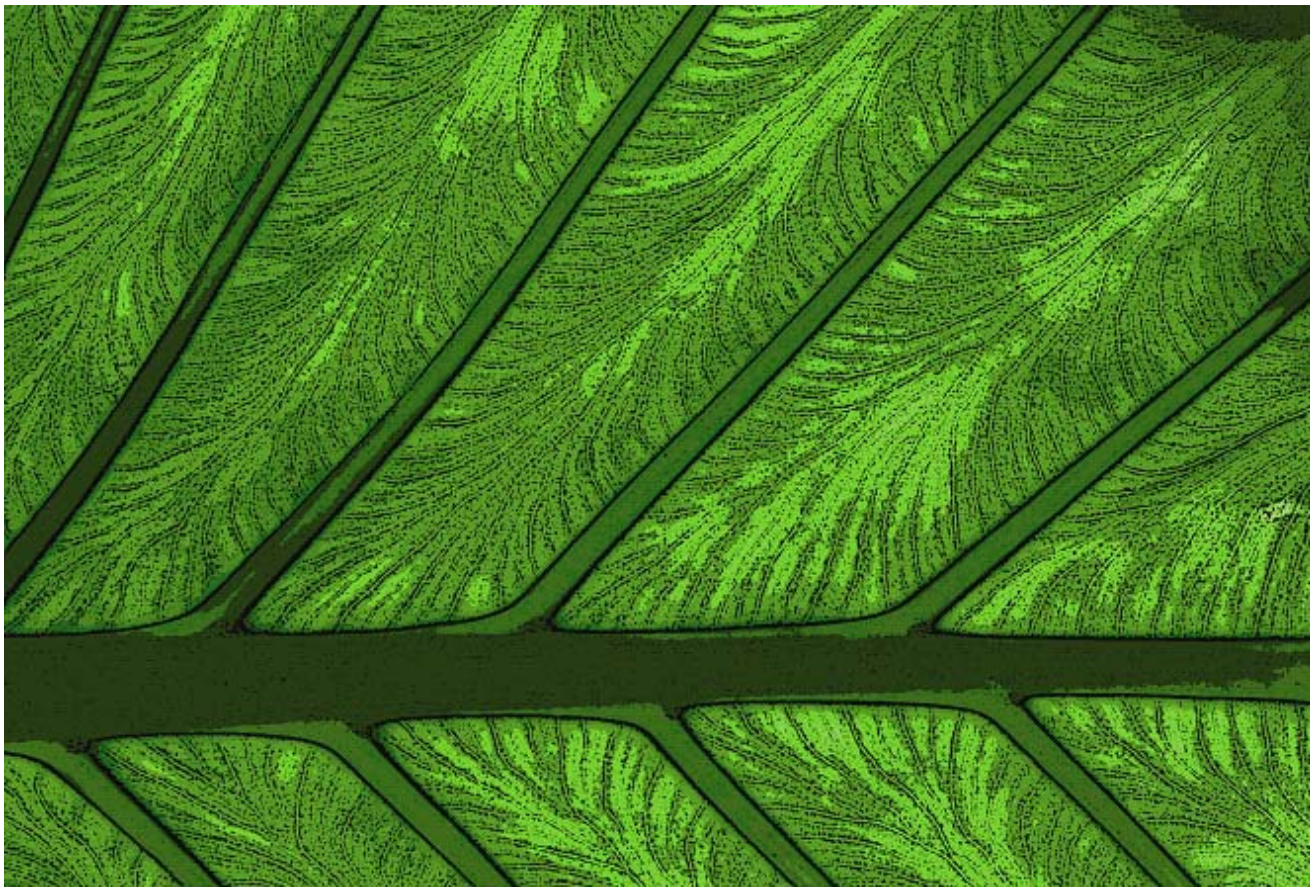
The Resilience of Ecosystems to Environmental Change (RECCE)

Funded by

defra
Department for Environment Food and Rural Affairs



Overview Report

The University of Nottingham

CEM
Centre for Environmental Management

CEM Report No 17

Project Team:

www.nottingham.ac.uk/CEM www.eci.ox.ac.uk/

Project funded by

Project code: NR0134

Notes:

This document reflects the views of the authors and not those of Defra.

If you use parts of chapters only – please quote the individual chapters. If you use this document please quote as:

Haines-Young, R. and M. Potschin (2010) (Eds): The Resilience of Ecosystems to Environmental Change (*RECCE*). Overview Report, 27 pp.
Defra Project Code: NR0134.

Project Coordinator:

Prof. Roy Haines-Young, CEM, School of Geography, University of Nottingham, Nottingham NG7 2RD.

Contact for Project Team: Marion.Potschin@Nottingham.ac.uk

Defra Project Manager:

Giles Golshetti, Natural Environment Strategy Unit, Defra, Area 3D Nobel House, 17 Smith Square, London SW1P 3JR, email: Giles.Golshetti@defra.gsi.gov.uk #

Content

Executive Summary

Background

1. If we are to live with environmental change, then we need to understand the limits of ecosystem functioning so that we can sustain them in the face of increasing human pressure. The identification of such limits is dependent upon knowing how ecosystems react to and buffer external pressures and how well ecosystems recover if they are damaged. The ability of ecosystems to withstand disturbance or to recover from them is generally referred to as 'resilience'. This study aims to provide a critical examination of what is currently known about ecosystem resilience and how that knowledge can be used by the UK to 'secure a healthy natural environment for today and the future'.

Approach

2. The study seeks to apply the methods of a systematic review to this broad question and reflect upon the effectiveness of these techniques, given the different meanings that can be ascribed to the notion of resilience. The difficulties of working with the resilience concept in the context of making a systematic review were noted, and a broader strategy 'knowledge mapping' was proposed as a way of achieving the project aims.

3. An initial scoping phase involving the Project Steering Group, Subject Expert and Policy Advisors identified a set of broad topic areas and focal questions within which resilience thinking might be explored. This resulted in the production of four stand-alone studies that examined the resilience concept in relation to: soils, biodiversity, water and air quality. Within each topic area the aim has been to look at the dynamics of ecological systems and to explore:

   (a) what is known about the way the resilience of systems might be impacted by climate change; and

   (b) how policy or management interventions could mitigate potentially damaging effects. In each topic area the goal was to refine a set of questions that could be addressed using systematic review methods.

Outcomes

4. Each of the four sets of review activities was designed primarily to examine the extent to which resilience concepts had been used in the different topic areas, and whether, therefore there was a significant body of evidence that could support the use of the concept in policy debates. In reviewing these materials it should be noted that the search and review processes described below were **not** designed to produce full systematic reviews of the impacts of climate change on ecosystems when viewed through the lenses of soils, biodiversity, water and air quality. Rather the purpose of the work to critically examine if and how 'resilience thinking' had been applied.

Soils

5. For soils the review looked at the intersection of the literatures on the relationship between soil resilience and climate and soil resilience and management to explore the question:

   Can soil management enhance, restore or protect the resilience or resistance properties of soils, given the likely impacts of climate change?

   Although the question is an open-framed one, not ideally suited to a systematic review, the study had identified a number of important insights. These can be summarised as follows:

   a) There is good evidence to suggest that a number of key soil properties linked to soil carbon are vulnerable to soil warming, and that increasing temperatures could lead to reduced levels of carbon stored in the soil; this conclusion is supported by existing, published meta-analyses.

   b) While there is considerable uncertainty as to whether increased soil respiration under a warmer climate will lead to a net, global transfer of carbon to the atmosphere, there is good evidence to suggest that in localities where there is a loss of soil carbon soil quality would be reduced, making them potentially vulnerable to extreme events and physical disturbances.

   c) There is evidence that management interventions can increase the resilience of soils to disturbance by increasing soil carbon content and enhancing soil structure; it has been argued management practices based on 'reduced' or 'conservation' tillage, particularly effective in this regard, but recent work appears to question this conclusion.

   d) There is good evidence that as soil carbon levels are increased, there is a saturation effect, and that while the benefits of improved soils quality would persist, the strength of the carbon sink provided by soils would diminish.

   e) There is limited evidence as to the economic benefits of investing in soil management from a resilience perspective.

6. Thus in terms of the review question for soils it can be concluded that there is good evidence to support the assertion that soil management can enhance, restore or protect the resilience or resistance properties of soils, given the likely impacts of climate change. However, the economic benefits of maintaining or enhancing soil resilience in the face of climate change cannot be easily estimated.

7. Although the review identified a number of issues relevant to the discussion of resilience within the context of soils, it was felt that the volume and coverage of material was insufficient to proceed with a full systematic review. Nevertheless it was clear that there is a good body of work within the soils domain that could be used to underpin the use of the resilience concept in policy debates.

Biodiversity

8. Two related questions formed the basis for the review of biodiversity and resilience:

   Can management interventions mitigate the impact of environmental change on biodiversity characteristics of UK Broad Habitats?

   How resilient are the biodiversity characteristics of the UK Broad Habitats to environmental change?

9. The review was complex and potentially wide-ranging. To give some added focus to the work more the notion of 'environmental change' was interpreted more narrowly as potential future climate impacts.

10. The analysis of papers selected using the search protocols suggested that there appeared to be only a limited body of material that could be used to address these questions; little of it explicitly used the resilience concept explicitly. It was concluded that this situation probably does not reflect the level or kinds of research being carried in the UK (or elsewhere), but rather, that it is premature for studies on the efficacy of (adaptation) management strategies governing the mitigation of biodiversity impacts to be measured. In essence the review question poses an issue that the body of current research is unable to resolve. The expert opinion that we gained during the scoping process suggested that since climate change impact research is focused on future changes, most of the empirical data would be either modelling or experimental, a pattern that has been shown in this review.

Water

11. For water two questions formed the basis of the review:

    Can management interventions mitigate the impacts of environmental change on the water regulating characteristics of ecosystems? And

    How resilient are the water regulating characteristics of ecosystems to environmental change?

    As in the case for biodiversity the topics also proved to be complex ones which did not easily lend themselves to a full systematic review. The reasons were as follows:

    a) While there were a number of studies investigating the impacts of climate change on aspects of hydrology, many of them did not contain either the necessary ecological or the management component to make an analysis of their responses to environmental change.

    b) Not all studies had the necessary climate change component, or, as with historical studies, did not provide sufficient measures for assessing the effect of any management intervention.

12. The questions posed in this component of the study are, however, important to the future management of water resources, but it appears that research is currently unable to provide a clear, quantifiable answer at this stage in terms of questions about resilience. The reviewers concluded that a more flexible search approach to the question could have helped, as there does appear to be a body of research looking at management impacts (especially deforestation)

on hydrological parameters relevant to water regulating services (both quantity and quality), which were not captured for the final analysis because of their lack of an explicit (as opposed to inferential) climate change component.

Air quality

13. The question identified in this topic area was:

    How resilient are England's major ecosystems to changes in air quality and how might this change under future climates?

    Secondary issues considered in the analysis concerned the extent to which management interventions might mitigate these effects, and to what extent the impacts on economic values had been considered in the recent literature.

14. Given the rather general character of the review question, it was decided to develop more focused analyses around a limited number of important or potentially important air quality issues: ozone; and nitrogen and sulphur deposition, and acidification effects. The analysis looked at the evidence for current impacts and any work that gave insights into how these impacts might change under future climatic conditions. The results can be summarised as follows:

    a) There is good evidence to suggest that currently exposure to ozone can impact at the individual and habitat levels. Although species vary in their responses to elevated ozone levels, changes in growth patterns and reproductive performance can shift the competitive balance within communities, potentially resulting in biodiversity loss. The evidence for habitat level transformation is more extensive for grassland communities, although effects on growth and performance have been detected in forests. The evidence linking the effects of ozone exposure to components of climate change is more limited, but it seems to indicate that elevated concentrations CO_2 increase the damaging effects of ozone rather than offsetting them.

    b) There is a considerable body of evidence that atmospheric inputs of nitrogen and sulphur can have chronic effects on vegetation, soils and drainage waters. Effects have been detected at sub critical-load concentrations, and can result in significant community level changes. However, the body of that is relevant to the question of how air quality impacts would change under future climates or how management interventions might mitigate those impacts is more limited.

    c) Similarly, while there is a considerable body of evidence to suggest that acidification has modified ecosystem structure and function, fewer studies have considered how these effects might be modified under future climatic conditions or what factors control the extent and speed of recovery.

