work can potentially give us insights about how, in particular geographical or problem contexts, people view the limits that 'experts' have suggested as being significant for individual indicators or the aggregated land use functions. Thus engagement with stakeholders can be used to help us understand how limiting values might need to be modified, and how trade-offs between the thematic areas covering the nine land use functions might be judged in different places. Engagement with stakeholders will also help us understand how *different groups* in society may vary in their responses. The 'contested' nature of economic, social and environmental limits needs to be conveyed in the design of SIAT.

While the primary goal of SIAT is to give an assessment of policies at pan-European scales, the availability of a rich body of information derived from stakeholders for particular areas and issues will allow the policy customer to explore how judgements may need to be modified where this richer body of information is available. The information gained from stakeholders through SENSOR for particular areas certainly ***cannot*** be extrapolated to other regions. However, the availability of such data can be used as part of the 'learning cycle' that both researchers and policy customers need to go through to move SIAT into the 'real world' where the 'democratisation of knowledge' is a pre-requisite.

By designing the SIAT in such as way that assumptions about limits can be examined, and values changed on the basis of expert and stakeholder views, a much richer and more flexible decision support environment can be created. If we can show how 'stakeholder views count' in particular places and for particular issues, future work may be initiated to extend the availability of this type of information to other geographical areas as part of a wider programme of stakeholder engagement.

7 Conclusions

Sustainability impact assessments are inherently difficult because they require policy advisors to compare things that are not easily compared. The concept of a sustainability choice space, however, provides a framework in which these complex types of judgements can be made. We have argued that decisions about the 'sustainability credentials' of different policy options do not depend on the search for optimal solutions. Rather, policy decisions are based on an understanding of the choices that we have available and the ways they are constrained by economic, social and environmental factors. If implemented within SENSOR, the sustainability choice space concept can lead to the development of a set of tools by which the different land use change trajectories can be compared, their impacts assessed, and the rationale used to make decisions set out in a more open and transparent way.

Acknowledgements

Parts of this study are funded by the following projects: EU 6th Framework Programme (SENSOR, 003874 GOCE), Natural England formerly Countryside Agency (CQC) and Department for Environment, Food and Rural Affairs (NR0102). The views expressed here are those of the author, and do not necessarily reflect the views of the funding agencies.

References

Bertrand N, Jones L, Hasler B, Omodei-Zorini L, Petit S, Contini C (2008) Limits and targets for a regional sustainability assessment: an interdisciplinary exploration of the threshold concept In: Helming K, Tabbush P, Perez-Soba M (eds) Sustainability impact assessment of land use changes. Springer, 405-424

Binder C, Wiek A (2001) Sustainability spaces: a new concept to evaluate development using indicator systems. Inaugural Conference for Industrial Ecology, Netherlands, November 12-14, 2001.

Bringezu S (2006) Materializing Policies fro Sustainable Use and Economy-wide Management of Resources: Biophysical Perspectives, Socio-Economic Options and a Dual Approach for the European Union. Wuppertal Papers No 160

Davidson C (2000) Economic Growth and the Environment: Alternatives to the Limits Paradigm. BioScience 50:433-440

Forman RTT (1995) Land Mosaics: The Ecology of Landscapes, and Regions. University Press, Cambridge

Frederiksen P, Kristensen P (2008) An indicators framework for analysing sustainability impacts of land use change In: Helming K, Tabbush P, Perez-Soba (eds) Sustainability impact assessment of land use changes. Springer, 293-304

Gallopín GC, Funtowicz S, O'Connor M, Ravetz J (2001) Science for the twenty-first century: from social contract to the science core. Int. Social Sci. J. 53 (2):219–229

Haines-Young R (2000) Sustainable development and sustainable, landscapes: defining a new paradigm for Landscape Ecology. Fennia 178 (1):7–14

Haines-Young R, Potschin M, Cheshire D (2006) Defining and identifying Environmental Limits for Sustainable Development. A Scoping Study. Final Full Technical Report to Defra, 103 pp + appendix 77 pp, Project Code NR0102. available from:
http://www.defra.gov.uk/wildlife-countryside/natres/evidence.htm

Haines-Young R, Langanke T & M. Potschin (2008) Landscape character as a framework for environmental assessment. – In: Petrosillo I., Müller, F., Jones K.B., Zurlini, G., Krauze K., Victorov, S., Li, B.-L. and Kepner G.W. (eds): *Use of Landscape Sciences for the Assessment of Environmental Security*. Springer, p. 165-174

Holling CS (1998) Two cultures of ecology. Conserv. Ecol. 2(2): 4 (online, available from the Internet. URL: http://www.consecol.org/vol2/iss2/art4, accessed 30.10.2006)

Kaine GW, Tozer PR (2005) Stability, resilience and sustainability in pasture-based grazing systems. Agricultural Systems 83: 27-48

