Forestry Commission

Research Report

Human dimensions of adaptive forest management and climate change:

A review of international experience

Forest Research

Forestry Commission

Research Report

Human dimensions of adaptive forest management and climate change: A review of international experience

Anna Lawrence and Sarah Gillett

Forestry Commission: Edinburgh

First published in 2011 by Forestry Commission, Silvan House, 231 Corstorphine Road, Edinburgh EH12 7AT.

ISBN 978-0-85538-848-5

LAWRENCE, A. and GILLETT, S. (2011).
Human dimensions of adaptive forest management and climate change: A review of international experience
Forestry Commission Research Report.
Forestry Commission, Edinburgh. i–iv + 1–44 pp.

Keywords: ecosystem management; innovation; learning organisations; monitoring; research; uncertainty.

FCRP016/FC-GB(KA)/0K/SEP11

Enquiries relating to this publication should be addressed to:

Forestry Commission
231 Corstorphine Road
Edinburgh
EH12 7AT

T: 0131 334 0303
E: publications@forestry.gsi.gov.uk

If you need this publication in an alternative format, for example in large print or in another language, please contact The Diversity Team at the above address. Telephone: 0131 314 6575 or Email: diversity@forestry.gsi.gov.uk.

The author can be contacted at:

Forest Research
Northern Research Station
Roslin
EH25 9SY

T: 0131 445 8716
E: anna.lawrence@forestry.gsi.gov.uk

Acknowledgements

This review was funded by the Forestry Commission's climate change adaptation programme. We are grateful to our colleagues who commented on an earlier draft and provided insightful feedback, particularly in relation to the relevance for British forestry: Richard Carrick, David Edwards, Mariella Marzano, Bill Mason, James Morison, Bruce Nicoll, Duncan Ray, John Weir and Vicky West. Helen Armstrong wrote the case study in Box 9.1. Anna Duckett redrew diagrams to comply with copyright requirements.

Contents

Executive summary 1

1. Overview 3
   - Purpose of this report 3
   - Relation to climate change 3

2. **Introduction** **5**
   - Background 5
   - Definitions and origins 5
   - Adaptive management as a social and institutional issue 7
   - Review methods 8
   - Steps in adaptive management 8

3. Stakeholder engagement 10
   - Which stakeholders? 10
   - Sources of knowledge 10
   - Role of researchers 11
   - Partnerships and networks 12
   - Communication 13

4. Planning and implementation 14
   - Asking whether adaptive forest management is the right approach 14
   - Fitting into the planning hierarchy 14
   - Managing by experimentation 14
   - Planning and scale 15
   - Planning and time horizons 16
   - Defining goals and options 16
   - Silvicultural options 17
   - Modelling and decision support 17

5. Monitoring 19
   - Challenges and constraints 19
   - Developing criteria and indicators 20
   - Starting from a good baseline 21
   - Monitoring by volunteers 21

6. Learning 22
   - Information management 22
   - Organisational cultures and risk 22
   - Organisational capacity 24

7. Evaluating adaptive management 25
   - Judging success 25
   - Cost-effectiveness 26

8. Institutionalisation of adaptive management 27
   - Policy processes 27
   - Adaptive forest management adopted in forest policy 27

Allowing risk 28
Operational guidance 29

9. Adaptive forest management in Great Britain 30
Precedents for adaptive forest management in Great Britain 30
Stakeholder engagement in Great Britain 30
Planning and implementation in Great Britain 31
Monitoring in Great Britain 32
Learning in Great Britain 32
Institutionalisation of adaptive forest management in Great Britain 32

10. Conclusions 34
Summary of key findings 34
Research priorities in the British forestry context 35

References 37

Appendix 43

Glossary 44
Abbreviations and acronyms 44
Definitions of related terms 44

Executive summary

1. This is a review of the literature about the concept and application of adaptive management (AM), in forests and other environments. It aims to understand the social and institutional requirements of adaptive forest management (AFM), and identify areas that require further study in order to better understand its relevance for forest management in Great Britain.

2. AM combines planning, implementation, monitoring and modification of resource management in response to monitoring. There are intentional connections between the planning, monitoring and modification steps. Many take the view that, correctly understood, AM is not simply 'trial and error' or 'learning by doing', but a highly structured approach to planning, implementing, monitoring, reviewing and modifying in the light of new evidence in collaboration with relevant stakeholders. Nevertheless there may still be important lessons from approaches that incorporate parts of this ideal.

3. AM explicitly addresses situations of complexity and uncertainty. It is widely seen as part of an appropriate response to climate change and other environmental change. Most examples to date have not been developed as a response to climate change, but this agenda has increased policy interest.

4. AM requires social science input because it involves multiple stakeholders, new forms of institutional partnerships, structures and processes for organisational learning, and innovative approaches to communication and information management between scientists, resource managers and other stakeholders. At an operational scale, forest managers may need to interact with other managers and owners across landscapes or catchments.

5. AFM represents a shift in forestry culture. It contrasts with planned adaptation to climate change, which aims to determine robust solutions a priori, by knowing and controlling all the variables. It also contrasts with the historical approach of economic optimisation of forest production.

6. Stakeholder engagement is now widely accepted as integral to forest management in many countries. Its value in AFM is particularly important because of the need to benefit from a range of different sources of knowledge, and the need to understand the impact of uncertainty and risk taking on stakeholders. Because of its systematic approach to dealing with uncertainty, AFM can help to reduce tensions and conflicts between stakeholders, particularly at the strategic and tactical levels.

7. AM requires particular attention to communication because it relies on new and unfamiliar relationships and interactions between stakeholders. In particular the roles of scientists and resource managers can become blurred, or cross pre-existing boundaries. The scale and complexity of experiments and the need to draw on multiple kinds of knowledges can benefit from partnerships and networks. The literature reviewed here, and feedback from colleagues, suggests that these relationships are less familiar than many researchers and practitioners believe.

8. AFM requires innovation. The literature is almost silent on the sources of ideas that fuel such innovation. It also requires conscious experimentation. This represents a challenge to many established organisational cultures.

9. Many authors highlight modelling as central to AFM, because of the need to test hypotheses in complex systems. Most examples from industrialised countries use computerised modelling to generate management options. However, this is not always the case and modelling can be more qualitative and participatory. Engaging stakeholders (particularly non-specialist stakeholders) with models is highlighted as a significant challenge.

10. Monitoring is a key characteristic of AFM. It is often a weak point in the process where many AM projects have faltered. This is because of the high costs of data collection, poor data management, the long timeframe over which monitoring must occur, and the challenges of designing indicators of complex concepts such as resilience. A greater role for volunteer data collection could be envisaged.

11. For a process to be truly adaptive, data collected from monitoring must be interpreted and compared with expectations. These findings then form the basis for the next iteration of planning and implementation. As with the collection of monitoring data, these stages often suffer from poor resourcing.

12. Organisational structures, values and tools that support learning are fundamental to AM. Environmental and forest management organisations typically see themselves as practical, 'can-do', non-reflective, competitive, expert, controlling and risk averse. These values undermine experimentation and learning. However, they are not universal values, and there is scope for learning from examples of successful organisational change.

13. It is challenging to define and measure successful AFM. This is because AM is a continuous process of moving towards a travelling goal (of enhanced resilience and decreased uncertainty). Approaches to evaluating AFM vary between evaluating the process, and evaluating the outcomes. One measure of success is the adoption of a robust approach to implementing AFM in an organisation. The greater challenge is to evaluate the outcomes. While there has been considerable work in developing indicators of resilience and uncertainty this has not, perhaps, been translated back into the practical contexts in which AFM is applied.

14. AFM is usually implemented first at the local scale. The literature suggests that institutionalisation (policy and organisational structures and processes) to support it follows in the wake of experience. There are, however, still few examples of wider policy and institutional contexts that can create the space in which local AFM takes place, or which build on experience through scaling-up and formalising the partnerships and structures required.

15. While there are a few good examples of technical guides to AM, much of the practical advice is currently available in case studies. Operational guidance will be needed that is tailored to particular ecological and institutional contexts.

16. AFM is not explicitly adopted in Great Britain and there is little documented experience. Recent innovations including continuous cover forestry and woodland grazing provide experiences that could contribute to a growing understanding of AFM. The British context is one of relatively small-scale and diverse patterns of land use, high societal expectations and use, relatively high proportions of private landowners, and an increasing institutional culture of partnership. These conditions are sufficiently different from conditions elsewhere to warrant a specifically British focus on relevant lessons from AFM.

17. The review concludes with proposed research priorities that would build on the experience summarised in this review, and enhance its relevance for the British context. These focus on how risk and uncertainty are perceived by relevant stakeholders, and how that affects their management practices; cross-sectoral collaboration and partnership; innovation, learning and institutional change; interactions at the interface between practice and science; and monitoring and evaluating the application and outcomes of AFM.

1. Overview

An adaptive management approach encourages a disciplined approach to management, without constraining the creativity that is vital to dealing effectively with uncertainty, risk, and change. (Bell *et al*., 2008a)

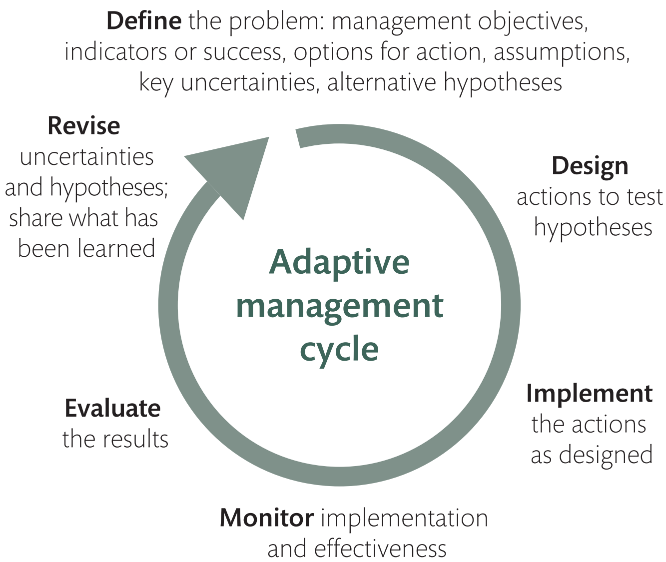
Purpose of this report

This report is a review of published literature on adaptive management (AM) in relation to forests, and is intended to help readers understand the implications for forestry in Great Britain (GB).

AM is an approach that aims to respond to uncertainty and increase resilience in complex social-ecological systems such as forests. It treats forest management as experimental, with strong reliance on monitoring, learning and feedback to adjust future decisions.

A simple model of AM is shown in Figure 1.1. More complex variations are cited throughout the review.

Figure 1.1 The adaptive management cycle (adapted from Murray and Marmorek, 2004).



In this report we use the term adaptive management to refer to experience of AM across a range of ecosystems and landscapes; adaptive forest management (AFM) refers to examples specifically located in forests. The latter are much scarcer in the literature, and there are useful lessons to be learnt from experience with wider AM. Oliver and Larson's (1996) book on stand dynamics did much to bring AFM to a wider forestry public. Where appropriate we highlight the implications of transferring lessons from AM to forests specifically. AFM is widely discussed in North America, but the term has only recently being used in UK forestry (Kerr *et al*., 2002; Mason and Kerr, 2004; Mason *et al*., 2009; Read *et al*., 2009). Globally, several authors note that the AM rhetoric greatly exceeds practice (Allan and Curtis, 2005; Gregory, Ohlson and Avrvai, 2006; McAfee, Malouin and Fletcher, 2006; Duncan and Wintle, 2008). This report examines lessons from experience and considers their relevance for the UK.