15. Given that the search protocols were mainly designed to examine how resilience concepts are reflected in the literature it is likely that the materials identified do not fully reflect the current 'state of the art' in relation to air quality and climate change impacts. However the range of materials probably are sufficient to draw some conclusions about the resonances between this

body of literature and more general notions of resilience. In this context, the key conclusion that can be drawn from the analysis of material on for air is that as a theoretical construct resilience is not widely applied in this segment of the literature. In the main, the work related to air quality looked at sensitivities in the form of dose-response relationships, critical limits and interactions between different drivers, and there appears to be much less attention to the dynamics of recovery, or threshold effects in the form of regime shifts. This is not to say such patterns of response cannot be imputed from the work, but rather that this kind of conceptual framework is missing from this literature.

Conclusions

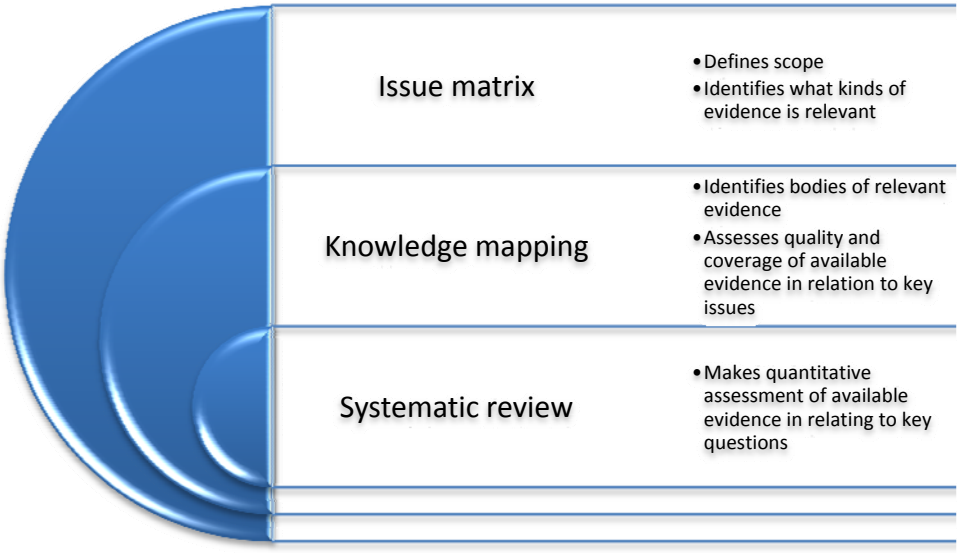
16. Although the aspiration of using systematic review to make an analysis of ecosystem resilience, climate change and management interventions was not realised in this study, the work has provided some insights into how such an investigation might be carried taken forward. The conclusions may be summarised in relation to the substantive scientific questions that surround the concept of resilience and the more general use of systematic review methods to explore complex 'open-framed' questions.

17. Although resilience as a general concept is widely discussed in the literature, there is limited consensus about how it can be assessed or characterised. However, in terms of specific types of ecosystem dynamic, the resistance of ecosystems to disturbance and their speed of recovery following some disruptive event are both highlighted as components of resilience. While both these ecosystem characteristics are in principle measurable, other attributes such as the capacity of ecosystems to transform and adapt in the face of environmental change are more difficult to operationalise.

18. There were considerable differences in the extent to which resilience thinking had been taken up in the four topic areas considered in this study. In some areas (e.g. soils) the concept was used explicitly, in other (e.g. air quality impacts) it was less so. This feature made the identification and extraction of evidence across the topic areas difficult. Measures or resilience based on the resistance of systems to disturbance and speed of recovery were useful to identify material that was implicitly relevant to the overarching question of resilience, but this linkage was often based on judgement rather than the tight search protocols usually required in systematic review. **In each of the four topic areas we therefore concluded that there was probably insufficient material available to make either full systematic reviews or smaller targeted analyses. However, it was apparent that the more informal review process carried out was valuable in mapping out some of the key questions that have to be addressed in order to form some understanding of ecosystem resilience, climate change and management.**

19. The study therefore moved on to look critically at how systematic review might be used to explore complex open-framed questions like those that surround resilience. It was concluded that while the idea of knowledge mapping as suggested by a systematic review is a useful one, as a device to help make review questions more specific it also needed to be used in conjunction with other framing devices. The idea of an 'issue matrix' or 'issues mapping' was proposed and described, and it relationship to the systematic review process considered (Fig.1).

Figure 1: Relationships between issue and knowledge mapping and systematic review.



20. When contemplating the requirements of a systematic review, the 'situational logic' suggests a reductionist approach, in which perspectives are gradually refined and focused so that precise questions can be asked. Although knowledge mapping may help this process, our experience indicates that it cannot simply be viewed as a means of identifying where effort might subsequently be directed without any regard as to how the results of those individual reviews would contribute to some overall conclusion. We conclude that the process of issue mapping, involving dialogue between policy and topic experts, provides a framework in which this could be done in an efficient and transparent way. We provide an outline of how the investigation of ecosystem resilience is to be taken further by Defra using the outputs of this study.

21. Defra's *Action Plan* for embedding an Ecosystems Approach in decision making emphasises that adaptive management involves consultation and the co-construction of knowledge, as well as making the use of the best evidence available. The recommendations we have made about the construction of an issue matrix are clearly consistent with this idea. The experience gained in this study has provided some pointers as to how this can be taken forward by combining the focused methods of systematic review, with more open-ended deliberative approaches designed to better understand how broad, normative policy concerns can be translated into manageable review questions.

Acknowledgements

We are grateful to Defra's Natural Environment Strategic Unit (NESU), and especially Giles Golshetti as NESU Project Manager, for guiding us through this project in a professional but also encouraging and calm way.

We are also grateful to those on the Project Steering Group for their valuable discussion of the issues:

- Dr Robert Bradburne (Defra, Head of Ecosystems Team – Natural Environment Strategic Unit)
- Dr Peter Costigan (Defra, Head of Natural Environment Science)
- Giles Golshetti (Evidence manager – Natural Environment Strategic Unit)
- Dr Mike Morecroft (Natural England – Climate Change)
- James Vause (Defra, Natural Environment Economics team)

During the scoping phase we ran an e-Forum to consult on draft questions and on our search strategy (see: www.recce.org.uk). We thank those who provided input. Defra's policy advisors also reflected on policy questions and search terms that we generated, and we hope we have reflected those comments sufficiently well.

We also interviewed a number of experts during the scoping and final phases of the project, and are grateful to the following people for their constructive comments on the draft version of the final report:

- Prof. Nigel Bell, Imperial College
- Dr Will Cook, Defra
- Dr Linda Davies, Imperial College
- Dr Deanna Donnovan, JNCC
- Prof Jim Harris, Cranfield University
- Prof. Kurt Jax, UFZ/Germany
- Dr Harriet Orr, Environment Agency
- Dr Judith Stuart, Defra
- Dr Allan Watts, CEH Edinburgh

1. Introduction

By Roy Haines-Young, Marion Potschin and Pam Berry

Living with environmental change poses a number of management and policy challenges. We need, for example, to understand how resistant ecosystems are in terms of buffering the impact of external pressures. We also need to know if they can recover from disturbances to their functioning. Finally, we need some understanding of the dynamics that ecosystems might exhibit in the future as a result of changes in external conditions, such as those related to climate, pollution loads or land management practices. Collectively the issues of ecosystem resistance and recovery have been addressed in the discussions surrounding the idea of 'resilience'.

The importance of the debate about resilience has been highlighted by recent initiatives such as the Millennium Ecosystem Assessment (MA), which showed how the well-being of people is linked to biodiversity (MA, 2005). The MA concluded that globally ecosystems are experiencing growing external pressures from drivers such as climate change, land use change, pollution and invasive species, which will impact on the functioning of ecosystems and on the provision of ecosystem services (Defra, 2007). In the wider research and policy literatures there is growing concern that losses in biodiversity may lower resilience to and/or recovery from disturbances (e.g. Loreau et al., 2002), although the relationship is yet to be confirmed. However the evidence that biodiversity and resilience are closely linked is growing. Thus Isbell et al. (2009) have shown that species richness and more diverse patterns of species interactions can promote ecosystem stability and thus sustain the output of ecosystem services.

1.1 Study aims and objectives

The aim of RECCE (The Resilience of ECosystems to Environmental ChangE) has been to undertake a review of resilience and how it relates to key policy areas of concern to Defra and its partners. The goal has been to better understand how policy action might help to sustain ecosystems in the face of environmental change or to protect the capacity of ecosystems to recover following disturbance. Thus the work has sought to take stock of the scientific, management and policy literatures on this topic, and assess the robustness of the current evidence base that could be used to frame policy and management responses. For details of the initial brief see Appendix 1. The work has also provided the opportunity of reflecting upon the appropriateness of the systematic review process when confronted with such a wide ranging topic as resilience.

The objectives of the study were as follows:

i. To work with Defra and other research partners to plan and refine the policy relevant questions and sub-questions relating to ecosystem resilience;
ii. To develop and test search appropriate protocols that will allow the published and grey literatures relating to the focal questions to be reviewed systematically;
iii. To identify a set of suitable publications for inclusion in the review, using clear and transparent inclusion criteria;
iv. To extract and analyse the key results from the selected reference base, and to synthesise the main conclusions and the strength of the evidence that underpins them; and,

v. To provide a commentary on the results of the study and its policy implications, and an assessment of apparent evidence gaps and the kinds of research that might be needed to resolve them.

1.2 Framing Notions of Resilience

The analysis of ecosystem resilience is challenging because there is considerable divergence in the way the concept of resilience has been framed. Moreover, since it is often discussed conceptually as a 'whole systems' property, it is often difficult to relate more focused empirical studies of individual ecosystem properties to the dynamics of entire ecosystems. Nevertheless, given present concerns that losses in biodiversity may lower the resistance of ecosystems to disturbances or their ability to recovery from external impacts (e.g. Loreau et al., 2002), it is important to examine what is known about what kinds of factors might enhance system stability and how policy or management intervention might help secure greater resilience to external pressures.

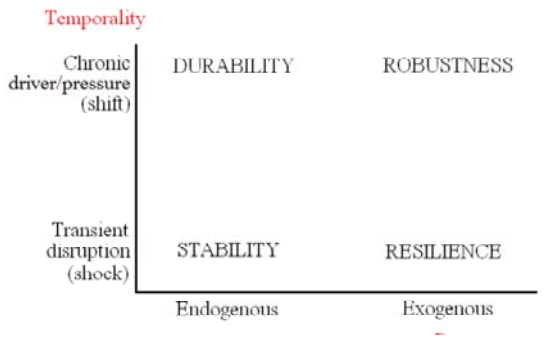
Brand and Jax (2007) provide a useful review of the different meanings ascribed to the term. They contrast usage in the ecological literature, with that from the social sciences, and then trace the evolution of a more hybrid concept that deals with problems at the interface between people and nature. Holling (1973) initially proposed the idea as a 'measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables'. Brand and Jax (2007) suggest that this formulation has been refined by subsequent work, especially that of Folke et al. (2002), Gunderson and Holling (2002) and Walker and Pearson (2007). Thus the term is now used to refer to two distinct ideas, namely:

- The magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour; and,
- The capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity.

However, there has also been some enlargement of the concept, and several other themes have been linked to discussions of resilience. For example, Janssen and Ostrom (2006) and Janssen (2007) have looked at the commonalities between three research domains concerned with the human dimensions of environmental change: resilience, vulnerability and adaptation. They found that not only have the number of publications referring to these concepts increased rapidly, but also that there is a growing overlap between them.