Kates RW, Clark WC, Corell R, Hall JM, Jaeger CC, Lowe I, McCarthy JJ, Schellnhuber HJ, Bolin B, Dickson NM, Faucheux S, Gallopín G., Grübler A, Huntley B, Jäger J, Jodha NS, Kasperson RE, Mabogunje A, Matson P, Mooney H, Moore B III, O'Riordan T, Svedin U (2000) Sustainability science. Research and assessment systems for sustainability program. Discussion Paper 2000-33. Belfer Center for Science and International Affairs, Kennedy

School of Government, Harvard University, Cambridge MA. URL: http://ksgnotes1.harvard.edu/BCSIA/sust.nsf/pubs/pub7/$File/2000-33.pdf

Kates RW, Clark WC, Corell R, Hall JM, Jaeger CC, Lowe L, McCarthy JJ, Schellnhuber HJ, Bolin B, Dickson NM, Faucheux S, Gallopín GC, Grübler A, Huntley B, Jäger J, Jodha NS, Kasperson RE, Mabogunje A, Matson P, Mooney H, Moore III B, O'Riordan T, Svedin U (2001). Sustainability science. Science 292:641-642

Kemp R, Saeed P, Gibson RB (2005) Governance for sustainable development: moving from theory to practice. Int. J. Sustainable Development 8(1/2): 12-30

Kuhlman T (2008) Scenarios – driving forces and policies. In: Helming K, Tabbush P, Perez-Soba M (eds). Sustainability impact assessment of land use changes. Springer, 131-157

Lomberg B (1998) The Skeptical Environmentalist: Measuring the Real State of the World, Cambridge University Press: Cambridge

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being: A Framework for Assessment*. Island Press

Malthus T (1798) An Essay on the Principle of Population, as it Affects the Future Improvement of Society with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers. London, Printed For J. Johnson, In St. Paul's MEA, 2005. Ecosystems and Human Well being. Island Press. Millennium Assessment. http://www.maweb.org/

Meadows DH, Meadows DL, Randers J, Behrens WH III (1972) The Limits to Growth. Universe Books: New York

Morris J, Camilleri M, Moncada S (2008) Key sustainability issues in European sensitive areas – a participatory approach. In: Helming K, Tabbush P, Perez-Soba M (eds). Sustainability impact assessment of land use changes. Springer, 451-470

Perez-Soba M, Petit S, Jones L, Bertrand N, Briquel V, Omodei-Zorini L, Contini C, Helming K, Farrington J, Tinacci Mossello M, Wascher D, Kienast F, de Groot R (2008) Land use functions – a multifunctionality approach to assess the impacts of land use change on land use sustainability In: Helming K, Tabbush P, Perez-Soba M (eds). Sustainability impact assessment of land use changes. Springer, 375-404

Petit S, Vinther FP, Verkerk PJ, Firbank LG, Halberg N, Dalgaard T, Kjeldsen C, Lindner M, Zudin S (2008) Indicators for environmental impacts of land use changes. In: Helming K, Tabbush P, Pérez-Soba M (eds). Sustainability impact assessment of land use changes. Springer, 305-324

Potschin M, Haines-Young R. (2006) Rio+10, sustainability science and Landscape Ecology. Landscape and Urban Planning 75(3-4):162-174

Renetzeder C, van Eupen M, Mücher CA, Wrbka T (2008) Clustering Europe:A Spatial Regional Reference Framework for Sustainability Assessment. In: Helming K, Tabbush P, Perez-Soba M (eds). Sustainability impact assessment of land use changes. Springer, 249-268

Sagoff M (1995) Carrying capacity and ecological economics. BioScience 45:610–620

Sartorius C (2006) Second-order sustainability – conditions for the development of sustainable innovations in a dynamic environment. Ecological Economics 58:268-286

Swaffield S, Primdahl J (2006) Spatial concepts in landscape analysis and policy: some implications of globalisation. Landscape ecology, 21:315-331

Scheffer M, Carpenter S, Foley JA, Folke C, Walker B (2001) Catastrophic shifts in ecosystems. Nature 413:591-596

Scheffer M, Carpenter SR (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. Trends in Ecology and Evolution 18(12):648-656

Scheffer M, Szabo S, Gragnani A, van Nes EH, Rinaldi S, Kautsky N, Norberg J, Roijackers RMM, Franken JRM (2003) Floating plant dominance as a stable state. Proceedings of the National Academy of Sciences of the United States of America 100(7):4040-4045

Tukker A, Binder M (2007) Governance of sustainable transitions: about the 4(0) ways to change the world. Journal of Cleaner Production 15:94-103

Walker B, Meyers JA (2004) Thresholds in Ecological and Social–Ecological Systems: a Developing Database. Ecology and Society 9(2):3 [Online]

Wiek A, Binder C (2005) Solution spaces for decision making – a sustainability assessment tool for city-regions. Environmental Impact Assessment Review 25: 589-608

Wiek A, Binder C, Scholz RW (2006) Functions of scenarios in transition processes. Futures 38 (2006) 740–766