AM requires a combination of particular technical expertise (e.g. in modelling and analysing complexity) and managing social and organisational processes (e.g. in stakeholder consultations, information management and decision-making processes). While our review refers to the technical challenges raised in the literature, the focus is on the social, cultural and institutional challenges that are less often considered in discussing AM.

Relation to climate change

The relevance of AM in the face of climate change uncertainty is well documented. For example, the International Union of Forestry Research Organisations (IUFRO) notes:

The uncertainties associated with climate change emphasise the need to identify robust forest management strategies – those that are likely to achieve the objectives of sustainable forest management in a wide range of potential future climate conditions. Such strategies must also be flexible and responsive to new information and therefore should incorporate the principles of adaptive management. (Seppälä, Buck and Katila, 2009a)

The same authors note that 'To date, forest-sector responses to climate change have mostly been reactive' (Seppälä, Buck and Katila, 2009a). In other words change has been unplanned and unmonitored. AM contrasts with this.

The Read Report, *Combating climate change – a role for UK forests*, notes the considerable potential for UK forests and trees to contribute to climate change mitigation and adaptation. However, to do so, it notes, 'substantial responses are required of the forestry sector' (Read *et al*., 2009, p. xii), and suggests that AFM be used to assess the impact of management options on carbon.

In the same report, the chapter on forest adaptation concludes:

There must be adequate monitoring of forest and woodland states and processes to assess and adjust the use of adaptive management; improved decision-making processes will be needed to cope with the assessment of risk, and the inherent uncertainties. (Kirby, Quine and Brown, 2009)

At a strategic level, this connection is now reflected in the UK Forestry Standard (UKFS), which is the Government's statement of criteria and standards for the sustainable management of forests and woodlands in the UK. The UKFS is accompanied by thematic guidelines, which since June 2011 include Climate Change Guidelines. These state:

The uncertainties over climate change, coupled with the long-term horizons in forestry, suggest that resilience to climate change will be a key attribute for most types of forests and woodlands ... Appropriate choice of species and origin, diversity in species and structure, and effective stand management may all help to build resilience. These measures will also develop the ***management flexibility*** *required for forests to thrive in a changing environment*. (Forestry Commission, in press; emphasis added)

This 'management flexibility' is described further in the 'Precedents for adaptive management in Great Britain' section on page 30.

Most of the work reviewed here does not specifically mention climate change, but instead relates the need for AM to address sustainability more widely. Ogden and Innes (2009) note that sustainability depends on adaptiveness, and comment:

Climate change is providing the impetus and a forum for discussing a broader issue: the need for a more comprehensive research and monitoring program to support the sustainable management of forest resources.

2. Introduction

Background

Forestry and forests form a key constituent of policy responses to both climate change mitigation and adaptation (Read *et al*., 2009). The climate change agenda places new socio-political demands on forestry, as well as biophysical opportunities and constraints. This means that the natural and social environment in which forest management is conducted is evolving. Forestry, as silviculture and as a component of wider land-use decisions, will need to evolve both to respond to new constraints and make best use of new opportunities.Until recently many authors noted a 'general lack of responsiveness to global carbon and climate change concerns' (e.g. Tittler, Messier and Burton, 2001). In the last few years, however, preparing for climate change has become more important to policy advisers in Great Britain, Europe and internationally (Nabuurs *et al*., 2007; Mason *et al*., 2009; Read *et al*., 2009).

Attention in climate change policy has shifted from an early focus on mitigation to an increasing focus on adaptation. This mirrors the changing emphasis of environmental science over recent decades, from a descriptive and narrow hypothesis-driven approach towards 'system manipulation' to test understanding more holistically (J. Morison, pers. comm.). The UK is a leading actor in the development of climate adaptation strategies, with the publication of the England strategy in 2009 (Swart *et al*., 2009). Two key challenges of climate adaptation are uncertainty (about the scale and impacts of climate change) and complexity (of social-ecological responses to, and interactions with, that uncertain change).

Most of the literature about adaptive management (AM) is not about climate change adaptation, but rather about working with uncertainty and complexity. Although 'adaptation' is now closely associated with the climate change agenda, it has been seen as an ongoing process integral to management of complex ecosystems, in some parts of the world since the 1980s. Much of the documented experience relates to natural resource systems, including water and forests (Espigares, Zafra-Calvo and Rodríguez, 2008). Some knowledge has arisen out of earlier debates (from the 1990s) about 'sustainable forest management' and 'ecosystem based management' (Farrell *et al*., 2000, Mendoza and Prabhu, 2000). This makes it a rich source of experience for climate change adaptation.

Definitions[1] and origins

Adaptive forest management (AFM) is a systematic process for continually improving forest management, in conditions of complexity and uncertainty, by learning from the outcomes of operational practice.

The term was coined in the 1970s, to describe an approach which uses management policies as a source of learning, which in turn can inform subsequent actions (Holling, 1978; Walters and Hilborn, 1978; Walters, 1986).

At its simplest it is used to mean 'learning by doing' but many authors reviewed here emphasise that it is a much more scientifically structured process than this implies. For example, the IUFRO overview notes:

True adaptive management rigorously combines management, research, monitoring and the means of changing practices so that credible information is gained and management activities can be modified by experience. (Innes *et al*., 2009)

Key features that most definitions have in common are:

- use of multiple sources and types of knowledge;
- learning processes which link planned experimentation with monitoring and feedback into management;
- collaboration between resource managers, scientists and other relevant stakeholders.

Other terms used to describe similar processes include 'process based forestry' (Fürst *et al*., 2009), 'options forestry' (Bormann and Kiester, 2004), 'decision theory' (Conroy *et al*., 2008), 'adaptive co-management' (Seppälä, Buck and Katila, 2009a), 'adaptive collaborative management', 'sustainability science' (Brooke, 2008), and 'adaptive ecosystem management' (AEM) (Manring and Pearsall, 2005).

Adaptive management (AM) is often contrasted with more traditional approaches to environmental management such as 'command and control' (Olsson and Folke, 2001), or 'prescriptive' forestry (Lane and McDonald, 2002), which rely on 'models of reductionist science and one-way transference of knowledge' (Allan and Curtis, 2005).

[1] Related terms such as adaptation, adaptive capacity, complexity, resilience, risk, uncertainty and vulnerability are defined in the Glossary.

AFM represents a shift in forestry culture. It contrasts with planned adaptation to climate change which aims to determine robust solutions a priori, by knowing and controlling all the variables (Crowe and Parker, 2008). It also contrasts with the historical approach of economic optimisation (Glück and Rayner, 2009).

Definitions of AM from the literature include the following:

- a formal and logical framework for decision making in uncertain management or policy situations in the 'real' world of operational management (Bell *et al*., 2008a; Duncan and Wintle, 2008; Armitage *et al*., 2009), and improving management and policy by learning from outcomes (Bormann, Haynes and Martin, 2007);
- a systematic and rigorous approach to learning from the outcomes of historical, current or simulated management actions (Manring and Pearsall, 2005; Bormann, Haynes and Martin, 2007; Bell *et al*., 2008a; Duncan and Wintle, 2008);
- an iterative learning process which provides the possibility of ongoing future refinements through feedback loops that monitor and ensure that the strategy better defines and approaches the objective or goal (Bormann, Haynes and Martin, 2007; Julius *et al*., 2008);
- a planned approach to reliably learning how to improve policies or management practices over time in the face of uncertainty (Bormann, Haynes and Martin, 2007);
- a method of reducing uncertainty (Julius *et al*., 2008) by developing alternative management strategies and monitoring and evaluating how different indicators within a system will respond and implementing the more favourable options (Bell *et al*., 2008a).

Adaptive management:

- may allow the simultaneous implementation of alternative measures so that their efficacies can be compared (Bormann, Haynes and Martin, 2007; Seppälä, Buck and Katila, 2009a);
- is supported by and works in conjunction with various organisations at different scales (Armitage *et al*., 2009);
- may improve resource management by changing institutional arrangements and improving co-ordination among the public, private and non-profit organisations that comprise the inter-organisational network (Manring and Pearsall, 2005);

and is:

- tailored to specific places and situations (Armitage *et al*., 2009);
- suited to working in natural ecosystems with highly variable dynamics (McAfee, Malouin and Fletcher, 2006);
- suited to working in situations with incomplete knowledge (McAfee, Malouin and Fletcher, 2006; Julius *et al*., 2008).

This range of definitions and terminologies makes it important to be clear about our focus in this report. Following the lead of several key papers we focus on:

1. **AM as *both* a technical and a social challenge:** Jacobson *et al*. (2009) identify two separate discourses or fields of discussion: AM by experimentation and AM by collaboration. They provide guidance on combining the two.
2. **AM based on planning, monitoring and adjustment of management in response to monitoring:** Some examples are given of adaptation through unplanned change, but this is not included in our definition here.

Within this definition of AM as **experimental, collaborative and intentional**, there are two variations: active and passive (Gregory, Ohlson and Avrvai, 2006; Linkov *et al*., 2006; McAfee, Malouin and Fletcher, 2006; Bell *et al*., 2008b).

- **Active AM:** managers typically seek to define competing hypotheses about the impact of management activities on ecosystem functions and, in turn, design management experiments to test them. In this way, systems are deliberately tested through management interventions, often with several alternative types of management activities attempted in sequence or in parallel so as to observe and compare results.
- **Passive AM:** managers typically use historical data, from the specific area under consideration or from areas considered to be ecologically comparable, to develop a 'best guess' hypothesis and to implement a preferred course of action. Outcomes are monitored and new information is used to update the historical dataset and, if necessary, the hypotheses and management action.

These differences are shown by Linkov *et al*. (2006) in Figure 2.1, where flow (a) represents traditional management intervention, (b) passive AM, or 'trial-and-error', and (c) active AM. Both passive and active AM always involve a learning feedback loop, but active AM is more structured, with multiple models defined and compared.

Despite the attention given to these distinctions by several authors, Duncan and Wintle (2008) report that active AM is not widely applied in practice, possibly because active AM would be more expensive. The body of experience in the literature focuses on passive AM, and on the need for rigour in planning, monitoring and feedback, which distinguishes it from a traditional or trial-and-error approach.

Figure 2.1 Comparison of (A) traditional, (B) passive and (C) active adaptive management (adapted from Linkov et al., 2006).