A further enlargement of the concept is also provided by Dawson et al. (2010) (Figure 1.1) who identify four distinct dynamic properties of ecosystems, based on the extent to which disturbance is transient or chronic and whether it is external (exogenous) or internal (endogenous) to the system. For them, resilience concerns the response of ecosystems to external shocks and must be looked at alongside other

Figure 1.1: Dynamic system properties defined according to temporal characteristics and provenance (after Dawson et al., 2010)



dynamics, namely durability, robustness and stability.

Yet greater complexity has been introduced into the resilience debate by the fact that while some commentators confine their attention to the biophysical aspects of ecosystems, others focus on the resilience of coupled social and ecological systems. Brand and Jax (2007) suggest that when used broadly to refer to social, political and ecological characteristics of ecosystems or desirable goals of ecosystem management, the term 'socio-ecological resilience' might be used. When used in a more 'scientific' context, they argue that its meaning must be tighter. Thus following Carpenter et al. (2001) and Cummings et al. (2005) they advise that when speaking about 'ecosystem resilience' or 'ecological resilience' we must be clear about what kind of ecosystem property we are considering by specifying the resilience 'of what to what'.

To make a systematic review of resilience it is suggested that the 'of what to what' principle provided a useful general framework. We have therefore focused especially on ecosystem or ecological resilience in its broadest sense, and in terms of developing an approach for this study have taken:

- The 'of' term in the principle as referring to ecosystems and their associated services. Thus the first task has been to identify the ecosystems and services that are of policy relevance to the UK; and,
- The 'to what' component of the principle as referring to the major disturbances or shocks that these systems or services are vulnerable to. Given the motivation for this study these are taken as the kinds of disturbance that policy interventions could potentially mitigate or insure against in the UK. Thus the second task has been to identify the important policy relevant issues surrounding the notions of resilience.

These two tasks formed the basis of the scoping work undertaken for this study and set the context for the review process, which seeks to follow the guidelines prepared by the Centre for Evidence based Conservation (Centre for Evidence-Based Conservation, 2010).

1.3 Resilience and the Systematic Review Process

The power of the systematic review process depends on the formulation of a clear question and the transparent and reproducible way the available evidence is assembled to answer it. According to the 'Guidelines for Systematic Review in Environmental Management' (Centre for Evidence-Based Conservation, 2010), questions for a systematic review should have the general form, namely:

'How does intervention X on subject Y produce outcome Z?'

When making a review of the evidence about the efficacy of any intervention the identification of some kind of 'comparator' is also essential so that the magnitude of the intervention effects can be assessed.

A systematic review works best when the target question is sufficiently specific to enable interventions and outcomes to be assessed in measurable ways, and where the subject itself is well defined and identifiable across different studies. For example, Benítez-López et al. (2010) recently constructed a systematic review around the question: *Are mammal and bird populations declining in the proximity of roads and other infrastructure?* In this study the subjects are populations of birds

and mammals, and the intervention disturbance associated with human infrastructure. The comparator is the distance from disturbance and the outcome a change in abundance.

Many other examples illustrating the structure of the systematic review process can be found though the Centre for Evidence-Based Conservation on-line library[1]. Such studies illustrate that the conclusions of systematic reviews are particularly effective when they are able to combine and summarise the results of a number of studies statistically, using meta-analysis techniques. For decision makers, the approach is therefore potentially more helpful than traditional literature reviews, which may be purely qualitative, subjective and open to publication bias. Systematic reviews can therefore be regarded as fundamental to the formulation of evidence-based policy.

Thus given the brief for this study, the components of the generic systematic review question were initially interpreted as follows:

- the **subject** element of the review question was taken as the 'of what' part in the 'of what-to what' principle noted above, and thus understood as an ecosystem, or an ecosystem component or an ecosystem property;
- the **intervention** element was taken as the 'to what' part in the 'of what-to what' principle, and was interpreted as either a specific management regime, policy or action which in the context of this study aimed at promoting the resilience of the ecosystem in its broadest sense, or the impact of another independent variable related to climate change; and,
- the **outcome** is the relevant objectives of the proposed management intervention that can be reliably measured, which in the context of this study is some measure of the resilience, resistance, durability or stability of an ecosystem to some transient or chronic disturbance (i.e. some kind of environmental change).

The **comparator** could then be considered as the availability of some baseline assessment that allows situations where an intervention or disturbance has occurred and to be measured against those where they have not.

Scrutiny of this initial attempt to translate the study brief into the format of a systematic review question suggests that it is probably too broad and open in its structure to be made operational. A number of difficulties are evident. The subject is, for example, heterogeneous, covering any ecosystem or ecosystem property. A further problem is that the intervention is complex in nature, involving two potentially independent influences: 'management' and 'climate'. Finally the formulation implies that the outcome in terms of the changes observed in a particular ecosystem parameter after intervention, can be measured in a number of ways, ranging from the ability to resist disturbance through to the speed of recovery. In other words, the initial formulation has too many sub-questions embedded within it to be viable s a starting point for a systematic review.

As the 'Guidelines for Systematic Review for Environmental Management' (see Centre for Evidence-Based Conservation, 2010, p.19), questions that are too broadly focused may not be suitable for a systematic review, and in these circumstances a two stage process might be considered, involving the construction of a 'knowledge map' for a given topic or research field, followed by one or more full syntheses on subsets of research identified in this map. The advantages of this approach is that it

[1] http://www.environmentalevidence.org/Reviews.htm

allows the users of the material to better understand the scope and content of the research that is relevant to a given issue before more detailed and specific investigations are made. The guidelines argue that knowledge mapping is distinct from a pilot review, which is often undertaken in preparation for a systematic reviews, in that the formulation of the search and inclusion criteria it is conducted with the same rigour as for the full review. However, knowledge mapping is also distinct from the full review in that the process may not initially extend to a final critical appraisal or data synthesis in the form of a meta-analysis. The assumption is that once a broad set of research findings have been described systematically in this way, 'pools of research' can be identified that can be explored to answer the more tightly specified question typical of a systematic review. The exercise can also help identify where the knowledge gaps appear to be. Examples of this strategic approach are to be found in the health and social science fields, and are illustrated by the recent review of nature and health by Bowler et al. (2010).

Given the difficulty of translating the study brief into a sufficiently narrow question suitable for a systematic review, it was decided to approach the task from the perspective of knowledge mapping. Thus the work began with scoping exercise, which was informed by two processes. First, a review of a set of policy-related documents suggested by Defra and its partners on the Project Steering group at an initial kick-off meeting. These documents were used to identify a set of broad thematic areas of current policy interest that could potentially be investigated. The second stage involved consulting a wider group of invited experts by means of a web-based discussion forum (www.recce.org.uk). The aim here was to develop a stronger review focus in each thematic area. The five thematic areas that were identified from the initial discussions were:

- Soils, resilience and the impact of environmental change
- Water futures and ecosystem integrity
- Biodiversity and vulnerability to environmental change
- Ecosystem resilience and air quality
- Economic values and well-being.

Further discussions suggested that the topic of economic values and well-being was so broad that it was not feasible to investigate this subject within the present study, and that the focus should be on soils, water, biodiversity and air quality. Even so, although it was agreed that the study should concentrate on these more specific topics, it was clear from the outset that the questions one might ask in the context of resilience remained very broad, and that the knowledge mapping approach was still the most appropriate way forward.

1.4 Structure of the report

Thus, while the aim of this study was to undertake a systematic review of resilience, the difficulty of formulating the study brief as a single, specific reviewable question meant that the focus of the study shifted to an investigation of the way resilience notions could be framed in relation to four distinct topic areas. The results of this study are therefore presented in Chapters 3 through 6 in the full technical report, as four 'stand-alone' reports dealing with resilience thinking as it relates to soils, water, biodiversity and air quality. In each case the work seeks to describe how resilience concepts have been framed, and what insight resilience thinking has brought to the debate, rather

than to provide a comprehensive analysis of the impacts of climate change across the different subject areas

Since it was the ambition of this study to bring the results into an integrated framework, we have attempted to use a common definitional and methodological approach across each of the topic areas. This is described in Chapter 2 of this document. In the last part of this Report we then bring the results together and reflect on what implications follow in terms of using resilience concepts in contemporary policy debates.

If we are to live with environmental change, then we need to understand the limits of ecosystem functioning so that we can sustain them in the face of increasing human pressure. The identification of such limits is dependent upon knowing how ecosystems react to, and buffer, external pressures and how well ecosystems recover if they are damaged. This study attempts to provide a critical examination of what is currently known about ecosystem resilience and how that knowledge can be used by the UK to 'secure a healthy natural environment for today and the future'.

2. Methodology

By Roy Haines-Young, Pam Berry, Paula Harrison, Richard Mercer, Marion Potschin and Gabriella Silfwerbrand

Given the wide-ranging nature of recent debates about ecosystem or ecological resilience, this study has sought to balance two contrasting pressures. First, the need to develop and refine a set of questions that are specific and suitable for investigation by means of a systematic review. Second, the need to retain a sufficiently broad focus so that the outcomes of the study cover a sufficiently wide spectrum of issues that allow us to look at what 'resilience thinking' might contribute to management and policy. As noted in the introduction, the result has been that four distinct, but linked reviews have been made, that collectively give some insight into the resilience of different aspects of ecosystems in relation to the impacts of climate change. The ambition is to provide a knowledge map that can be used to take these debates further.

In order to give unity to this study, we have used a common set of definitions and synonyms for key concepts throughout, and applied a similar search methodology across the four topic areas. The separate studies also drew on a shared scoping study. In the first part of this Chapter we describe the scoping work in more detail. The Chapter concludes by summarising the search terms used to explore different aspects of resilience and types of intervention and the sets of published materials identified for each thematic area.

2.1 Scoping the review - ecosystems, services and policy themes

In addition to the initial discussions with a project steering group, we invited a number of subject ah and policy experts to contribute to an on-line discussion forum on the RECCE website (Figure 2.1)

Figure 2.1: The RECCE Website (www.recce.org.uk)

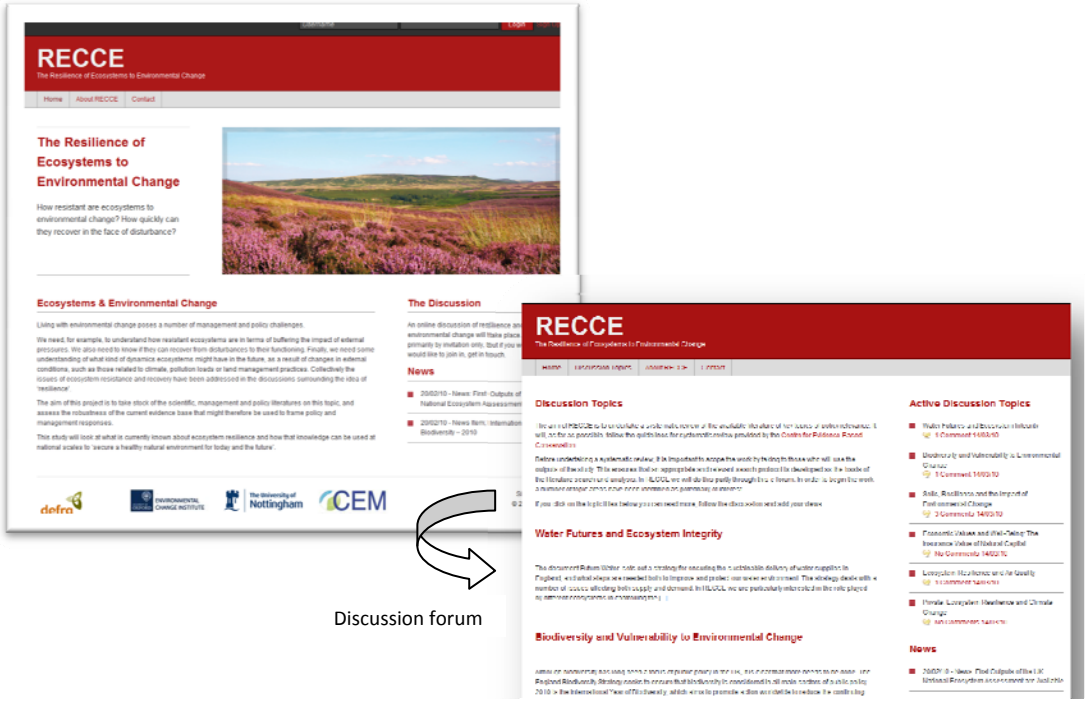


Table 2.1: Candidate focal questions posed in the scoping study (the questions shown in italics were proposed to stimulate discussion; questions not in italics are those suggested by the consultees)