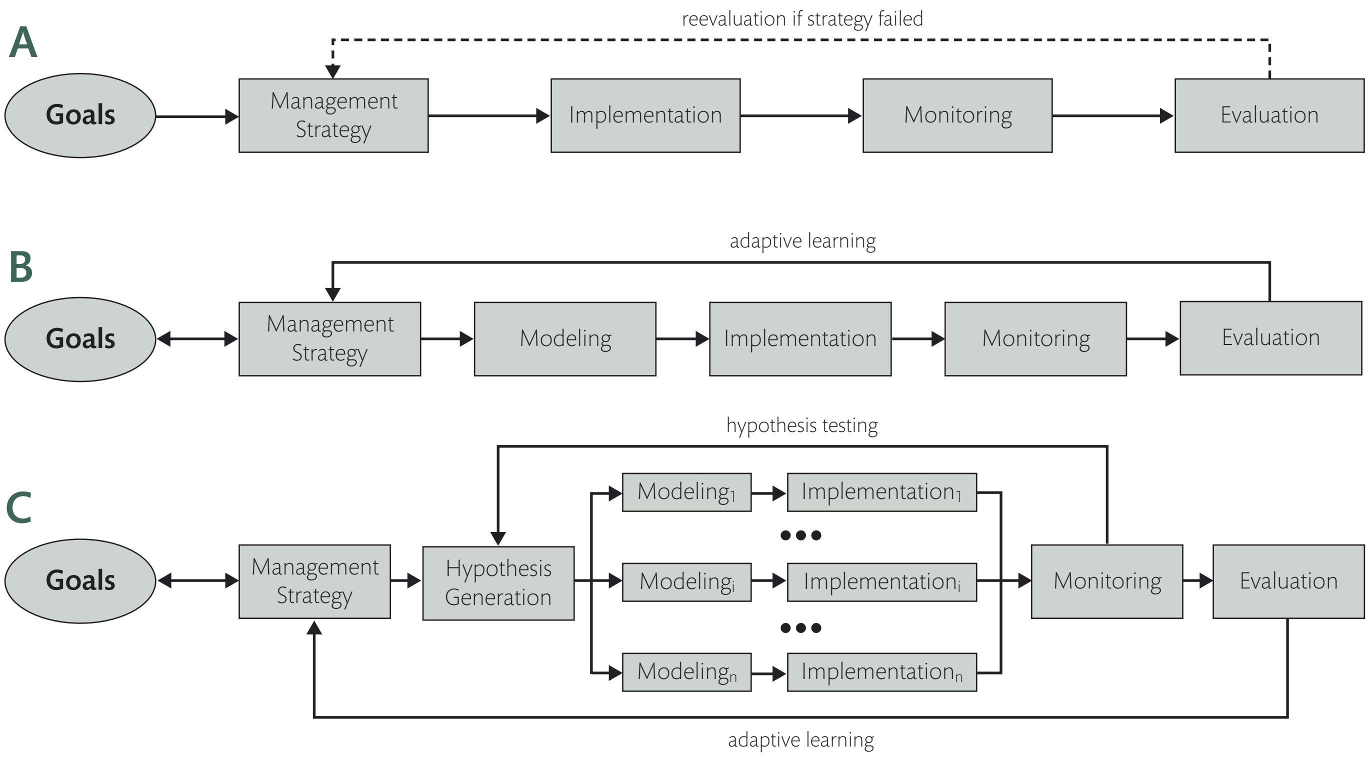
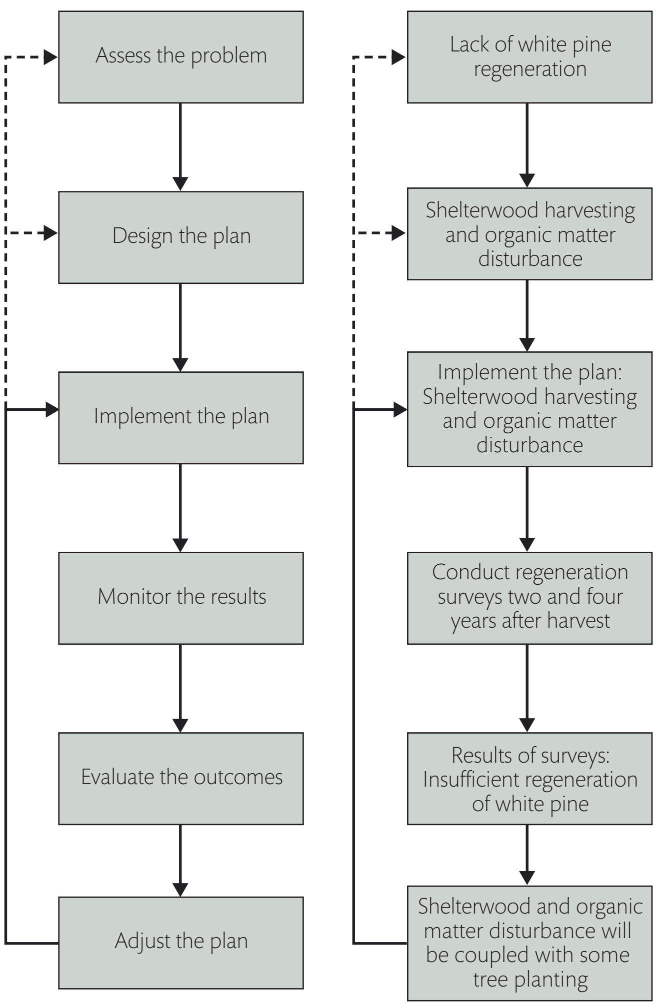


Figure 2.2 The application of AM to an example. Redrawn from D'Eon (2008).



A very simple example of the AFM process is given by D'Eon (2008), where each stage of the AM approach is applied to the problem of lack of white pine regeneration (Figure 2.2); the stages of AM are shown on the left, and an experiment carried out on white pine regeneration mirrors the stages of the process on the right. Here, the 'modelling' stage is represented by the hypothesis that shelterwood harvesting will increase regeneration. Many examples involve more complex hypotheses, whose assumptions are often explored using more complicated models or simulations of the processes under observation (see the 'Modelling and decision support' section on page 17).

Adaptive management as a social and institutional issue

Although originally proposed as a technical, rational planning approach (e.g. Oliver and Larson, 1996), AM has increasingly come to be seen as a process that requires integration of environmental science (or forestry) with social science.

As noted above, the large literature on AM includes two strands – one emphasising the technical processes of modelling complexity and experimenting, the other emphasising the social processes of collaboration (Jacobson *et al*., 2009). The 'experimental' approach is most often taken in industrialised countries, and the 'collaborative' approach in developing countries (Espigares, Zafra-Calvo and Rodríguez, 2008). However, there are many calls in the literature to take a more integrated approach.

There are a number of reasons why AFM demands more social engagement than conventional forest management. Broadly, these reasons are scale (and localness); relevance and incorporation of different stakeholders' knowledge; and the need for behavioural and organisational change in forestry. We elaborate on these below.

In the context of climate change, adaptation is a more localised challenge than mitigation. Adaptation has to occur everywhere, in response to the specific local phenomena that arise with climate change. This means that there needs to be a 'proper balance between generic knowledge development and targeted, context-specific research, in close collaboration with local and sectoral stakeholders' (Swart *et al*., 2009), which in turn requires an increased role for the social sciences (Swart *et al*., 2009).

Indeed, while mitigation policies are usually developed and applied in a top-down, large-scale manner, adaptation policies are often developed on a smaller scale in contexts specific to particular communities or sectors (Swart and Raes, 2007). For example, trees planted in any part of the world can be used to mitigate increases in greenhouse gases, which has a global benefit; on the other hand trees planted in a particular watershed will only help settlements in that watershed to adapt to increased risk of flooding.

Complex systems are managed at a range of scales. This is one of the challenges that makes management decisions particularly difficult. What is experienced as beneficial on a large regional scale may not provide benefits locally, and vice versa. AM therefore requires stakeholder engagement, collaboration, mutual learning and institutional development (e.g. through networks and partnerships) at a range of scales (Bormann, Haynes and Martin, 2007; Armitage *et al*., 2009).

AFM includes the social institutions and processes whereby forestry decisions are made – including policy and planning processes, land ownership, partnerships etc. Case studies from around the world show that institutional and economic barriers have often been more limiting than technical barriers. Building and maintaining the partnerships between existing institutions and newly involved stakeholders requires considerable effort. MacDonald and Rice (2004) note that opportunities for conflict are greatest in the assessment and design steps of the AM cycle; however, they found that progress could be maintained by promoting flexibility, trust and consensus building.

Review methods

This review draws on papers and reports from across the temperate regions of the world, in particular from the USA, Canada, Australia and Europe. Focusing on these regions, we searched bibliographic databases and the internet to identify academic papers, policy documents and reports which either indicate a need for, or analyse the use of, AM processes in forestry and other natural resource management.

Two experiences have been analysed in particular detail in the literature, and their background is described in Box 2.1 to orientate the reader. In one case biological conservation was the priority objective, while in the other increasing timber production was the aim of the approach. While these are the most prominent cases of AFM they represent contexts dissimilar to those in Great Britain and we have included in our review a much wider literature beyond that of forests. We have not aimed to reference everything we have read but rather to find key references which provide overviews and insights, and to supplement these with a range of examples.

Steps in adaptive management

AM is an iterative or cyclical process that incorporates learning as part of the management approach. In this sense it is similar to the policy development cycle, which incorporates monitoring and evaluation as part of an evidence-based approach.

Despite the multiple interpretations of AM, practices labelled as AM share a common methodological scheme (Espigares, Zafra-Calvo and Rodríguez, 2008), which includes monitoring, active management approach, participation by the local population and experts, and modelling techniques.

Various authors present between four and seven steps in the AM model (Bormann, Haynes and Martin, 2007; Bell *et al*., 2008a; Jacobson *et al*., 2009). After deciding on the need to take an AM approach, the process can be summarised as:

1. Stakeholder engagement
2. Goal setting
3. Model or experimental development
4. Action
5. Monitoring
6. Interpretation and feedback

This fits closely with the conventional research cycle but 'interpret' replaces 'evaluate' (Bormann, Haynes and Martin, 2007).

Box 2.1 – Long-running cases of adaptive forest management

Northwest USA: protecting communities and the economy after the northern spotted owl

By the early 1990s the US Forest Service was facing irreconcilable difficulties in achieving the multiple goals of forest management (biological, social and productive) in the Pacific Northwest. Concerns over the decline of the northern spotted owl led to a court injunction against timber harvesting and, following presidential intervention, a new Northwest Forest Plan took an AM approach that reduced productive area by 80%. The prominent role of scientists in the process was notable, but so too was the resulting focus on AM because of 'the explicitly acknowledged uncertainties in the conservation biology approach' and its outcomes (Bormann, Haynes and Martin, 2007). However, while science was well incorporated when designing the initial management experiments, results from those experiments were not accounted for in the second iteration of experimentation (Gosselin, 2009).

A cornerstone of the Northwest Forest Plan was AM and in particular the establishment of Adaptive Management Areas. It attempted to link the biophysical and socio-economic goals of forest management by creating high quality jobs for residents of forest communities in forest stewardship and ecosystem management work (Charnley, 2006). While success was judged to be 'mixed' (McAlpine *et al.*, 2007), the Northwest Forest Plan has been studied and evaluated very thoroughly, leading to sound lessons based on 10 years of experience. The example in particular highlights the limitations of institutional capacity, funding and leadership.

Ontario: increasing timber production through active adaptive management phase, experiments in IFM have been established

Another well-documented case is the Canadian Ecology Centre – Forestry Research Partnership (CEC-FRP), which was established in the Canadian province of Ontario between commercial, scientific and state forestry partners (Bruemmer, 2008). The three primary partners agreed in 2002 to support it for an initial period of 5 years, and reaffirmed commitment in 2008.

The motivation for the partnership was to find a way to maintain forest productivity in the face of new legislation to increase the area of protected forest, combined with predicted timber shortfalls 2020–40 (Bell *et al.*, 2008b). This has taken shape as the 10/10 goal: to allow Tembec (the commercial partner) to increase its annual allowable cut by 10% in 10 years, by shifting from the prevalent extensive forest management to intensive forest management (IFM).

Although the partners expected to begin IFM immediately, it became apparent at an early stage that the programme would need to progress in two phases: a research focused phase, and a forest management phase. The first, research focused phase, has taken 6–8 years, consisted of 140 individual projects, and focused largely on reviewing and synthesising existing information, prioritising areas for IFM and identifying knowledge gaps (Bell *et al.*, 2008a). Following this phase, experiments in IFM have been established.

Jacobson *et al*. (2009) set out these steps along with questions to guide the manager. These questions are designed as a checklist (see Appendix 1) to ensure that AM is both scientifically robust and socially inclusive throughout the process. The steps in AM are discussed in further detail in the sections below.

3. Stakeholder engagement

Which stakeholders?

The first stage in the adaptive management (AM) process is to identify and engage stakeholders (Jacobson *et al*., 2009). Stakeholders are those who have a legitimate interest in the way that the resource is managed, and/or have knowledge or perspectives which will contribute to the usefulness of planning and evaluation. For example, adaptive forest management (AFM) applied at a landscape level may involve forestry professionals (both public and private), private landowners, government agencies, scientists, community members, conservation non-governmental organisations (NGOs) and farmers. In other cases the range may be smaller, but still challenging: Rouillard and Moore (2008) describe the challenges of involving forest planners and scientists in joint decision making.

The literature often expresses this need for wider participation of stakeholders in AM, but leaves some questions unanswered, about how those stakeholders are chosen, and which stages of AM they can, should or do participate in. Tuler and Webler (2010), for example, provide evidence to show how different social and environmental contexts affect stakeholders' preferences for participation. Work from Canada questions the selection of representatives on decision-making panels and highlights a tendency for committees to include those with existing contacts and power (Parkins, 2006, 2010; Reed and Varghese, 2007). Furthermore, stakeholders may differ in their interest or willingness to engage with the specific challenges of forest decision making. For example, in relation to envisioning different forest future scenarios, Frittaion, Duinker and Grant (2011) find that participants differ in their abilities to 'suspend disbelief', and are affected partly by their past experiences and expertise.

Stakeholder involvement can, but does not always, include the 'general public'. Several authors point out the need for both the public and politicians to be assured of the wisdom of experimentation, particularly on public land. As noted in a study on public perception of climate change and forest management:

Perception of risk or subjective risk is playing an increasingly important role in risk assessment. (Williamson, Parkins and McFarlane, 2005)

In such cases, public engagement can give foresters the 'social licence' to take the risks that members of the public are concerned about (Butler and Koontz, 2005; Innes *et al*., 2009).

Conventionally, forestry professionals make forest management decisions, and hold expertise about how to implement such decisions. Some of the scientific reviewers of an earlier draft of this report expressed discomfort with the idea that AFM might involve participation at all stages of the process. Not all stakeholders will understand ecosystem complexity and uncertainty.[2] Most will not be trained in conventional forest management planning and practices – and many others may lack the interest or desire to be involved with these technical stages (Frittaion, Duinker and Grant, 2011). In AFM it may be the case that foresters decide how to implement decisions based on participatory assessment of options. It is highly likely that, in many cases, stakeholders will willingly engage in appraising options, selecting preferred management outcomes, and evaluating those outcomes after implementation, while forestry professionals will be responsible for implementation. However, we emphasise that this separation of roles has not been established by documented published evidence, and that there are open questions about the roles of foresters, scientists and other stakeholders at all stages of AFM.

Another assumption that remains relatively unproven is that of conflict management. Some authors indicate that AM is intended to reduce tensions between stakeholders (Bormann, Haynes and Martin, 2007; Bell *et al*., 2008a). While experience and anecdotal evidence suggests that stakeholder engagement is likely to achieve this, there is in fact little documentation of the outcomes of such approaches. Allen *et al*. (2001) provide one example where involving stakeholders reduces opposition, by combining and meeting the needs of different stakeholders in the tussock grasslands of New Zealand's South Island.

Sources of knowledge

Involving other stakeholders in forest management often opens up access to new sources of knowledge about the forests, and different points of view on forest management based on the various remits and priorities of the wide-ranging stakeholder groups. Quantitative information provided by

[2] AM is a good example of what has been termed 'post-normal science' (Funtowicz and Ravetz, 1994; Ravetz 2006; Swedeen 2006). This includes multiple perspectives on sustainability, combined with multiple objectives, not all of them mutually compatible.

scientists can be supplemented by the experiential knowledge of practitioners and experts, and by local knowledge of other stakeholders.

Stakeholder engagement is a form of networking that can facilitate information exchange and promote cross-sectoral learning. Private foresters, community groups and scientists may have knowledge of forests that complements the technical knowledge of state foresters. Communities may hold knowledge about forests or climate that is specific to their local context, and may have long-term observations which can be of importance when assessing change and rate of change due to both climate and management.

Experiential knowledge, for example, can enhance understanding and predictions in AFM (Kimmins *et al*., 2005; Fazey *et al*., 2006).

Given the complexity of environmental systems and the need for immediate action, experiential knowledge is often the best evidence that is available … [There is] *considerable difference between disseminating the opinions of an individual and using rigorous methods to elicit the experiential knowledge of a group of people with extensive experience of an environmental system.* (Fazey *et al*., 2006, p. 1)

This recognition of the value of 'implicit' or 'tacit' knowledge has grown among ecologists over the last decade. The conservation biologist M.E. Soulé acknowledged in 1985 that conservation biology (another complex uncertain science) needed to be 'holistic, synthetic, eclectic and multidisciplinary', dependent on both biology and social science, and a 'mix of science and art requiring **intuition as well as information**' (Soulé, 1985) (cited in Fazey *et al*., 2006, p. 4, emphasis added).

Experts may be able to make accurate predictions without necessarily being able to articulate the reasons for their predictions. This can be combined usefully with more objective knowledge. For example:

expert opinion proved valuable for assessing the impacts of grazing levels on bird density in woodland habitat when it was combined with survey data using a Bayesian statistical approach, especially when survey data were unavailable. When the experts agreed, predictions were found to improve considerably, and when the experts did not agree, the results were similar to those obtained when expert information was not used. (Fazey *et al*., 2006, p. 3)

We have not found any studies of the use of experiential knowledge in forestry. It is clear, however, from personal communication with practitioners that forest managers draw heavily on experience, often to the extent of ignoring quantitative knowledge of the kind presented in yield tables. While Fazey *et al*. (2006) express doubts about the acceptance of experiential knowledge in conservation biology, it is possible that such acceptance is higher in forestry, but this needs to be explored further.

Other kinds of knowledge may also contribute to the AM process. Local landowners, residents and land users will have knowledge of the site and management options that can be tested. This use of 'local knowledge' is used well in contexts which include indigenous people (e.g. Berkes, Colding and Folke, 2000; Elmqvist *et al*., 2004), and for adaptive collaborative management in tropical forest contexts (e.g. Colfer, 2005). To understand the role of private landowners' knowledge in contributing to land management, however, the best documented examples are from agricultural conservation. For example, ditch cleaning practices of farmers in the Pevensey Levels proved to be more favourable for the conservation of a rare spider than the expert guidelines provided by English Nature (Harrison, Burgess and Clark, 1998).

Involving communities and local people may also enable a greater understanding of the social, cultural and political contexts that influence attitudes and behaviours. The contribution of volunteers to biodiversity data and awareness of environmental change is widely recognised and can be incorporated explicitly into AM (Lawrence, 2006, 2009a).

Role of researchers

AM changes the relationship between researchers and forest managers. By definition, there is a research process contained within the management process. In addition, there is a need for closer links between research off-site (e.g. pre-existing data), and management (Gosselin, 2009). Researchers will have to include or account for messy human and institutional factors in experiments, which may complicate professional achievements, such as publishing work in journals that require statistically rigorous and repeated trials. Conversely, managers may have to be prepared to be challenged by researchers, to be open to uncertain outcomes, and to collect data for monitoring (Kimmins *et al*., 2005; Bormann, Haynes and Martin, 2007; Koontz and Bodine, 2008). These new relationships do not always come easily:

Scientists, for example, can become frustrated by the lack of support from policy makers and managers who are impatient with the long time periods that may be required for acquiring statistically valid field trial results. Conversely, administrators can become frustrated by scientists who appear to be insensitive to the risks posed by experimentation and seem to believe that the *pursuit of scientific knowledge is a justified end in itself.* (Gregory, Ohlson and Avrvai, 2006)

Managers, too, can be reluctant to engage with existing scientific knowledge. Researchers can want results to be conclusive before releasing them, or managers can ignore research altogether. For example, in the case of management for the northern spotted owl in the Pacific Northwest (Box 2.1), stakeholders (managers or scientists) were reluctant to treat current knowledge about habitat as incomplete and needing further testing (Gosselin, 2009). As the experience with CEC-FRP shows, the process of assembling relevant knowledge and testing its rigour can be a long and expensive one (Bell *et al*., 2008a).

Successful AM therefore throws researchers and resource managers into much closer partnership. Several papers describe a typical relationship between forest researchers and managers, which lacks a systematic learning approach. Bormann, Haynes and Martin (2007) note that before the Northwest Forest Plan, 'learning was rarely considered a legitimate task for managers; learning was the task of researchers, who transferred "technology", usually in a one-way fashion, to managers' (p. 187). Forest researchers are accustomed to designed reductionist experiments, whereas AM requires them to engage with large-scale, complex management strategies, and to engage much more closely with the forest managers.

This change in role can be one of the most difficult parts of AM adoption (Bormann, Haynes and Martin, 2007). The forest managers can see it as a loss of autonomy and influence. Both scientists and managers can see it as an infringement of the boundary between science and practice. Specific mechanisms therefore need to be designed to help address these concerns. Two studies note the success of asking independent scientific panels to review management options before experimentation (Keough and Blahna, 2006; Gosselin, 2009). Another method is to involve scientists in the planning stages of AM, to advise on experimental design and/or modelling. Gosselin (2009) suggests 'scientific ad-hoc groups are useful reviewers of management plans and interpreters of best scientific data available'.

This relationship will also change over time. One of the longest-running AFM projects in the Pacific Northwest (Box 2.1) has shown that the need for general data and scientific opinion decreases with time, as more location-specific data become available and forest managers increase in confidence. Not all AFM programmes are led by scientists, but in cases such as these, where foresters are not used to experimenting and scientists have contributed much to the AM process in terms of guiding experiments, Bormann, Haynes and Martin (2007) recommend a 'handshake approach', which formally hands over the 10-year report from scientists to the forest management agency.

Partnerships and networks

Beyond the key relationship between scientists and resource managers, wider partnerships are a core component of AM. The importance of building partnerships and networks between stakeholders in complex systems (such as forest management) is cited repeatedly in the literature (Kimmins *et al*., 2005; Van Gossum *et al*., 2005; Brown, 2009; Gosselin, 2009; Rayner and Glueck, 2009).

Ambrose-Oji *et al*. (2010) offer a range of definitions of 'partnership'. One that illustrates the more formal end of the scale is:

a dynamic relationship among actors, based on mutually agreed upon objectives, pursued through an understanding of division of labor based on the respective comparative advantage of each member. (Gutrich *et al*., 2005)

Networks are less formal, defined by one AM review (Manring and Pearsall, 2005) as 'a decentralised and shifting set of alliances among independent strategic stakeholders'.

Networks, partnerships and co-operatives allow participants to exchange knowledge and information, to learn from each other, build social capital and promote innovation (Brown, 2009). Collaborations can encourage greater stakeholder participation, and can ensure that marginalised stakeholders are involved. Networks can also provide developmental support to stakeholder groups (Wolf and Hufnagl-Eichiner, 2007). By improving inter-sectoral and inter-institutional co-ordination, management at the landscape level can be optimised (Kimmins *et al*., 2005; Rayner and Glueck, 2009).

Sometimes networks and partnerships can be 'emergent' or 'self-organising' (Manring and Pearsall, 2005), while in other cases they depend on individuals with leadership qualities. Olsson, Folke and Hahn (2004) give an example where:

one key individual in a wetland landscape in Sweden, described as a 'local policy entrepreneur', initiated trust-building dialogue, mobilized social networks with actors across scales, and started processes for coordinating people, information flows and ongoing activities, and for compiling and generating knowledge, understanding, and management practices of ecosystem dynamics.