Thematic area	Potential questions
Soils, Resilience and the Impact of Environmental Change	• *How resilient is soil function to pollution inputs?* • *How is the risk to human health and the environment from soil pollution likely to change under future climates?* • *What kinds of land management intervention are needed to ensure that soils cope better with drought and regulate drainage of heavy rainfall and flooding?* • *How do changes in levels of soil carbon affect the resilience of soils?* • *To what extent can the integrity of soils be restored through remediation and restoration measures?* • *How is the resilience of soils affected by the spreading of organic and inorganic materials as part of recycling?* • What are the win-win options that improve resilience and reduce GHG emissions and increase soil carbon? • Can agricultural production be enhanced or maintained in a sustainable way? • How can soil resilience be managed and how (and over what periods of time) can we practically impart resilience properties on soils that would not otherwise be stable?
Water futures and ecosystem integrity	• *How does drought affect the capacity of bogs to regulate water?* • *How can surface water management be used to promote the resilience of freshwater ecosystems to extreme weather events?* • *How significant is water abstraction, eutrophication, drainage and physical modification of river courses in reducing the resilience of freshwater ecosystems to climate change?* • *How can we understand and value the resilience of an ecosystem at the scale of a river catchment so as to better manage land and water in a more integrated way to provide optimum goods and services. Thus:* • *What proportion of the land should be assigned to different ecosystem goods and services (ESS) – producing food, biodiversity, landscape, and water protection – and how can we combine these roles in the landscape?* • *How can we develop a better understanding of the connectivity between environmental compartments?* • *What tools can we use to help land/water managers understand the interactions?*
Biodiversity and Vulnerability to Environmental Change	• *Is the maintenance of native biodiversity in ecosystems important in terms of their resistance to alien species and how might this change under future climate regimes?* • *What level of ecological habitat variability is beneficial to providing suitable future conditions under climate change?* • *How far can maintaining habitats in favourable condition help their resilience to environmental change?* • *Where are 'buffer zones' most effective for conserving biodiversity and what characteristics should they have?* • *Do ecological networks promote ecosystem resilience?* • Which UK Broad Habitats are most vulnerable to climate change?
Ecosystem Resilience and Air Quality	• *Which pollutants are most important in reducing the resilience of ecosystems (e.g. woodlands, heathland, grasslands and wetlands) to climate change?* • *How significant is acid rain in reducing the resilience of ecosystems to environmental change?* • *How significant is eutrophication in reducing the resilience of ecosystems to environmental change?* • How significant is the interaction between ozone and climate change?

Users could login to the discussion forum and suggest or make comments on a range of potential review questions. The website was designed to provide input across the topic areas: soils, water biodiversity and air quality, as well as economic valuation and human well-being. Altogether 17 people signed up for the discussion forum. The number of comments was small than anticipated, but they were nevertheless useful in identifying area of potential interest. The outcomes of the scoping phase are described below.

2.1.1 Soils

The background to the issue of soils and resilience was provided by the *Soil Strategy for England* (Defra, 2009). This document has set out the aim that all soils will be managed sustainably and degradation threats tackled successfully by 2030. The *Strategy* argues in particular that we have to better understand the impact of climate change on our soils and identify what must be done to enable them to adapt. To do this the *Strategy* suggests we need to develop the evidence base dealing with the impact of climate change on soils, and consider what might be done to ensure that our soils are resilient in the face of a changing climate.

Given this background an initial broad, policy relevant question that suggested itself as a starting point for a systematic review in this area was:

> ***What kinds of soil management interventions will protect the integrity of soils, given likely patterns of climate change?***

At the outset we recognised that this was such a broad issue for a systematic review that the study would have to possibly break it down into a set of more specific questions. Thus from our reading of this document and more general experience in this area a more focused set of questions were suggested through the discussion forum (Table 2.1).

In Table 2.1 the questions shown in italics are the examples proposed to stimulate discussion. Those questions not in italics are those suggested by the consultees. During the scoping stage there was no attempt to make their form correspond to that used in a systematic review; the main purpose of the consultation was to explore the subject areas of interest in a policy context.

In relation to the soils theme one consultee endorsed the relevance of the questions initially proposed and suggested a number of further issues, namely the resilience of soils to loss of soil carbon and release of Green House Gases (GHG). Although not framed as a set of questions, another consultee suggested that an important focus for review in this area could be the soil biota and its critical role in governing soil function. The specific areas suggested for investigation were the relationships between 'biomass vs diversity', 'the importance of the community configuration, community conditioning' and how these properties might be managed. However, they also cautioned that any investigation should be careful to note the different meanings that surround the resilience concept and be clear about what particular aspect of resilience is being investigated.

2.1.2 Biodiversity

No additional questions on biodiversity were proposed through the consultation process, although the one respondent who added comments in this area confirmed that the initial questions posed were relevant. However, they doubted that there was sufficient literature available to review most of them. Although the question on ecological networks was considered particularly timely. However,

given the 'Lawton Review' that was being undertaken at the time of this study[2], it was agreed that this topic should be avoided to prevent duplication of effort.

In relation to climate and biodiversity, the study by Mitchell et al. (2007) on the England Biodiversity Strategy and adaptation to climate change was noted. It was suggested that the tabulation of vulnerabilities of the UK Broad Habitats to climate change provided by this study that was based on expert judgement could be followed up through systematic review – but again there were some doubts about the volumes of literature available. On the basis of our inspection of these materials, one strategy might be to investigate first those areas considered to be at the high or medium risk, in terms of ecosystem function; about 19 habitats fell into this category. The suggestion for a follow-up study to that of Mitchell et al. (2007) confirmed the general question posed by the study team in this topic area, namely:

> ***Which ecosystems are most vulnerable to climate change and what can be done to protect the biodiversity and ecosystem services associated with them?***

2.1.3 Water

The document *Future Water* (Defra, 2008) has set out a strategy for ensuring the sustainable delivery of water supplies in England, and what steps are needed both to improve and protect the water environment. The strategy deals with a number of issues affecting both supply and demand, and from our reading of this publication we suggested the following broad question as the basis for discussion:

> ***How can we best protect the capacity of England's major ecosystems to supply and regulate the quantity and quality of water?***

In response it was suggested that a primary focus for review might be the resilience of ecosystems at the catchment scale, and what types of land management strategy might best deliver a range of ecosystem services, including water quantity and quality. It was also suggested that in general terms, policy makers needed to understand better the 'connectivity between environmental compartments', and that land and water managers needed better tools for understanding the interactions between ecosystems. None of the additional comments obtained through the forum were, however, in a form that could easily be used as the basis of a systematic review and further refinement of thinking was needed in this area in the main phase of the study.

2.1.4 Air quality

Only one additional question was suggested as a result of the consultation process in relation to air quality. Our initial broad question was:

> ***How resilient are England's major ecosystems to changes in air quality and how might this change under future climates?***

and the more detailed variants used to stimulate discussion are shown in Table 2.1. The additional topic suggested dealt with the effects of interactions between ozone and climate change.

The questions identified in this topic area concerned the impacts of changes in air quality on ecosystems, rather than the regulation of air quality by ecological structures and processes. This perspective was suggested by the discussions at the initial kick-off meeting and the more general

[2] http://www.defra.gov.uk/environment/biodiversity/documents/201009space-for-nature.pdf

policy concerns expressed in the recent document *Air Pollution: Action in a Changing Climate* (Defra, 2010a). The latter noted that while compared to human health effects, the damage caused by air pollution on ecosystems may be less obvious and more difficult to quantify and monetise, but it nevertheless remains important. Issues include the impacts of sulphur and/or nitrogen deposition when critical loads for acidity are exceeded.

2.1.5 Economic Values and Well-Being

Ideas about ecological resilience, economic values and human well-being are currently being widely debated by the policy and research communities. As the work undertaken through international studies such as TEEB has argued, biodiversity may in fact have an 'insurance value', and serve to buffer society against the impacts of sudden shocks or disturbance. The case of mangroves in protecting coastal areas from damage due to tsunamis is often quoted as an example in the international literature. In the UK it is accepted that appropriate land management may also mitigate the risk of flooding or other hazards.

Following the discussion at the kick-off meeting it was suggested that one area that might be explored was the extent to which ecosystems can provide some kind of buffering or insurance service to society, and how this might change under future climates. From a policy and management perspective it is clearly important to know both what the costs associated with promoting or maintaining resilience are, as well as the size of the resulting benefits of any intervention. Thus the following general question was therefore posed in the discussion forum:

> ***How might climate change affect the capacity of England's major ecosystems to buffer human well-being against shocks or disturbances?***

However, no comments from the e-forum were received. Compared to the other topic areas being explored in this study the capacity of ecosystems to buffer communities against environmental shocks and disturbances and the implications for people both in monetary and non-monetary terms is a more wide ranging issue. It would take in the whole spectrum of regulating services potentially provided by ecosystems. It was concluded that if a systematic review was to be undertaken in this area, it would be useful to consult further to prioritise which of the many areas might be looked at, or consider whether any literature exists in relation to the economic or other benefits arising from the main regulation services provided by UK ecosystems. The topic was therefore dropped from the present study, although it was decided to look at whether in relation to the other four topic areas, there was any associated material dealing with economic issues, and whether any insights into changing values could be derived.

2.1.6 Conclusions arising from the scoping work

Although the questions posed in the discussion forum did not conform to the structure needed to undertake a systematic review, it was clear from the preliminary work that an investigation of a broad range of issues linked to notions of resilience would be of general relevance to current policy debates. Any systematic review is, however, limited by the volumes of material available, and so while the identification of policy relevant questions is important; they must also be looked at in relation to the extent of the evidence base. We therefore turned to look more closely at what resources were available and how they might be accessed efficiently.

2.2 Development of search protocols for the knowledge mapping and review

With the structure of the type of question needed for a systematic review in mind, a series of search protocols to cover the cross-cutting issues of resilience and environmental change were developed and tested.

To ensure that the results of the reviews in the different topic areas could later be integrated, a hierarchical or tiered approach was proposed, involving extracting a common set of studies that make reference to 'resilience' or one of its synonyms, that could be used in conjunction with general descriptors of some aspect of environmental or climate change and management intervention.

Table 2.2: Synonyms and associated concepts used to create common search strings

Concept	Synonyms and associated concepts
Resilience:	*resilience, resilient, adaptation, adaptability, adaptive, resistant, resistance, threshold, vulnerable, vulnerability, recover, recovery, stability and variability, durability and threshold, limit, resistance.*
Environmental change:	*Climate change, climatic change, global warming, environmental change, land use change, shocks, extreme events, outbreaks, disturbances.*
Intervention:	*Manage, management, restoration, restore, conserve, conservation, protect, protection, remediate, remediation, intervene*, *intervention.*

Table 2.3: Results of pilot study using common search strings

Search	Concepts	Search Strings - Web of Science (incl. conference proceedings)	Hits
A1	Resilience	TS=(resilien* OR adapt* OR resistan* OR threshold* OR vulnerab* OR recover* OR stability OR variability)	>100,000
A2	Environmental change	TS=(climat* change OR global warming OR environment* change* OR land use change* OR shock* OR extreme event* OR outbreak* OR disturbance*)	>100,000
A3	Management	TS=(manage* OR restor* OR conserv* OR protect* OR remediat* OR interven*)	>100,000
A4	Combined	TS=(resilien* OR adapt* OR resistan* OR threshold* OR vulnerab* OR recover* OR stability OR variability) AND TS=(climat* change OR global warming OR environment* change* OR land use change* OR shock* OR extreme event* OR outbreak* OR disturbance*) AND TS=(manage* OR restor* OR conserv* OR protect* OR remediat* OR interven*)	27,994

Search date – 2010/05/28: Databases=SCI-EXPANDED, CPCI-S Timespan=All Years, All searches, unless otherwise explicitly stated, are conducted using the "Topic" field tag (denoted as TS). The "Topic" field tag includes searches within Title, Abstract, Keyword and Keyword Plus fields within Web of Science.