Many authors advocate employing a facilitator or 'collaborative capacity builder' to help build and maintain networks and 'foster the transfer, receipt and integration of knowledge' (Brooke, 2008; Brown, 2009). This could be an individual, or a 'boundary' organisation. Boundary organisations are defined as organisations or institutions (such as NGOs) that bridge scales or services between different stakeholders, helping to build adaptive capacity (Brooke, 2008; Brown, 2009).

Networks and partnerships are particularly important when AM is applied at the landscape scale, especially when managing fragmented forest landscapes (as in Great Britain) for common goals (such as improving resilience to climate change). There are several case studies in Europe and Canada of private forest owners (non-industrial private forestland) successfully engaging in co-operatives, and thus fostering a community in which owners and managers can share knowledge and expertise (Kittredge, 2005; Hull and Ashton, 2008). Examples of networks are showcased in Alaska for fire management (Chapin III *et al*., 2008) and in British Columbia for management of mountain pine beetle infestations (Parkins, 2008).

Institutions often find it hard to work together due to difficulties in communication and issues of power. Successful efforts to build, manage, and maintain a functional network:

depend largely on the extent to which this network evolves as a learning organisation whose members become capable of developing and pursuing systemic solutions through collaborative consensus-building dialogues. (Manring and Pearsall, 2005)

It can also be hard to ensure involvement of different stakeholders, particularly marginalised groups. In Canada adaptive capacity of forests to climate change is enhanced by links between NGOs, government, academics and the forest industry, which create opportunities for learning. However, Brown (2009) suggests that better links between provincial government and local communities and First Nations would enhance adaptive capacity of forests yet further.

The literature on partnerships, networks and other stakeholder relationships reaches far beyond the subject of AM, of course, and there is much to be learnt from that wider literature. In the context of AFM, however, one key issue is emphasised: the time and effort needed to develop good communication between partners in what is often a very new kind of relationship characterised by 'strong emotional responses' to the subject of forest management (Gregory, Ohlson and Avrvai, 2006).

Communication

When bringing together multiple actors from across multiple disciplines or sectors, communication is always going to be challenging. Different stakeholders can use different vocabularies, and misunderstanding can lead to mistrust (Kimmins *et al*., 2005; Koontz and Bodine, 2008). To make AM work at the regional or landscape scale, communication must be effective both within and across sectors. Several reviews note a lack of emphasis or attention to these processes. For example, Gregory, Ohlson and Avrvai (2006) conclude that scientists can tend to overstate their capability to measure complex functional relationships while misunderstanding the wider information needs of decision makers.

Manring and Pearsall (2005) describe a successful case study of AM of a river system in North Carolina, USA, which established a virtual network among stakeholders. Helped by facilitators in the early stages, relationships became more informal, and stakeholders were able to discuss ideas and ultimately come to decisions in a 'safe' forum. In North Carolina the network was virtual, but other authors feel that regular face-to-face communication is necessary (Koontz and Bodine, 2008). Others highlight the value of visualisation – using diagrams and models – for understanding complex scientific information (Kimmins *et al*., 2005).

Overall the AFM literature says little about the process of communication, and in particular about its effectiveness with different stakeholders, but it is clearly critical to a successful AFM process.

4. Planning and implementation

Asking whether adaptive forest management is the right approach

Before planning, it is necessary to consider whether adaptive management (AM) is the most desirable approach. Gregory, Ohlson and Avrvai (2006) express concern that AM is applied indiscriminately in too wide a range of contexts. They call for its need to be assessed against four categories of criteria: spatial and temporal scale, kinds of uncertainty, evaluation of costs and benefits, and institutional and stakeholder support. Scale is discussed later in this section, cost-effectiveness in Section 7, and institutional support in Section 8. Within these contexts, the problem to be addressed will be characterised by various types of uncertainty (elaborated in Box 4.1), and a scientific assessment will need to decide whether any of these sources of uncertainty are so great that an AM approach will not contribute valuable knowledge. Instead, effort may need to be invested in conducting baseline studies, or modelling, before clear hypotheses can be developed.

Box 4.1 – Sources of uncertainty to be appraised before embarking on adaptive management (from Gregory, Ohlson and Avrvai, 2006).

Structural – when important relationships between ecological variables have not been identified correctly or when their functional form is not known with precision.

Parameter – this dimension refers to the uncertainty associated with parameter values that are not known precisely but can be assessed and reported in terms of the likelihood or chance of experiencing a range of defined outcomes ... the ability to successfully meet the strict requirements for randomisation, replication, and representation lessens with both the number and scope of the uncertainties that must be probed.

Stochastic – AM may be an unreasonable concept when the resolution of key sources of uncertainty relies on low probability, randomly triggered, and highly variable events.

Confidence in assessments – if the level of uncertainty is high, then the use of AM may be inappropriate because the results of planned experiments will not be interpretable.

Fitting into the planning hierarchy

Management planning is a core activity of forest management, at a range of levels. If adaptive forest management (AFM) is to be integrated into forest management, it needs to be included in the management plan. A review of experience with AM planning finds that adaptation is often absent, or confusing and intimidating because it tries to 'answer too many questions, test too many treatments, or incorporate too complex a monitoring design' (Morghan, Sheley and Svejcar, 2006).

In order to fit with forest planning, the design needs to be clear, testing the outcome of one or a few selected options, and based on a well-defined decision-making process. Furthermore, to fit with existing organisational structures and systems, AM needs to be included at the **right level** of planning. Forest management plans are hierarchical, with operational plans nested within higher-level strategic plans (Tittler, Messier and Burton, 2001). Ogden and Innes (2007) provide a range of climate change adaptation options that can be included in plans at different levels. For example, an option at the strategic planning level is to 'adjust harvest schedules to harvest stands most vulnerable to pest outbreaks', while an option at operational level is to 'shorten rotation length to decrease the period of stand vulnerability to damaging insects and disease'.

Managing by experimentation

Several authors highlight the cultural challenges of the experimental approach in AM. Duncan and Wintle (2008) note the prevalence of the phrase 'best practice', which implies consensus on what is currently believed to provide the best chance of success. However, with the uncertainties associated with a rapidly changing climate, the need has arisen to monitor this success rate and test new methods that may provide better success rates going forward. This new complexity requires us to '[spread] management over a range of competing options in order to learn about them' (Duncan and Wintle, 2008, p. 160). Such options need to be planned and structured like experiments if this learning is to be rigorous. The experimental process is summarised below (taken from Lawrence *et al*., 2007):

- **Hypothesis formation:** a hypothesis should be formulated by taking into account historical and local data or information, expert and other stakeholder knowledge.

Discussion, qualitative or quantitative modelling can help to predict the outcomes of the hypotheses, and support the decision as to which hypothesis should be tested.

- Experimental design: experiments should be designed to test the hypothesis chosen, and to be rigorous should include controls (plots where variable(s) being tested are not changed), replication (multiple plots where the hypothesis is tested) and randomisation of the plots (to avoid bias, and to control for natural environmental variations in the woodland or forest).
- Development of monitoring plan: choosing the variables (indicators) that will be measured to enable the management intervention under experiment to be assessed against the hypothesis, or whether the experiment is producing the expected result.
- Collection of baseline data: all data chosen to be collected in the monitoring plan should be measured before the experimental treatment is applied to provide baseline data.
- Application of treatments and monitoring plan: the chosen management interventions are applied to the experimental plots, and monitoring data are collected regularly in line with the monitoring plan.
- Analysis of results: monitoring data are analysed and the hypothesis either proved or disproved. At this point results should be shared with the wider community.
- Re-formulation of the hypothesis: using the information from the results of the management intervention just tried, a new hypothesis should be formulated, and the process repeated.

While experimental approaches are designed to be rigorous, the reality of a complex system such as a forest sometimes makes controls and replication difficult or impossible.

Adaptive management, in any form, differs from basic science in that there is limited ability to 'control' for all factors influencing the effectiveness of management actions, making causal relationships difficult to delineate. In addition, opportunities for replication are limited: Management areas utilized as replicates for particular management treatments may differ in land use history, ecological characteristics, and locally associated values and constraints. In some situations, management is non-replicable and there is no opportunity for testing multiple hypotheses—for example, where whole catchments represent management units, or when management units are unique. (Jacobson *et al*., 2009)

The difference between passive and active AM lies in the experimental approach. Active AM is planned rigorously, as described above, while passive relies on existing data to inform new management decisions which are not tested, simply applied.

One barrier to applying an experimental approach to management is an entrenched view that 'management' and 'research' are separate budget categories. For example, Allan and Curtis (2005) describe cases where learning did not happen, because new planting was funded by 'implementation' money rather than 'research' money. This labelling of categories meant (in this case) that monitoring and evaluation did not take place (Allan and Curtis, 2005).

The challenge of introducing experimentation into management activities can be more than inadvertent category problems. Murray and Marmorek (2004) report that some organisations are hostile to AM training, and imply that they know what is best, illustrated by such comments as: 'we don't need to waste money on management experiments and monitoring'.

Planning and scale

There is a tension between scales inherent in AM. AM is most feasible when applied at small and local scale, involving fewer stakeholders and with lower risk impacts (MacDonald and Rice, 2004; Murray and Marmorek, 2004; Bormann, Haynes and Martin, 2007), but 'some of the management contexts where help to deal with scientific uncertainty is most needed are undeniably large and complex and messy' (Gregory, Ohlson and Avrvai, 2006). Furthermore, across these wider scales, it would be logistically impossible to treat all management as experimental, and it becomes necessary to select small sites from which lessons are then scaled up. The shift from local to wider scale implies not only an increase in the dimensions of the task, but new stakeholders and levels of governance. This is still a challenge (Gregory, 2002).

The cases where AFM is implemented most thoroughly are the vast forests of the northwestern USA, and central Canada; and where the great majority of the forest land is owned by the state. In the CEC-FRP (Ontario) private land was included in the programme, with the result that forests of up to 1.5 million hectares were covered by single management plans (McPherson *et al*., 2008). Indeed, in some cases the scale of forest cover is simply so vast that management intervention cannot be envisaged for the majority (McKinnon and Webber, 2005).

In most other contexts, the landscape-scale management required to address climate change will require interactions between multiple landowners. In much of Europe, this scale implies not only multiple owners, but also multiple land uses in which forestry is only one component. Thus:

A more integrated approach to land use is highly desirable since many ecosystem service flows depend on the interaction between wooded and open elements of the landscape. (Kirby, Quine and Brown, 2009)

This links the question of scale to the question of land use. While there is a considerable literature on AM in agri-ecological landscapes (Tengo and Belfrage, 2004), we have found little direct evidence of adaptive landscape level management involving trees. Because of the complexity of scale, Bolte *et al*. (2009) propose an integrative AM concept that combines (1) species suitability tests and modelling activities at the international scale, (2) priority mapping of adaptation strategies at the national to regional scale, and (3) implementation at the local scale. However, such an approach appears to leave no scope for learning upwards, from the experience of implementing such 'adaptation strategies'.

Hobbs (2003) advocates a different approach. Emphasising the serious challenges of working at meaningful ecological scales, he takes the view that it is possible to build upwards from the small scale to the large:

Multi-scale understanding is fostered by adaptive management, which uses fine-scale, mechanistic understanding to screen hypotheses to be tested at large-scales. (Hobbs, 2003)

He highlights the role of models in this, and advocates:

innovations in statistical analysis and study design, and a shift in the philosophy of science favoring model selection over traditional hypothesis testing. (Hobbs, 2003, p. 223)

This debate has implications for the relationships between science and practice, and the importance of communication between stakeholders about the inputs and outputs of the modelling process.

Planning and time horizons

There are challenges associated with time as well as spatial scale. Forestry is known as an activity which demands long-term planning, and it is over the long term that uncertainty is expressed. This is a particular challenge for AFM, where the traditional long-term time horizons need to be applied not only to planning but to monitoring and feedback. It is perhaps surprising that this feature is considered very little in the literature. Several studies noted long intervals between planning and monitoring. In both the Northwest Forest Plan and the CEC-FRP (Box 2.1) nearly a decade passed before the first phase of data collection was complete. In Oregon, the first 'action' stage of AM was completed only after 10 years (Bormann, Haynes and Martin, 2007). In Ontario, after 10 years, the first information gathering stage has been completed (Bell *et al*., 2008a).

The scarcity of comment in the literature can be explained by the fact that few AFM programmes have been running for long enough to fully understand the institutional challenges of these experimental timeframes. Nevertheless, emerging analyses of experience suggest some important implications.

Over the course of long-term experiments, policies and institutions are changing, and it can be difficult to maintain the momentum and commitment to processes which unfold over these kinds of timeframes (B. Mason, pers. comm.). At the same time, resource managers are often under pressure to make quick decisions or provide immediate advice, for example in relation to climate change uncertainty (J. Weir, pers. comm.).

There is another, human, factor involved. A study from the Netherlands and Germany suggests that foresters cannot identify with planning horizons beyond 15 years and, in practice, think about much more immediate time horizons when planning operations (Hoogstra and Schanz, 2009). This professional dimension, combined with changing external contexts, could lead to unplanned drift in the management of AFM experiments over longer time periods.

Defining goals and options

During the planning phase of AM, management objectives are defined. Beyond the usually political processes of setting broad societal goals for forest management, the definition of particular objectives for particular forests is in many countries an interactive and participatory process involving experts and local stakeholders (Duncan and Wintle, 2008). This activity is not without challenges, as it invites landowners and community members to engage in a process where foresters are on their traditional territory and can still rely on a 'sermon' approach to technology transfer (Hokajärvi *et al*., 2009).

The experts (including forest managers and scientists) have a key role in comparing goals with known management options. From these a set of core questions is chosen to test the options (Bormann, Haynes and Martin 2007). The process can be greatly facilitated by decision support systems (DSS), which incorporate structured comparison of options and associated risks (Ohlson, McKinnon and Hirsch, 2005; Gregory, Ohlson and Avrvai, 2006).

One important aspect seems to be missing from most studies. Numerous authors call for innovation in forest management (MacDonald and Rice, 2004; Innes *et al*., 2009), and highlight the need for 'imaginative approaches' (Seppälä, Buck and Katila, 2009a). We define 'innovation' in this context as management trials that differ from best practice recommendations. Concrete examples of such innovation, and more particularly its formal inclusion in AFM planning and monitoring, appear to be absent. As we discuss in Section 8, institutional cultures do not provide conditions that encourage innovation.

Forest planning is a highly structured process and, particularly in relation to public forests, each country usually has a specific hierarchy of increasingly detailed plans (Tittler, Messier and Burton, 2001), with varying specifications for stakeholder input at each level. It would be valuable to understand more clearly how such 'imaginative' options are generated and spread.

Silvicultural options

The silvicultural options for testing through AM are specific to each environmental, social and legislative context (Seppälä, Buck and Katila, 2009a), and in the context of climate change it has been noted that 'Practical adaptation measures need to be tailored to the different types of woods, woodland owners and their objectives' (Kirby, Quine and Brown, 2009).

Nevertheless, there are many proposals, working hypotheses and context-specific examples of suitable approaches, which can act as starting points for an AM approach.

As this review focuses on the social and institutional aspects of AFM it is not the place for a comprehensive review of the silvicultural options for consideration at the planning stage. However, some examples of options that have been explored in an adaptive way are listed in Box 4.2. These may help to orientate the reader.

It becomes clear, when we focus on concrete examples, that the kind of rigour required in AFM is not easily applied to broad 'principles' and that management options will need to be precisely defined in each case, in order to both test them, and to learn from the results. Ogden and Innes (2007) provide a much wider range of options, and link them to the strategic or operational level. From their examples too, only the options at operational level provide enough specificity to enable experimentation.

Box 4.2 – Examples of management options that can be tested through AFM.

- Shift from single-tree selection to group selection and shelterwood systems, to enhance quality of natural regeneration.
- Augment natural regeneration through planting where species diversity and potential adaptability is likely to be limited.
- Select species and management systems expected to reduce susceptibility to new pests and pathogens.
- Modify management practices such as rotation length, coupe size, tree species composition and canopy cover to favour current levels of production, habitat conditions, features or species.
- Increase biodiversity by encouraging a variety of species which can occupy the same functional space within a forest ecosystem to promote resilience.
- Increase diversity of planting material both at the species and provenance level.
- Manipulate land cover and vegetation structure to create different stand structures, increasing microclimate variation and resilience.
- Apply low impact silvicultural systems, alternatives to clearfell, continuous cover.
- Change rotation lengths in response to changing productivity and wind risk.
- Change planting seasons in response to changing conditions and establishment success and promote natural regeneration.
- Improve the ecological connectivity of the landscape for woodland species by extending and linking woodland habitats.
- Improve control of deer, grey squirrels and invasive species that threaten regeneration and growth.

Adapted from: Broadmeadow and Ray (2005), Crowe and Parker (2008), D'Eon (2008), Koontz and Bodine (2008), Ray (2008), Kirby, Quine and Brown (2009), Mason *et al.* (2009) and the UK Forestry Standard Guidelines on *Forests and Climate Change* (Forestry Commission, in press)

Modelling and decision support

Decision support in forest management is widely seen as necessary when the process of making decisions is so complicated that the decision makers are unable to compare the alternatives by themselves, and find an optimal alternative (Vainikainen, Kangas and Kangas, 2008). Boerboom (2010) reviews a wide range of definitions for DSS, noting that some refer to the **processes** used in developing or using those systems, while others refer to the **tools and models**. Typically they use computer modelling programmes developed by experts (Sheppard and Meitner, 2005). Broadly, DSS is usually held to include both computer-based models, and the processes that link those models to user inputs and outputs.

AFM is characterised by complexity, and many authors indicate a central role for DSS that relies on modelling, to generate options or forecasts that help to inform the choice of management strategies and activities. For example, a survey of 21 cases of AM in 'developed' countries found that 83% used modelling in their approach (Espigares, Zafra-Calvo and Rodríguez, 2008).

Modelling can be used to help explore or predict what management options (or hypotheses) may work well on a particular ecosystem. Models can be based on field data or on hypotheses and prediction, and may include quantitative and qualitative data. In an adaptive approach, the modelling process is iterative, with new data from monitoring of each AM cycle incorporated to refine the model (Fürst *et al*., 2009), and models based on hypotheses and prediction can be refined and improved over time through the incorporation of field data collected from AM experimentation.

However, experienced silviculturalists do not agree that complex modelling is essential to AFM (B. Mason, pers. comm.). Models are not **necessarily** computer-based systems, although many authors imply that they are (e.g. Sheppard and Meitner, 2005). Qualitative interactive modelling processes such as cognitive mapping have been used successfully in participatory contexts (Mendoza and Prabhu, 2006).

The challenge, in the context of this report which focuses on the human aspects of AFM, is to understand how such tools can be made compatible with the engagement of multiple stakeholders. Models can help to ensure that findings are incorporated into management practice (e.g. through DSS), can inform choice of indicators for monitoring, and can be of importance in explaining technical concepts to non-experts. Jacobson *et al*. (2009) explain how the **process** of modelling can serve as a focus for knowledge exchange and development among stakeholders:

Model development involves transforming knowledge about a management situation into a model of it, with the purpose of exploring and clarifying assumptions, acknowledging uncertainty, and identifying knowledge gaps. The use of models ensures that upon review, new knowledge is incorporated and learning is made explicit. The model may be qualitative, mathematical or both. (Jacobson *et al*., 2009)

To achieve this stakeholders need to be able to use the tools. In a review of the literature about these aspects, Lawrence and Stewart (2011) focus on the concept of 'usability' – achieved through participatory design, testing and evaluation of effectiveness. Much of the scientific literature on forest decision-making tools does not offer any analysis of the social and institutional processes of designing, testing or using such tools. The **concepts** of combining technical decision making with stakeholder participation are well presented, and methodological manuals are available to help. The challenges lie more in the implementation of these approaches.

The few case studies which do report on the process of testing (or piloting) models or DSS, show that the use of such tools can challenge and contribute to relationships between stakeholders, and depend on knowledgeable and skilled facilitation (e.g. Mendoza and Dalton, 2005; Pykäläinen, Hiltunen and Leskinen, 2007; Hubacek and Reed, 2009).

5. Monitoring

Systematic and planned monitoring of management actions is an integral part of adaptive management, because of its learning focus. Monitoring is the key to ensuring rigor in knowledge about the effectiveness of management actions. (Jacobson *et al*., 2009)

The importance of designing monitoring schemes (e.g., sampling strategies, sample sizes and stratification, assessment protocols and identification of relevant drivers of change) based on best available science, can not be overlooked. (McAfee, Malouin and Fletcher, 2006)

Monitoring is central to successful adaptive management (AM). It is the collection of data on each experimental alternative in order to assess and compare the success of different management options. For forest management to be adaptive, planning must satisfy the requirements of controlled experimental design, and monitoring data must be collected, compared between test and business-as-usual sites, analysed, evaluated and incorporated into decision making, to help direct further iterations of the AM process (Espigares, Zafra-Calvo and Rodríguez, 2008; Innes *et al*., 2009).

There is a large body of work dedicated to developing criteria and indicators for monitoring sustainable forest management (e.g. Mendoza and Prabhu, 2003; Siry, Cubbage and Ahmed, 2005; Gough *et al*., 2008). Two themes emerge. One is the importance of involving stakeholders in the process, and the other is the need to link indicators closely to models (Allen *et al*., 2001).[3]

These twin aspects are considered throughout the following subsections.

Challenges and constraints

Despite its central importance in AM, monitoring is often the stage where the process is let down. Allan and Curtis (2005) note a large number of missed opportunities for 'implementation' to become 'experimentation' because monitoring data were not gathered. There are several reasons for this.

Several authors emphasise the high costs of monitoring:

Economics dictates the level of staffing, data collection, data management, and data analyses that can be allocated over the time span required to obtain reliable results. (McAfee, Malouin and Fletcher, 2006)

For example, monitoring the status and trends of northern spotted owl and murrelet populations and habitat, older forests, aquatic habitat, and social and economic conditions cost more than US$ 50 million over 10 years (Bormann, Haynes and Martin, 2007). Although they point out that this equates to only US$ 0.42 per hectare per year, the total is expensive. Very little work is published on such costs, and a wider study would be valuable to compare costs of different approaches to monitoring, over different scales.

When monitoring is carried out, it can produce large quantities of data, which may be poorly synthesised and evaluated, often because of budget constraints. If this is the case, monitoring data may be of limited value to forest managers and policy makers (Kimmins *et al*., 2007). To support AM, funders need to emphasise the role of monitoring and learning from results (Allan and Curtis, 2005; McAfee, Malouin and Fletcher, 2006).