The concepts that were common to each of the topic areas form the top tier of the proposed search strategy. The subject specific searches could then be nested beneath them as appropriate. In this way the separate topic reviews could effectively draw from the same 'virtual' database if they each used the same search engines.

Our initial review of the resilience literature and the set of documents identified as setting the broad policy context were used to develop a set of synonyms and associated terms for the key concepts (Table 2.2). For resilience, *associated* terms such as threshold and limit were included because these ideas are often used in conjunction with the more theoretical discussions that surround the resilience concept, and it was thought that they might potentially identify papers that could provide further insights. The development of the search terms and synonyms followed an iterative process of testing that involved reviewing a random but small number of the publications identified with a view to identifying additional search terms and synonyms or deleting or modifying existing ones.

Using Web of Science as the test-bed, the search strings for the individual concepts were found to identify very large numbers of studies (>100,000). However, when they were combined (Table 2.3) a set of about 28,000 references was extracted. Although this was still large, it was taken as a potentially suitable pool from which the more topic specific papers could be derived.

As a test of the approach during the pilot phase, a set of more focused searches from this large pool was made using subject specific terms (e.g. 'soils', 'biodiversity', 'water', 'air quality') **and various inclusion or exclusion criteria, such as studies only dealing with terrestrial ecosystems or location of an empirical investigation**. These subsets were used both to check the relevance of the material to the broad questions identified during the scoping phase, and the extent to which independent experts agreed on their inclusion within some kind of analysis.

The pilot results were as follows:

- For ***soils,*** a subset of around **500** papers were identified within which the most frequently investigated topics were changes in soil organic carbon and GHG emissions in relation to land use change, and how different agricultural practices (e.g. tillage or no tillage) impact the physical properties of soil and aggregate composition.
- For ***water,*** a subset of **1100** was identified. The topics covered by the material included the effects of ecosystem modification on flood risk, environmental or management impact on river regimes, eutrophication management and risk assessment in relation to water quality and quantity.
- For ***biodiversity,*** a subset of around **450** papers was identified. The subject was taken to include species diversity, ecosystem diversity, morphological diversity and genetic diversity at a range of scales; marine and coastal systems were however excluded from the analysis. The analysis suggested that the most common subjects considered were the responses of biodiversity (across all its definitions) to disturbances. The majority of these disturbances were anthropogenic and most of these were single factor impacts with few studies examining the confounding effect of multiple disturbances on biodiversity. Promoting biodiversity, through land management practices and conservation, and restoration or regeneration studies made up the next major component of the literature.

- For ***air quality,*** a subset of **400** papers was identified. A scan of a sample of these suggested that three themes were common, namely: the effects of disturbance on CO_2 flux in terrestrial ecosystems and the effects of elevated CO_2 levels for biomass production; the impact of nitrogen compounds including ammonia, on ecosystems; and, the effects of phosphorous and heavy metal deposition.

Again, although the subsets identified were still quite large, they were considered to be of manageable size to be useful in the systematic review process.

In the chapters that follow the form of the final search strings varied in some cases from those shown in Table 2.2, as seemed appropriate given the particular area being considered. It was found, for example, that the management string was too general to be applied across the board and that in the case of soils, for example, more topic specific concepts like 'tillage' were needed. Elsewhere other search and exclusion criteria had to be introduced to constrain the search outcomes. The application of the general search terms is therefore discussed in more detail in the four specific topic areas described in the subsequent parts of this Report. An assessment of the general search strategy and the extent to which it was possible to develop a common search strategy is given in the final Chapter.

2.3 Wider consultation

Following the preparation of a draft of the knowledge mapping and reviews in each of the four topic areas, two further rounds of consultations with subject experts was undertaken. The aim of the exercise was to examine whether they felt the searches were sufficiently comprehensive, and subsequently whether they felt the balance between issues suggested by the searches was appropriate. Their comments on the initial draft text have, where possible, been built into this finalised version.

3. Ecosystem resilience, environmental change and the role of a systematic review

By Roy Haines-Young and Marion Potschin

3.1 Introduction

This study has explored two issues. First, a substantive scientific question concerning how policy action might help to sustain ecosystems in the face of environmental change or be designed to protect their capacity to recover following disturbance. Second, a methodological question, concerning the extent to which a 'systematic review' can be used to explore how policy and management interventions might promote ecosystem resilience. Given the brief for this study (see Appendix 1), and the way it has been constructed, it is essential that these two points are taken together to fully evaluate the contribution that this study is attempting to make.

While we have presented the material on soils, biodiversity, water and air quality as four 'stand-alone' reviews, their design was based on a common underlying motive: namely to examine whether the general ideas that surround notions of resilience can usefully connect up current evidence *across* different discipline areas in ways that can inform policy debates concerned with managing the impacts of climate change on ecosystems. The requirement that the analysis should be based on systematic review methods, rather than more informal review approaches, clearly constrained the nature of the task. As a result the outputs of the reviews must be considered from this perspective. It is however worth commenting, that the systematic review in environmental field related to policy questions are not going to deliver the kind of results achieved in medicine but could inform a useful debate around gathering evidence about the environment. Thus while the reviews have sought to identify and report on the available empirical literature in systematic and repeatable way, their coverage was clearly controlled by the need to seek out material that explicitly dealt with the resilience concept or ideas closely associated with it. The reviews are 'stand-alone' but they may not be as comprehensive as one might expect if one considered stability and recovery of ecosystems in relation to soils, biodiversity water and air quality as separate topics. In other words, the purpose of this study is mainly to help understand the contribution that systematic reviews can make in relation to general policy questions about resilience, rather than to explore ecosystem dynamics across these four thematic areas in isolation.

We begin this critical reflection on the results of this study first from the resilience perspective, and then for the systematic review process. The discussion continues with the presentation of a knowledge map for resilience that synthesises the study outputs across the four topic areas, and then concludes with our recommendations for further work.

3.2 Framing resilience

In the introduction to this study we noted the difficulties that surround the notion of resilience. These initial discussions summarised the key aspects of resilience that would be considered, namely the resistance of ecosystems to disturbance and their speed of recovery following some disruptive

event, but the wider semantic and theoretical debates were largely avoided. It is now appropriate to consider them in more detail.

Brand (2009) has recently presented an extensive review of resilience and sustainable development, and has argued that currently the idea of resilience is 'in jeopardy' as a result of a number of conceptual and theoretical difficulties. On the one hand there is the problem of 'conceptual vagueness'. This has come about, he suggests, since the concept was first introduced into ecology in the 1970s as a result of interest being taken up in a number of different discipline areas. Increasingly the word is being used with a number of different intentions and understandings, including both the *description* particular ecosystem characteristics or dynamics (e.g. in terms of 'stability in the face of disturbance' and 'ability to recover following impact') as well as representing some kind of *normative* proposition about what kinds of ecosystem characteristics are desirable or necessary in the context of sustainable development, say. It also appears to reflect particular cultural and philosophical assumptions. As a result we see in the literature usages based on fairly well defined measures, closer to the original 'engineering' formulation derived from systems theory, through to more open-ended treatments of the idea[3]. Brand (2009) interprets the transformation as suggesting that resilience has become more of a 'boundary object', helping to transmit and coordinate thinking between disciplines even though there is no commonly accepted or precise definition of the term. This is supported by the increasing number of such concepts in ecology and conservation biology meanwhile others are "biodiversity", "ecosystem functioning", "ecosystem integrity", etc. The very fact that it can be open to interpretation and debate is, Brand (2009) adds one of its advantages, because it can help bridge between different areas of knowledge. On the other hand it can equally become a drawback because the very 'malleability' of the idea can frustrate scientific progress since it is not easily operationalized.

Brand (2009) concludes that as resilience is increasingly used as a perspective rather than a clear well defined concept, the original ecological dimension of the idea is about to disappear. His analysis suggest that recent studies tend to emphasise more the social, political and institutional asperities of resilience, or deal with notions of resilience from the integrated or holistic perspective of socio-ecological systems, while focused ecological studies become increasingly rare.

The results and difficulties encountered by this study clearly reflect some of the wider issues identified by Brand (2009). For example, part of the stimulus to this work has been the need to deliver the Public Service Agreement (PSA) to *"...secure a diverse, healthy and **resilient** natural environment, which provides the basis for everyone's well-being, health and prosperity now and in the future...",* with policies based on 'evidence', but used in this way the notion of resilience is much more all-encompassing and normative than that envisaged in the original ecological formulation. In fact, if we unpack the way in which the idea of resilience is used in discussions surrounding the PSA target, we can appreciate just how multi-faceted and malleable the idea can be. Thus it can be interpreted from the perspective of *conservation*, namely in terms of finding ways to protect important aspects of our natural capital base, by designing, say, an appropriate network of marine protected sites. It can also be interpreted and applied in the sense of *restoring* ecological function by, for example, reducing the fragmentation of habitats and building functional ecological networks or reducing the impacts of pollutants. Finally, it can be looked at from the perspective of ensuring

[3] In fact Brand (2009, p. 201) outlines 10 different meanings of ecological resilience that can be derived from the current literature.

that ecosystems can *transform* and *adapt* in the face of climate or other environmental changes involving long term directional change in some external driver. Clearly in the context of sustainable development we need all these different types of thing. Moreover, to secure them we would probably need to pay attention to social and institutional arrangements as well as the characteristics of ecological systems. However, while these goals are worthy and important, it seems unlikely that they can be bound together unambiguously in a single, *operational* concept.

Brand (2009) argues that to accommodate the different usages surrounding the notion of resilience, more precise terminology is required. As noted in our introduction, the distinction he suggested between *ecological* or *ecosystem resilience* and *socio-ecological resilience* is a useful one that captures the spectrum of intentions. However, the outcomes of this study suggest that it may not alone be sufficient. Even though we have focussed on the more easily defined idea of ecological resilience, the experience we have gained from our review in the four different topic areas is that resilience *per se* is not central to current debates which are much better understood in terms of the more distinct ideas of stability, the ability to recover following some transient disturbance, and the extent to which these systems might be transformed under longer-term changes in some set of exogenous or external controlling factors.

The concept of resilience, we suggest, is therefore more useful in policy debates if we recognise that principally it is a normative concept, valuable in identifying the types of range of ecosystem characteristics that might be promoted through management and policy designed to secure 'sustainability'. Equally we should avoid the temptation of thinking that the design of particular aspects of policy or management can be unambiguously underpinned with evidence as to their effectiveness, without more clearly stating what particular aspects of ecosystem dynamics are being considered. To make progress, we clearly need to find ways of mapping or translating the normative aspects of 'resilience' onto more precisely defined concepts that can be used to explore the available empirical literature.

3.3 Systematic Review and Knowledge Mapping

The difficulty of undertaking a systematic review on resilience was discussed in the introduction to this Report (Section 1.3). Given the 'open-framed' nature of the questions about ecosystem resilience implied by the study brief, we suggested that a two stage approach was more appropriate. Following the 'Guidelines for Systematic Review in Environmental Management' (Centre for Evidence-Based Conservation, 2010, p.19) it was proposed that this would involve the construction of a '**knowledge map**' describing the main areas of concern in the present literature, which could then be used to undertake more focused analysis using systematic review methods.

Although the idea of knowledge mapping fits well with the suggestion that resilience thinking has to be refined around a more specific and measurable set of characteristics, techniques for knowledge mapping are much less well-developed than those for systematic review. This situation meant that the current study was somewhat exploratory in nature, and it is useful to reflect now on how successful this strategic approach was, since ultimately it must control the quality of subsequent outputs.

All systematic reviews have to start with a scoping phase to ensure the structure and relevance of the review question, and the robustness of the search protocols. Knowledge mapping is a much broader and wide-ranging process, which involves more interpretation than systematic review. Although knowledge mapping seeks to identify the specific topic areas within which unified or coherent bodies of evidence exist, difficulties arise in deciding the boundaries of the mapping process when the field itself is poorly defined, or there is little consistent usage of terminology. This problem was particularly acute in the case of resilience. While there is a considerable body of literature dealing with the resilience concept in general terms, this study found that empirical studies that explicitly explored the idea in an analytical way are far fewer in number; this was particular apparent in the case of biodiversity and water, for example. To overcome this difficulty an attempt was made to expand the body of potentially available material by identifying additional terms that captured different aspects of 'resilience thinking' such as 'stability', 'vulnerability' or 'recovery'. Although this strategy was successful it resulted in the selection of a number of sources whose relevance to the overall topic of ecosystem resilience had to be established. As far as it is possible, the systematic review process tries to eliminate bias by making the selection process as transparent and repeatable as possible. Knowledge mapping is, it seems, more open to an interpretation because the links between concepts and terms are not there in the literature, waiting to be discovered or revealed, but involve a process based on judgement. Thus in the case of soils, soil quality was used as a way of framing aspects of resilience thinking, but much of the soil quality literature makes little reference to the term resilience. More generally, while many papers dealt with the effects of changing moisture and temperature regimes on soils, they did not always link this explicitly to the issue of climate change. Clearly decisions about what to include in the knowledge map are therefore critical because they will define the geometry or configuration of the systematic reviews that are then undertaken within each area of knowledge.

The need to identify more specific or focused sets of review questions that nested within the general resilience topic was recognised in the design of this study, and the team sought to develop a consultation process to achieve this. However, experience suggests that the study team probably attempted to move too quickly to the review stage without exploring fully what resilience itself implied from a policy perspective. Once the topic areas of soils, biodiversity, water and air quality had been identified, the team then sought to consult with 'subject' and 'policy' experts within each of the thematic areas. Their concerns linked more to the issues in each field rather than on the general utility of the resilience concept for policy or management. Their involvement bought insights, but the process did not achieve an integrated framework for the analysis of *resilience*. Moreover, by constructing a set of stand-alone analyse they have in a subsequent round of consultation, tended to be considered in terms of their individual adequacy as a review of the 'state-of-the-art' in each field, rather than as an examination of whether a body of cross-cutting evidence existed that might support the use of 'resilience' as an idea in policy debates. Possible alternative approaches are discussed below (see 3.4. & 3.5).

When contemplating the requirements of a systematic review, the 'situational logic' suggests a reductionist approach, in which perspectives are gradually refined and focused so that precise questions can be asked. Although knowledge mapping may help this process, our experience indicates that it cannot simply be viewed as a means of identifying where effort might subsequently be directed without any regard as to how the results of those individual reviews would contribute to some overall conclusion. A shortcoming of the present study was, perhaps, that the decision to

identify four distinct topic areas as a framework for review was made without any clear understanding of how the separate findings could subsequently be linked to each other in some final analysis of the overarching notion of *resilience*. For example, while the focus of the investigation of air quality was on the impacts of changing atmospheric inputs on ecosystem function, that for water looked at how the evidence on how the water regulating characteristics of ecosystems changed under future climates. A more integrated picture of ecosystem resilience might have been achieved if, instead, the impacts of changing moisture regimes on ecosystem function had been looked at. These findings could then have been aligned more easily with those for soils, biodiversity and atmosphere to determine the vulnerability of ecosystems to environmental change.

Given the need to base policy on the best available evidence, any study what seeks to inform discussions surrounding the aspiration of, say, securing *a diverse, healthy and **resilient** natural environment* must start with a clear understanding of what appropriate policy outcomes might be *vis à vis* resilience. In relation to the impacts of climate change, for example, is it that that ecosystems should be resistant to such change or is it that they should be adaptable and capable of adapting to new conditions while maintaining the ecosystem service we currently enjoy or might need in the future? Should management or policy intervention seek to buffer the effects or promote adjustment? The answers depend on the situation one is looking at, and if context matters it seems unlikely that any single body of evidence can determine whether or not building resilience *per se* is an appropriate or relevant policy goal. Anderies et al. (2006) has argued that the notion of resilience is best thought of a set of ideas about how to interpret complex systems. For those who seek to apply those interpretations through policy or management action, a knowledge map that describes qualitatively the different ways the concept has been constructed and used, could possibly be more helpful than a specific quantitative meta-analysis that deals with only one ecosystem component.

By moving too quickly to the review stage, without refining what was embedded in the resilience concept from a policy or management perspective, the literature searches generated a rather narrow range of material that neither usefully extend thinking about resilience, nor completely reflect the current state of knowledge in each topic area. Instead of trying to discover whether there was evidence across different topic areas that systems showed some kind of 'resilience' in the face of climate change, a more fruitful approach might have been to examine how the multiple ideas embedded in the resilience thinking are reflected or constructed in different discipline areas. This would involve building up a rich picture of equivalences between different concepts and terms in different subject areas. It is unlikely that this could be achieved by literature searches alone, and probably requires a more extensive use of experts than was possible in this study.

The lesson from this project is that when seeking to use the methods of systematic review to ensure that policy is based on evidence, the importance of an initial phase of knowledge mapping should not be overlooked. It is particularly important when addressing open-framed questions involving concepts like resilience which may be used in a normative rather than analytical way in policy debates. The systematic review process can deliver insights, but as this study illustrates to make progress we have to be clearer from the outset about the kinds of evidence that would support the assertion that resilience, for example, is an *appropriate* and *achievable* policy or management goal.

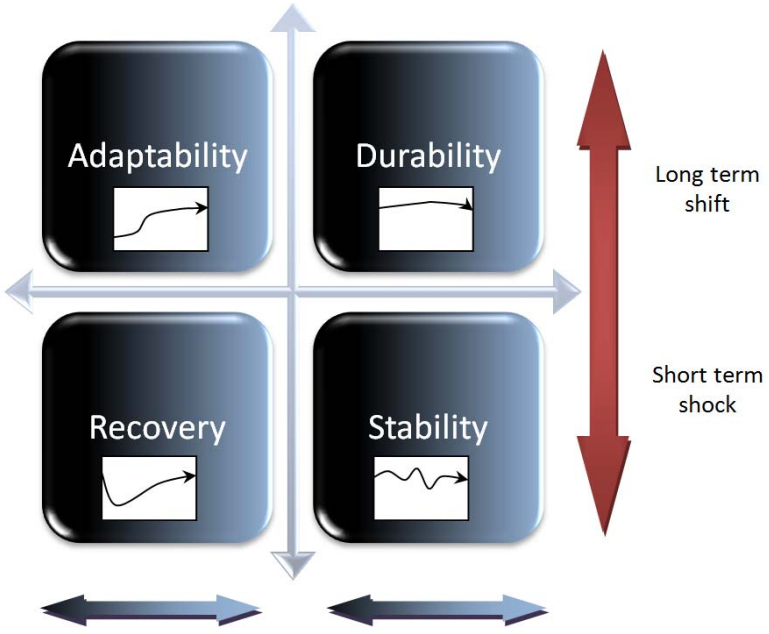
3.4 Knowledge Mapping for Resilience

Although this study did not, perhaps, focus sufficient resources on building a knowledge map for resilience as might have been desirable, the work did identify a range of material that can, nevertheless, be used retrospectively to construct a 'first draft'.

While commentators vary in the terminology that they use when discussing resilience, there is a large degree of agreement that it covers both the resistance of systems to disturbance *and* their ability to recover following some kind of perturbation. This was particularly evident in the material extracted on soils, and also apparent in the air quality analysis. Figure 3.1 shows one way in which the different dimensions of resilience might therefore be represented. It is based on a reworking of the model proposed by Dawson et al. (2010) (see also Figure 1.1), who usefully distinguish between the dynamics of systems subject to short-term, transient shocks or disruptions, with those subject to more longer lasting (chronic) changes or shifts in key drivers or pressures. Thus stability is a measure of the systems tolerance or sensitivity to short-lived perturbations, while durability is the capacity of the system to tolerate or buffer longer term stress. Where framework shown in Figure 3.1 differs substantially from the Dawson model is that it includes the concepts of 'adaptability' and 'recovery'.

Dawson et al. (2010) refer to the ability of systems to rebound and return to equilibrium as 'resilience'; we prefer instead to use the term 'recovery' to describe this concept and follow convention by using resilience as label for all the concepts shown in Figure 3.1. More significantly we have replaced 'robustness' with adaptability to more clearly capture the idea that systems may be resilient because they can sustain their functioning because the can adjust, adapt and reorganise as a result of changing external pressures, and move to some new equilibrium state. The lack of any reference to the ability of systems to adjust seemed to us, to be a deficiency of the Dawson model.

Figure 3.1: A framework for representing ecosystem resilience
(adapted from Dawson et al., 2010)



The reorganisation proposed here has a major consequence in that the distinction that the original model proposed by Dawson et al. (2010) made between internal (endogenous) short-term disturbances and external (exogenous) long-term stresses or drivers no longer applied so elegantly. Instead, we have suggested that they apply across the board. According to the model proposed in Figure 3.1 the left-right contrast between adaptability/recovery and durability/stability concerns the dynamics of systems in relation to some equilibrium state. The durability/stability paring attempts to capture the extent to which systems can maintain that equilibrium in the long and short term. By contrast, the adaptability/recovery paring focuses on the dynamics of the system if equilibrium conditions change either temporarily or over longer periods.

Figure 3.1 is clearly more complex than the original model proposed by Dawson et al. (2010). However, we suggest that it is more helpful in summarising the different research concerns identified by this study, and can be used to construct an initial knowledge map for resilience across the topic areas that have been investigated. As part of the process of developing and applying the framework shown in Figure 3.1, we have grouped in a more detailed way the different concepts that are used in discussion of resilience (Figure 3.2). This arrangement of concepts could be used as a diagnostic tool to help decide how to group the various sources of evidence in relation to the overarching question about how the resilience of systems change in the face of climate change.