Other problems relate to lack of conceptual clarity about what is being monitored. Kimmins *et al*. (2007) argue that too often monitoring is conducted as though the underlying forest ecosystem should remain static. Instead, they contend that data should be collected and compared against 'forecasts of expected change in sustainably managed, post-disturbance ecosystems' (p. 502). They describe 'process based ecosystem monitoring' in detail in the paper. This challenge relates monitoring back to the modelling issues discussed above. In order to keep costs to a minimum, data collection should be planned carefully so that information feeds back into the decision support model (Jacobson *et al*., 2009).

Common features of successful long-term monitoring programmes have been identified by Lindenmayer and Likens (2009), reflecting the combination of the technical and organisational challenges that characterise all aspects of AM. In addition to:

1. well-formulated questions posed at the outset of the work;
2. ongoing development of new questions as necessary;

[3] Forest Research is currently collaborating in several research projects, including ForestClim and Nortosia, which will contribute further knowledge to this topic.

3. robust experiment design;
4. high quality data collection and storage;

there are social and institutional dimensions such as:

5. well-developed collaborative partnerships among scientists, resource managers and members of other key groups;
6. access to ongoing sources of funding; and, importantly,
7. strong and enduring leadership.

We see that, again, it is not just a question of getting the science right, but getting the social relations right.

Developing criteria and indicators

The development of indicators to measure the progress towards the goals and objectives and to maximize learning from the system under management is the cornerstone of the monitoring strategy. (McAfee, Malouin and Fletcher, 2006)

Jacobson *et al*. (2009) reiterate the themes laid out in the 'Steps in Adaptive Management' section on page 8 (see also Appendix), in relation to the process of developing indicators and a monitoring plan. They suggest reviewing the process in relation to the following questions:

- Is monitoring conducted systematically and in relation to hypotheses?
- Are short- and long-term responses monitored?
- Are appropriate criteria used in indicator selection?
- Have stakeholders been given an opportunity to be involved?
- Has data been collected so that management processes can be evaluated?

Policy and management objectives will of course guide the selection of indicators (McAfee, Malouin and Fletcher, 2006).

Involving stakeholders in the development of the monitoring plan and indicators may appear to complicate the process, as indicators have to cover a range of variables instead of maximising one (Norton and Steinemann, 2001). However, some authors consider that it is worth the effort, as it increases the possibility of building ecological resilience (Olsson and Folke, 2001), and it may also help to reassure the public about the impact of forest management (Bormann, Haynes and Martin, 2007).

Several authors report that it is in fact the more technically qualified stakeholders who are sometimes left out of the process. As discussed above, when developing a model, mathematicians and scientists should be involved to advise on both the modelling and experimental process (Gunn, 2005; McAfee, Malouin and Fletcher, 2006; Lindenmayer and Likens, 2009). For example:

Although good design is an inherently statistical process, professional statisticians are often left out of the experimental design phases of monitoring programs. Key issues are then overlooked, such as calculations of statistical power to detect trends, the importance of contrasts between treatments (e.g. where there is a human intervention and where there is not) and the value of innovative rotating sampling to increase the number of sites in a monitoring program and improve power for detecting effects. (Lindenmayer and Likens, 2009)

Armitage *et al*. (2009) suggest that as AM is different for every situation, and is inherently locally adapted, new indicators should be developed for each case. Clearly this needs to be offset against the need to use the same indicators across different sites and projects, to allow comparison between sites and projects, but in order to monitor the impacts of climate change on forests new indicators and sampling designs could be required (Innes *et al*., 2009).

Much of the literature highlights the range of demands on such indicators. In addition to the need to develop indicators collaboratively (Armitage *et al*., 2009; Jacobson *et al*., 2009; Lawrence, 2010c), successful identification and use of indicators includes processes that:

- incorporate slow and fast variables (Armitage *et al*., 2009) or short- and long-term variables (Jacobson *et al*., 2009);
- take account of ecosystem conditions, socio-economic and livelihood outcomes and process and institutional conditions (Norton and Steinemann, 2001; Armitage *et al*., 2009);
- consider both implementation and effectiveness (Murray and Marmorek, 2003);
- match indicators to the scale of the socio-ecological system (Norton and Steinemann, 2001; Armitage *et al*., 2009);
- but at the same time are consistent across sites in terms of parameter and indicator selection in order to be comparable and facilitate learning across sites (Armitage *et al*., 2009; Jacobson *et al*., 2009).

On top of all this, they should be easy to measure, cost-effective and related to management goals (Drever, 2000). This is neatly illustrated by the example described in Box 9.1.

One area which will be novel and challenging to many forest managers is that of socio-economic indicators. Examples in the Northwest Forest Plan (Box 2.1) included producing predictable levels of timber and non-timber resources, maintaining the stability of local and regional economies, assisting with long-term economic development and diversification, promoting collaboration in forest management, and protecting forest values associated with aquatic and older forest ecosystems (Routman, 2007). These do not deal with the more intangible, but equally important, cultural and emotional values associated with forests and forestry, and many challenges remain in this field (Parkins, Stedman and Varghese, 2001).

This very large scope of demands on indicators highlights an area of research need. Few of the papers reviewed contain specific examples, and some of the recommendations are not mutually compatible. There is a need for case studies of indicator choice and use by a range of stakeholders.

Starting from a good baseline

To monitor effectively, the data collected during experimentation usually need to be compared with data collected before experimentation started. Such baseline data are often scarce or incomplete (McAfee, Malouin and Fletcher, 2006).

Sometimes the process of planning a monitoring programme can reveal flaws in existing baseline data. For example, the CEC-FRP programme spent 6–8 years consolidating existing knowledge, and made some surprising discoveries about the quality of Ontario's forest inventory data. Researchers found that about 30% of stands were misclassified, and common species were misidentified in about half the stands (Bell *et al*., 2008a).

Monitoring by volunteers

The involvement of volunteers in environmental monitoring, also known as 'citizen science', is covered by an ever-growing body of literature. It is one where the lessons for AM are highly relevant, because AM involves a wide range of stakeholders, and because it is 'data hungry'. However, very few examples make this connection. One concern raised, which is a common concern in voluntary monitoring, is that of rigour (Murray and Marmorek, 2004). However, many studies show how voluntary monitoring can be rigorous (Engel and Voshell, 2002; Brandon *et al*., 2003; Newman, Buesching and Macdonald, 2003), and at the same time enhance stakeholder commitment and involvement (Ballard, Sturtevant and Fernandez-Gimenez, 2010; Lawrence, 2010b, 2010c).

6. Learning

'Learning' has already been mentioned as a key challenge: in partnerships, in interactions between stakeholders, and particularly between scientists and resource managers:

adaptive management is less about current decisions than about mutual learning that might lead to better future decisions. (Borchers, 2005)

Monitoring of experiments and record keeping of non-experimental areas is the most formal manifestation of 'learning'. However, monitoring is of no use if the data are not analysed and interpreted, and fed into decision-making processes.

Formalising the lessons from experience, is another level of learning. Very few studies focus on this. However, the Northwest Forest Plan provides a good example. After the first 10 years, scientists formally handed over to the forest management agencies, who have since published decisions to:

- redesign adaptive management (AM) approaches to be more rigorous and systematic;
- develop more active forms of silvicultural intervention (in this case, reducing fuels in fire-prone forests);
- review changes to the monitoring plan.

(Bormann, Haynes and Martin, 2007)

Information management

The first challenge in linking monitoring with learning lies in data management. Bormann, Haynes and Martin (2007) found that poor record keeping (linked to budget decline) hampered use of monitoring data.

Others have focused on the approach needed to share information between providers and users. They have noted that:

in the shorter term strong emotions associated with information often create a barrier to its availability. (Allen *et al.*, 2001)

Likewise, concerns over the use of monitoring data can lead citizen scientists to withhold it (Lawrence, 2010b). Protocols are only a starting point to building goodwill, trust and fairness in sharing information (Allen *et al.*, 2001).

Organisational cultures and risk

Some of the more interdisciplinary literature about AM focuses on the challenges of established institutional culture. As Brown (2009) concludes:

new institutional arrangements that foster learning and continuous exchange of different types and sources of knowledge across scales are an important indicator of adaptive capacity.

However, institutional culture can act against this. Some authors point to a reluctance to 'do things differently' in the face of public involvement in discussions about climate change and resource management (Kimmins, 2008). Others highlight a slow adoption rate for new technologies (such as risk assessment, decision analysis and landscape simulation models) (Murray and Marmorek, 2004).

Attitudes to risk are central to this (MacDonald and Rice, 2004). As Gosselin (2009) points out, risk aversion is common. At the national scale, risk avoidance may be encouraged by law, policy and economics, while at the local scale a forester's responsibilities to provide certain goods and services in the short term may constrain his or her ability to take risks. As discussed above, forests (which are often in the public domain, or are providing public benefits) are highly visible arenas where failure could be conspicuous and unpopular. We can speculate, based on anecdotal evidence, that private forest managers might be less constrained by public opinion and therefore more free to experiment; this is likely to be highly variable between different countries and cultures.

Furthermore, where forests are managed rather than simply mined for timber, forest management has been based on the sustainable yield model (i.e. on timber production). Despite the shift to multipurpose forest management in the last two decades, the goal of maintaining timber flows remains central to many forest agencies.

Because predictability and a steady flow of outputs are desired by [the US] Congress to satisfy constituents, there has been little incentive in the past for agencies to take the risks involved in adaptive management. (Koontz and Bodine, 2008)

However, there are intrinsic factors that also contribute to this risk aversion. Allan and Curtis (2005) have conducted a valuable study of the beliefs and behaviours of resource managers, which inhibit learning and risk taking. They identified seven 'imperatives' frequently cited by respondents that characterise these behaviours:

- 'got to keep moving' – action is better than reflection;
- 'got to have control' – reflecting an implicitly hierarchical society;
- 'got to see well' – reflecting a desire for clarity, which can tend to reduce complexity;
- 'got to sell' – i.e. convince landowners to adopt AM, an imperative which inhibits questioning of the process itself, or recognition of the learning element;
- 'got to compete' – reflected in 'win/lose' language;
- 'got to maintain institutions';
- 'got to be comfortable' – leading to a tendency to present projects as 'successful' and to claim that 'we are already managing adaptively'.

Added to the typically hierarchical structure of forest agencies, all of these imperatives act to suppress doubt, complexity and questioning, the factors that in turn contribute most to learning. As participants in the Northwest Forest Plan found, a top-down approach to planning:

stifled local flexibility, limiting how local societal concerns and site-specific understanding of ecosystem function could be accommodated in the standards and guidelines. (Bormann, Haynes and Martin, 2007)

By involving other stakeholders in adaptive forest management (AFM), many of these imperatives are challenged, and power or authority may be distributed more equally among the different interest groups involved (e.g. foresters, community groups, scientists). However, these are precisely the factors that can worry those in positions of existing power and which may subconsciously deter efforts to start AFM.

The picture is not universally pessimistic. For example, Manring and Pearsall (2005) describe an approach which they term 'generative learning' (collaborative problem solving), which resulted in new ways of looking at resource issues, beyond the boundaries and views of individual stakeholders. However, the overwhelming balance, among those studies that address issues of organisational culture and professional norms, suggests that ingrained behaviours inhibit learning and adaptation.

Summarising, Murray and Marmorek (2003) conclude in a review of cases in North America that principles for applying AM include:

- promoting institutional curiosity and innovation;
- valuing failures and learning from mistakes;
- expecting surprises and capitalising on crises;
- encouraging personal and organisational growth by hiring people who are committed to learning.