Figure 3.2: Relationship between resilience concepts

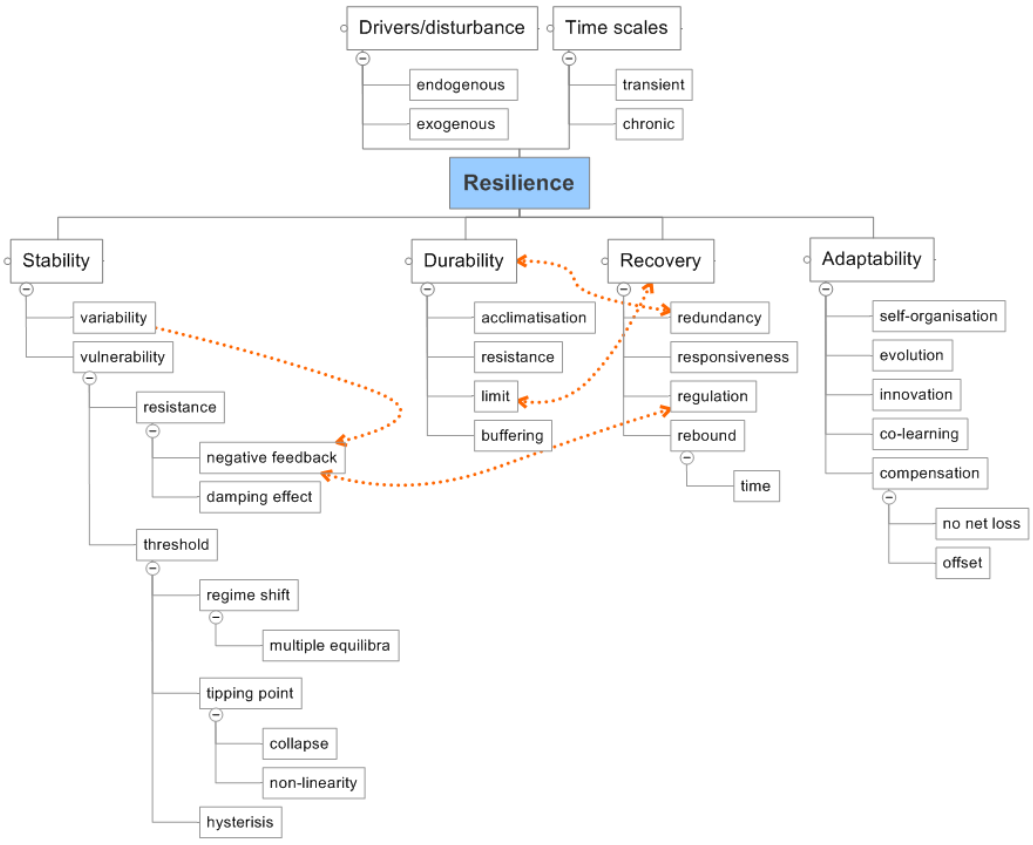


Table 3.1 is the result of applying the conceptual framework described above to the issue of how the resilience of ecosystems might change under future climates. It attempts to set out a unified constellation of questions across the four thematic areas considered in this study using the ideas of stability, recovery, durability and adaptability as a template. The table could, perhaps, be described more of an '**issues map**' or 'issue matrix' than a 'knowledge map', because it does not present results. Nevertheless, starting with questions such as these it is easy to see how it could be developed into a more comprehensive review, once the content of the individual questions had been agreed and an assessment made of the extent to which individual systematic reviews were possible within each area, given the available evidence.

The issues identified in Table 3.1 have partly been drawn from the materials identified in the separate reviews. This is particularly so in the case of soils and air quality. As noted above, the water review looked more at the impacts of changes in biodiversity on the water regulating characteristics of ecosystems, and so less easily linked into the this general framework. However, the merits of using this approach in terms of identifying a more coherent set of issues to investigate are clear. Inevitably, given the wide ranging nature of questions about resilience, evidence is likely to be spread across a number of discipline areas. The four topic areas are not the only ones that could have been considered in a review of resilience. Nevertheless they are useful to illustrate how we could use the idea of an issues map to look at the kinds of evidence that would be needed to make an overall judgement about ecosystem resilience and climate change.

Thus in developing the issues set out in Table 3.1, we have not confined ourselves to the materials identified in the separate reviews, but also drew more widely on the questions and linkages between the topic areas.

An illustration of the benefits of using this 'issues mapping approach' is provided by the identified in the soils review. This analysis showed that key questions in the field, for example, concerned the sensitivity of soil respiration warming and changes in CO_2 concentrations, how these factors interacted with each other and how the overall balance between storage and loss of soil carbon might shift as ecosystem productivity was modified. There we also note the potential interaction effects with other components such as changing moisture regimes and changing nutrient input. The construction of Table 3.1 attempts to indicate where these cross-linkages exist, and where therefore a more integrated consideration of the available evidence might have been attempted. The table highlights these cross-cutting issues in the last row of the matrix.

At this stage it must be acknowledged that the issues map shown in Table 3.1 is a preliminary one, and ideally should be refined not only by bibliographic analysis but also by the involvement of policy and subject experts seeking to apply the key resilience concepts (Figure 3.2). With the benefit of hindsight, this study should perhaps have devoted more time to the construction of this framework, and paid more attention to its refinement and testing via a review of the available evidence. **Starting with a more formal 'issues matrix'** would have helped to more clearly define the scope and focus of the review activities. The value of the matrix approach is that it also defines the context in which individual reviews might be set and evaluated. Thus unlike those presented here, experts would not assess adequacy in terms of stand-alone reviews of each topic, but rather as ***contributions*** to an evidence base constructed to address a specific science or policy question.

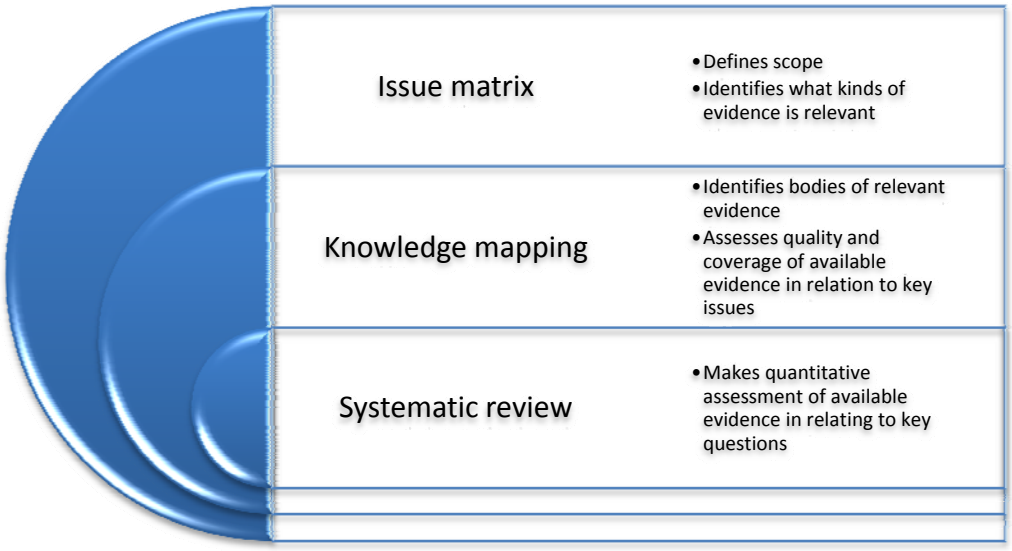
Table 3.1: 'Issue matrix' based on the framework for representing ecosystem resilience (Fig. 3.1) and climate change impacts

	Soils	Biodiversity	Water	Air quality
Stability & Sensitivity	• How sensitive is soil respiration to changes in temperature and CO_2 concentrations? • Overall how sensitive are soil carbon stores to changes in temperature and CO_2 concentrations given the wider feedback effects on productivity levels?	• How sensitive are different habitats to changes in climate regimes in terms of composition and above and below ground productivity? • How sensitive is community productivity to changes in biodiversity characteristics?	• What is the impact of changing moisture regimes on ecosystem productivity and soil function? • How do changing moisture regimes impact on community composition?	• To what extent will changing levels of O_3, nitrogen, sulphur and acidification changes growth patterns and reproductive performance that can potentially shift the competitive balance within communities?
Recovery	• How effective are management interventions as a means of increasing soil carbon?	• To what extent is the speed of recovery of community processes dependent on biodiversity?	• How do changes in biodiversity affect the drought resistance of communities?	• To what extent can ecosystem processes recover if critical loads are no longer exceeded?
Durability	• How vulnerable are carbon stores represented by organic soils to changing climate? Where are the tipping points? • Are there acclimatisation effects in relation to impact of warming and CO_2 on soil respiration? • What are the ancillary benefits of increasing soil carbon levels on other aspects of soil quality?	• To what extent can the effects of climate change on community characteristics be mitigated by management interventions?	• How will extreme moisture events impact on the structure and function of ecosystems (including soils)? • How does moisture stress affect the sensitivity of species and habitats to changes in air quality?	• How sensitive are community processes to chronic impacts at sub-lethal critical loads? • How will critical loads exceedances change under conditions of future climate change?
Adaptability	• How do soil microorganisms react to changes in temperature, moisture and CO_2 levels? • Is there an upper limit to the amount of carbon that can be sequestered in soils as a result of warming and CO_2 changes?	• To what extent can shifts in community composition buffer changes in biogeochemical cycles within ecosystems? • What opportunities does management offer in terms of increasing the climate mitigation potential of different habitats?	• What kinds of shift in community composition can we expect under future moisture regimes and where are these effects likely to occur?	• How will changing species and habitat patterns affect the assessment of critical loads?
Uncertainties	• *Significant interaction between community processes an climate variables makes outcomes in terms of carbon balance difficult to determine.*	• *Sensitivity of community processes such as productivity and nutrient cycling to changes in biodiversity are unclear.*	• *Impacts of changes in moisture regime in community composition and soil function are uncertain.*	• *There may be significant interaction effects between air quality parameters at higher temperatures and CO_2 levels.*

3.5 Implications and Next Steps

There is little doubt that systematic review is a vital part of developing evidence-based policy. However, it must be recognised that policy questions are often more complex and open ended than the methods of systematic review seem to allow. This certainly seems to be the case for resilience. Systematic review has its place in taking discussions of resilience forward in a policy context, but they should not be embarked upon lightly. The experience of this study is that when terms are so malleable and open to different readings and interpretations, an important preliminary stage in any review process must be something equivalent to issues mapping.

Figure 3.3: Relationships between issues and knowledge mapping and systematic review



As part of our critical reflection on the outcomes of this study we have described how this issues mapping process might work. Figure 3.3 describes its relationship to the knowledge mapping and systematic review process as described by the 'Guidelines for Systematic Review in Environmental Management' (Centre for Evidence-Based Conservation, 2010). We suggest that it is perhaps distinct from the knowledge mapping process they outline and can usefully precede any mapping and systematic review exercise. We also suggest that it is distinct from the idea of a 'pilot review', which mainly focuses on the potential availability of evidence given a defined review question.

We suggest that review activities driven by policy needs would often use concepts like resilience in ways that have multiple meanings and that imply normative perspectives. To some extent this is the very essence of policy debates, which depend on these kinds of 'boundary objects' or open-framed concepts to enable discussion between different interest groups and knowledge domains. However, if we are to bring evidence to bear in these debates, then we must find ways of operationalising the process of making evidence open to scrutiny. While decisions are ultimately always based on judgement, we have to find ways of agreeing about what kinds of evidence that we consider relevant it a particular policy context. A rigorous 'issues mapping' exercise may provide part of what is required.

Thus if the objectives set for the present project are to be fully realised, then we suggest that unfortunately further work is required. Specifically we suggest the following next steps:

1. that there should be a round of further discussion to refine the issues matrix proposed above, with the specific aim of agreeing just how the answers to these questions would inform the use of 'resilience thinking' in a policy context;
2. that the existing preliminary but partial reviews be used to refine and extend the initial search strategies so that the outcomes are potentially more relevant to the overarching question about resilience and climate change;
3. that a detailed knowledge map is then prepared, based on an agreed set of keywords and codes that can be used to classify and to characterise the different studies so that information can be extracted from them in a systematic and transparent way;
4. that once the availability of evidence in the specific areas identified in the 'issue matrix' is established through the knowledge mapping process, targeted quantitative systematic reviews are constructed if no published material exists;
5. that where quantitative, systematic reviews cannot be undertaken, peer reviewed descriptive reviews should be made; and,
6. that the conclusions from the separate systematic and descriptive reviews be assembled and discussed using the framework of the issues matrix, to form a judgement about the nature of ecosystem resilience in the face of climate change.

The Action Plan for embedding an Ecosystems Approach in decision making (Defra 2007, 2010b) emphasises that adaptive management involves consultation and the co-construction of knowledge, as well as making the use of the best evidence available. The recommendations we have made about the construction of an 'issue matrix' via a dialogue between policy customers and topic experts is clearly consistent with and compatible with this proposition. Brand (2009) has argued that 'resilience thinking' is probably best viewed as part of the process of adaptive ecosystem management. The experience gained in this study has provided some pointers as to how this can be taken forward by combining the focused methods of systematic review, with more open deliberative approaches designed to better understand how broad, normative policy concerns can be translated into manageable review questions.

References

Anderies, J. M., B. H. Walker, and A. P. Kinzig (2006): Fifteen weddings and a funeral: case studies and resilience-based management. Ecology and Society 11(1): 21. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art21/

Benítez-López, A.; Alkemade, R. and Verweij, P.A. (2010): The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. *Biological Conservation* **143:** 1307–1316

Bowler, D.E., Buyung-Ali, L.M., Knight, T.M. and A.S. Pullin (2010): The importance of nature for health: is there a specific benefit of contact with green space? *Environmental Evidence*: www.environmentalevidence.org/SR40.htm.

Brand, F. (2009): Resilience and Sustainable Development: an Ecological Inquiry. PhD Thesis at Technischce Universität München, Lehrstuhl fuer Landschaftsökologie, accepted 14.05.2009, 354 pp.

Brand, F.S. and K. Jax (2007): Focussing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. *Ecology and Society* **12(1)**.

Carpenter, S.; Walker, B. Anderies, J.M. and N. Abel (2001): From metaphor to measurement: resilience of what to what? *Ecosystems* **4(8)**: 765-781.

Cummings, G.S; Barnes, G.; Perz, S.; Schmink, M.; Sieving, K.E.; Southworth, J.; Binford, M.; Holt, R.D.; Stickler, C. and Van Holt, T. (2005): An Exploratory Framework for the Empirical Measurement of Resilience, *Ecosystems* **8**, 975-987.

Dawson, T.P.; Rounsevell, M.D.A.; Kluvánková-Oravská, T.; Chobotová V. and A.Stirling (2010): Dynamic properties of complex adaptive ecosystems: implications for the sustainability of services provision. *Biodiversity and Conservation* 19(10): 2843-2853..

Defra (2007): Securing a healthy natural environment: an action plan for embedding the ecosystem approach. http://www.defra.gov.uk/wildlife-countryside/pdf/natural-environ/eco-actionplan.pdf

Defra (2008): Future Water: The Government's Water Strategy for England. HM Government and Defra. http://www.defra.gov.uk/environment/quality/water/strategy/pdf/future-water.pdf

Defra (2009): *Safeguarding Our Soil: A Strategy for England*, PB13297, London: Department of Environment, Food and Rural Affairs.

Defra (2010): Delivering a healthy natural environment. An update to "Securing a healthy natural environment: An action plan for embedding an ecosystems approach".

Folke, C., S. et al. (2002): Resilience and sustainable development: building adaptive capacity in a world of transformations. Scientific Background Paper on Resilience for the process of The World Summit on Sustainable Development on behalf of The Environmental Advisory Council to the Swedish Government.

Gunderson, L. and Holling, C.S. (eds.) (2002): *Panarchy: understanding transformations in human and natural systems*. Washington, DC: Island Press.

Holling, C.S. (1973): Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* **4**: 1-23.

Isbell, F.J., Polley, F.W. and B.J. Wilsey (2009): Biodiversity, productivity and the temporal stability of productivity: patterns and processes. *Ecology letters* **12**: 443-451.

Janssen, M.A. (2007): An update on the scholarly networks on resilience, vulnerability, and adaptation within the human dimensions of global environmental change. *Ecology and Society* **12(2)**: Article No.: 9.

Janssen, M. A. and E. Ostrom (2006): Resilience, vulnerability, and adaptation: A cross-cutting theme of international human dimensions programme on global environmental change. *Global Environmental Change-Human and Policy Dimensions*, **16(3)**: 237-239.

Loreau, M., Downing, A.L., Emmerson, M.C., Goinzalez, A., Hughes, J.B. and P. Inchausti (2002): A new look at the relationship between diversity and stability. *Biodiversity and Ecosystem Functioning: Synthesis and Perspectives*. In: Loreau, M., Naeem. S. and Inchausti, P (Eds.), Oxford University Press, Oxford, pp79-91.

MA (2005): Ecosystems and human well-being: synthesis. Millennium Ecosystem Assessment, Island Press, Washington, DC.

Walker, B. H. and L. Pearson (2007): A resilience perspective of the SEEA. *Ecological Economics* **61(4)**: 708-715.

Appendix 1: Invitation to Tender for this study

#

Research Study

TITLE: - A SYSTEMATIC REVIEW INTO THE RESILIENCE OF ECOSYSTEMS AND THE SERVICES THEY PROVIDE TO SOCIETY IN THE FACE OF CHANGING EXTERNAL PRESSURES.

Policy Background

1. The UK Sustainable Development Strategy[4] identified protection of natural resources and enhancement of the environment as a key priority. It recognised the progress made in dealing with threats to the environment (e.g. point sources of pollution) but recognised the more complex and cross-cutting challenges we now face such as diffuse pollution and climate change. It identified the need for a more integrated policy framework to address these challenges, with decisions made based on consideration of whole ecosystems, and the services they provide. It identified living within environmental limits as one of five key principles. And it also committed to piloting open and innovative ways to allow stakeholders to influence decisions.

2. The Natural Environment Public Service Agreement (PSA 28), states the government's vision for the Natural Environment is to secure a diverse, healthy and *resilient* natural environment, which provides the basis for everyone's well-being, health and prosperity now and in the future; and where the value of the services provided by the natural environment are reflected in decision-making.

3. In December 2007, Defra published *Securing a healthy natural environment: An action plan for embedding an ecosystems approach*[5]**.** Alongside this action plan was also published *An introductory guide to valuing ecosystem services*[6]**.** Both documents highlight the need to develop a more strategic framework for policy-making and delivery on the natural environment, based on the principles of an ecosystems approach.

4. This approach lies in integrating and managing a range of demands placed on the natural environment in such a way that it can indefinitely support essential services and provide benefits for all. The approach requires shifting the focus of policy making and delivery away from looking at the natural environment policies in separate silos e.g.- air, water, soil, biodiversity- and towards a more holistic or integrated approach on whole ecosystems. It also seeks to ensure the value of ecosystems is fully reflected in policy and decision-making at all levels. Further information relating to this work can be found on our website at **http://www.defra.gov.uk/environment/policy/natural-environ/index.htm.**

[4] 'Securing the Future: Delivering UK Sustainable Development Strategy' 2005, http://www.defra.gov.uk/sustainable/government/publications/uk-strategy

[5] The action plan can be found by following the links at this address http://www.defra.gov.uk/environment/policy/natural-environ/index.htm

[6] The valuation guide can be found by following http://www.defra.gov.uk/environment/policy/natural-environ/index.htm

5. The Delivery Plan for PSA 28 states that: "*to ensure a healthy and resilient natural environment, it is vital to take into account the impacts of climate change.*" The Adapting to Climate Change Programme and UK Climate Projections 2009 form part of a concerted programme of action in response to climate change currently being pursued across Government and form the basis for Defra's *Natural Environment – Adapting to Climate Change* project. This project focuses on reviewing policy and practice within Defra and its network to ensure that they are well placed to respond to a changing climate. The output will be a clearly articulated framework setting out current and planned activities aimed at adapting management of the natural environment in England within the context of PSA 28 and Defra's Departmental Strategic Objectives 1 and 2 (**http://www.defra.gov.uk/corporate/about/what/objectives08.htm)**

Rationale for Research

6. Generating evidence to assist policy making around an ecosystems approach and adaptation to climate change requires knowledge from a broad range of scientific, economic, and social science disciplines to be integrated to answer policy-relevant questions. For this reason, Defra and NERC commissioned through the Living With Environmental Change (LWEC) initiative six pilot systematic reviews relevant to Objective B of LWEC (**http://www.lwec.org.uk/objectives**) which focuses on the management of ecosystems for human well-being and protecting the natural environment as the environment changes. Two of these pilot reviews suggested that the topic of ecosystem resilience in the face of environmental change would be highly suitable for a full systematic review to bring together the existing scientific evidence to answer questions relevant both to climate change adaptation policy and policy aiming to take an ecosystems approach. These reviews can be found at (**http://www.defra.gov.uk/evidence/science/publications/index.htm)**

Aims of research

- 7. Through a thorough review of the existing evidence base, the aim of the research is to examine critically a small set of policy relevant questions based around the theme of the resilience of ecosystems and the (ecosystem) services and benefits that they provide to society and the economy in the face of changing external pressures, including (but not limited to) those from a changing climate.

8. Generic guidance on running a systematic review in the natural sciences can be found in: (Pullin & Stewart 2006. Guidelines for systematic review in conservation and environmental management. Conservation Biology vol. 20, no6, pp.1647-1656).

The objectives for this particular study will be to:

a. Define the question and the sub questions that the review will answer. This will need to be tested and possibly modified as the review progresses and may involve science/policy expert input.

b. Develop and deploy a search strategy and selection of search terms to ensure that publications relevant to exploring the question(s) are accessed. It is important to note that, in this cross cutting area, the selection of and access to a variety of evidence sources (i.e., not just academic journals) will be key to a thorough understanding of the issue.

c. Select relevant publications for further investigation by developing and using inclusion criteria that capture the wide range of evidence necessary to address the question, yet filter unrelated publications from the process.

d. Through the development of a set of criteria, quality assure the information generated through the search and selection processes and ensure that the evidence is both robust and truly pertinent to exploring the review question(s).

e. Synthesise and critically examine the remaining information to explore the review question(s) and provide a report on the policy-relevant conclusions that can be drawn from the existing evidence, together with an annotated reference library of the publications forming the evidence base for the review.

f. Drawing from the outputs of objectives a-e, provide an evidenced commentary on apparent evidence gaps in the current body of literature and, where appropriate, provide suggestions as to what sort of evidence activity would be most appropriate to fill these evidence gaps.

Scope

9. Although the specifics of the review question and search protocols will be refined in the early stages of the study, researchers should show in their tender application a clear understanding of how they will develop the processes and protocols required for each of the objectives, giving examples of suggested review questions, likely literature sources, and ideas for quality and selection criteria in their application.

10. The range of evidence relevant to this area is broad, and will encompass both scientific literature (social and natural), economics literature, and other sources of "grey" literature, including government reports and publications from non-governmental organisations. The researchers will therefore be expected to show how they intend to access a wide range of information sources in performing their searches and how they will quality assure the data they collect before using it to examine the policy relevant questions.

11. Similarly, researchers should show clearly how they intend to incorporate expert advice into their review, and how they will engage with the wide range of expertise relevant to the ecosystems and environmental change agendas.

Uses and Users of the Results

12. The customer for this work will be Defra's Environmental and Rural Group but the findings and recommendations will be relevant to a wider audience interested in policy surrounding the natural environment and environmental change, including, but not exclusively, other Government Departments and the Defra Network.

-
- **Research methods**
- 13. We do not believe that a survey is necessary to complete this study, but if an external survey is to be undertaken as part of this study approval will need to be gained from the Survey Control Liaison Unit (SCLU) in Defra. The Defra Policy Division will make the application for approval, but a contract involving a survey cannot be let prior to receipt of outline approval from SCLU.

Key Deliverables

20. Interim report(s) at appropriate point(s) in the contract.

21. A final "overview report" covering the policy and scientific background to the work, the methodologies employed, results, and conclusions. This should follow the format of the Defra SID5 form (max. about 50 pages). This final report will contain an Executive Summary of no more than 2 pages. There should also be a headline messages paper of approximately three to five pages aimed at policy-makers. Any further reports (and e.g. reference libraries) can be provided as Annexes to the SID5. All reports should be written in plain English.

Timetable

22. The contract is expected to commence by the start of February 2010. The contract is envisaged to last 4-5 months from the date of contract award.

Publication

23. It is the intention of Defra to publish the results of the work on the external website. All reports should therefore be suitable for publication on the Internet and should be accessible to a wide audience.

24. If you are going to include verbatim comments in your reports, please do inform people of your intention to do so, and obtain their permission.