Naturally these kinds of principles are more difficult to make concrete. Senior decision makers need to endorse the strategy, and find effective ways for including what scientific expertise there is in political and social processes that inform, educate and modify policy (Stankey *et al*., 2003; Matta *et al*., 2005). In case studies from northwest USA and Australia, Allan and Curtis (2005) note that funding, monitoring, stakeholder engagement in partnerships and networks and the lack of support for AM at various management levels were all weaknesses. They conclude that the US Forest Service attempted to insulate itself from risk, requiring almost foolproof experiments. Furthermore, it avoided learning through neglecting to create systematic processes to record and incorporate new experience.

The situation may vary according to cultural context. For example, in the Netherlands a more 'entrepreneurial' attitude to the future is identified, with uncertainty being seen as a resource (Schanz and Ottitsch, 2004; Hoogstra and Schanz, 2008):

It could be argued that the characteristic Dutch tradition of pragmatism in long-term iterative planning, with a high readiness for change and adaptation to changing situations, may also account for a stronger future orientation. (Hoogstra and Schanz, 2008)

It can also vary on a finer scale. In the Northwest Forest Plan (Box 2.1) the formally designated Adaptive Management Areas attracted scrutiny and nervous attitudes to risk taking, with the result that some of the most successful application of AM was outside these areas (Bormann, Haynes and Martin, 2007).

Experienced observers suggest that these challenges are often underestimated. For example:

Structuring a learning-based adaptive organization can be handicapped by a pervasive belief that adaptive management does not constitute a significant departure from the past, but is only a process of adjusting over time. One consequence is that little attention is given to the institutional barriers to its implementation, and little effort is expended on the redesign of organizational structures and process to accommodate an adaptive style of management. At a minimum, it is necessary to rethink the notions of risk and risk aversion, and to promote conditions that encourage, reward, and sustain learning by individuals. (Williams, Szaro and Shapiro, 2009, p63)

Organisational capacity

Some of these challenges can be addressed through training for resource managers, and for scientists. Various pointers in the literature suggest that training needs to address:

- working with uncertainty and risk;
- innovative and flexible attitudes to forest management;
- using options based on models and inputs from both quantitative and qualitative data sources;
- engaging with stakeholders to assess such options, and to communicate the results of applying them;
- social science methods;
- organisational learning and change.

(MacDonald and Rice, 2004; Butler and Koontz, 2005; Bormann, Haynes and Martin, 2007).

In addition to the cultural challenges, a number of specific skills are required. The level of statistical and analytical sophistication for modelling and interpretation is high (e.g. Gregory, Ohlson and Avrvai, 2006; Failing, Gregory and Harstone, 2007).

Of course there are also budgetary and administration requirements. In many cases, AM is not even considered by senior staff because it does not have budget, time and support staff allocated to it, nor staff reward systems (Murray and Marmorek, 2003; Gosselin, 2009). In the case of the Northwest Forest Plan:

When elements of adaptive management were treated as core business, as in the regional monitoring and interpretive steps, they influenced agency decisions considerably more than when elements were not treated as core business. (Bormann, Haynes and Martin, 2007)

7. Evaluating adaptive management

In addition to the monitoring, evaluation and learning that take place **within** the adaptive management (AM) cycle, there is a level of evaluation and learning that takes place **outside** the AM cycle. This has been called 'second order learning' or learning about the learning process (Bateson, 1972; Argyris and Schön, 1978). The questions to be asked here are:

- How useful or successful is AM (adaptive forest management, AFM, in this case) in terms of improving forest management?
- How much does it cost?
- How well does it fit with current institutional practice?
- Does anything need to change to make it fit better?

It is also possible to assess the successful **uptake** of AFM by both institutions or sectors, but that is a separate issue discussed in Section 8 below.

We address the first two of these questions in this section, and consider the second pair of questions in Section 8.

Judging success

Scientists and policy makers find it difficult to evaluate AM and its outcomes. Part of the problem is that stakeholders (e.g. scientists and managers) may not agree on the definition of what they are trying to do, or on the goals. Another aspect to the challenge is that there may be no fixed point when it can be stated that adaptation has successfully taken place.

AM is a continuous process of moving towards a travelling goal, so in some respects proving or disproving the initial hypothesis can be counted as success, even though the hypothesis is then reformulated and retested in an AM cycle. AM should be considered successful if forest management intervention is seen to have improved on previous scenarios. Success also includes increasing resilience and decreasing uncertainty, two components that are hard to measure (Plummer and Armitage, 2007).

There are some easily observed criteria for **lack** of success, as the range of examples above illustrate. Mostly this is judged at project level, and failure is attributed to lack of communication, institutional support, effective data use and management, and absence of learning links. So we might infer that these components need to be present. Some do explicitly judge success by evaluating the process. Allan and Curtis (2005) compare an Australian watershed case study to forestry in the Pacific Northwest of the USA. They conclude that the USA example was not adaptive because management practices did not have methods for seeking or incorporating new information.

However, none of these components or inputs is sufficient to guarantee that AM is taking place. How have contributors tried to evaluate outcomes? The literature on this is sparse. Success can be judged on the basis of whether learning is taking place (Bormann, Haynes and Martin, 2007). They provide some more specific indicators:

Adaptive management is not an end in itself, but a means to more effective decisions and enhanced benefits; thus, its true measure is in how well it helps meet environmental, social, and economic goals, adds to scientific knowledge, and reduces tensions among stakeholders. (Bormann, Haynes and Martin, 2007)

Any of these alone might still be insufficient. One of the most comprehensive papers on this subject combines both approaches: evaluating the process and the outcomes. Plummer and Armitage (2007) link the desired outcome of AM to enhanced resilience, and present a range of measures for assessing resilience at different levels. What they call 'generic outcome parameters' might also be termed 'indicators'. At project level tangible indicators include:

- resource management plan;
- sanctions agreed among stakeholders.

Indicators at this level can also be intangible, and include:

- enhanced legitimisation for policies and actions;
- creative ideas for solving problems.

At a higher level (outside the project) indicators might include:

- new co-operative undertakings beyond the specific issues.

And at the highest level (visible only subsequently), they suggest indicators including:

- ongoing use of co-operative approaches;
- new institutions enshrined in law.

None of these indicators include 'sustainable resource management'. While that is clearly one of the objectives, it is not measurable. This brief review of approaches to evaluating AM highlights again the importance of social and governance processes, in contributing to and understanding the success of AM. In summary, Plummer and Armitage (2007) point out that complex systems require a 'new mindset' for evaluation. Goals are non-measurable and ever moving. Indicators are needed for process as well as outcomes at a range of spatial scales and timescales.

These difficulties in judging whether AM has been successful can make institutions reluctant to adopt the approach, because institutional culture is often based on the idea of constant progress towards an end goal, and employee performance is assessed on the amount of distance covered in approaching that goal over a specified timeframe. Because AM is about taking risks and experimenting with new modes of management, there is also a risk of apparent 'failure', which is experienced as unacceptable, particularly for projects that have received outside funding.

Cost-effectiveness

With the wide range of possible outcomes, and difficulties in judging success, it is also difficult to assess cost-effectiveness of AM.

AM comes with extra costs compared to business-as-usual, because of the high scientific inputs at the beginning, the need for intensive monitoring, and the need to involve multiple stakeholders in the process. These costs are sometimes seen as prohibitive (Bormann, Haynes and Martin, 2007). The requirement to work in partnership can further complicate this, in the eyes of agencies used to competing for budgets, delivering against short-term aims, and fitting expenditure neatly within administrative and line-item budget boundaries (Koontz and Bodine, 2008). For example, opportunities for AM were foiled by the classification of new planting as 'implementation' rather than 'research' in the example discussed in the 'Managing by experimentation' section on page 14 (Allan and Curtis, 2005).

Some authors conclude nevertheless that AM is cost-effective, combining as it does both credible information and time-effective modification of management policies and practices (Drever, 2000). Ludwig, Hilborn and Waters (1993) in a seminal paper argue that 'basic' ecological research deflects attention and resources from the real need to manage resources experimentally. So AM can (we might infer) save costs by encouraging investment in research where it is most needed.

8. Institutionalisation of adaptive management

For all the reasons discussed above – need for learning and flexibility, partnerships and organisational culture shifts – the idea of 'institutionalising' adaptive management (AM) might seem at best to be challenging, at worst an oxymoron. Many consider that change happens first at the small scale:

An adaptive management attitude can be fostered by starting with small successes: applying the approach to relatively simple problems in relatively small areas that can be resolved in a reasonably short time frame. (Murray and Marmorek, 2003)

Nevertheless there are ways in which the wider policy and institutional context can either create the space in which these 'small successes' happen, or build on them through scaling-up and formalising the partnerships and structures required. In this section we look at three aspects of this:

- The processes whereby relevant policies are made.
- Examples of how AM is referred to in policy.
- Ways in which organisations provide guidance to their staff in relation to AM.

Policy processes

The institutional challenge of AM is experienced at all scales and replicated in the policy-making process. In an influential IUFRO study, Seppälä, Buck and Katila (2009b) conclude:

Existing governance systems and policy designs are not coping well. A hierarchical, top-down style of policy formulation and implementation by the nation state and the use of regulatory policy instruments, such as forest laws, is likely to be insufficiently flexible in the face of climate change … Given the uncertainties surrounding the impacts of climate change, a more flexible and collaborative approach to forest governance is needed that can respond more quickly to policy learning.

Specifically, they advocate that national policies take a precautionary approach but encourage flexible approaches to policy design that are sensitive to context. Others in the same study team conclude that '"locking in" to bad policies is as dangerous as doing nothing at all', and that uncertainty and complexity are best addressed through incentives for innovation, rather than regulatory approaches (Rayner and Glueck, 2009).

They and others highlight the need for policy making that:

- incorporates deliberative approaches[4] at every level of governance;
- is supportive of multi-level learning networks;
- rewards scientists and managers for participating in networks;
- ensures long-term funding to science and AM;
- removes policy conflicts;
- removes barriers to interagency co-ordination.

(MacDonald and Rice, 2004; Butler and Koontz, 2005; Brooke, 2008; Armitage *et al*., 2009).

Adaptive forest management adopted in forest policy

Despite these challenges a number of countries have incorporated references to adaptive forest management (AFM) in their policies. AFM is perhaps most explicitly indicated in Australia's 1992 Forest Policy, which states:

Managing Australia's forests in a sustainable manner calls for policies, by both governments and landowners, that can be adapted to accommodate change. Pressures for change may result from new information about forest ecology and community attitudes, new management strategies and techniques (such as those that incorporate land care and integrated catchment management principles), and new commercial and non-commercial opportunities for forest use. (Commonwealth of Australia, 1992, revised 1995)

Furthermore, the 2005–2010 Strategic R&D Plan refers specifically to the role of research:

At policy levels, we will try to close the gap between research activities and policy formulation so that research is working more closely with policy in an adaptive management sense. (Land and Water Australia, 2005)

[4] A 'deliberative' approach is one where the opinions and preferences of stakeholders evolve through engagement with each other and with various types of information, such as scientific research, to reach a consensual decision that may not have been envisaged by any of the stakeholders at the start of the process.

More recently, in the *National Climate Change and Commercial Forestry Action Plan 2009–2012*, the Australian Department for Agriculture, Fisheries and Forestry (DAFF) recommend AM processes specifically to cope with the uncertainties of climate change:

Those changes in climate and associated risks which can be foreseen will require active and adaptive management to cope with the new conditions in which the forestry sector operates. (DAFF, 2009)

Policy regimes across North America tend to accommodate degrees of AM to account for future uncertainty (Smith and Johnson, 2007). However, this does not mean that AM is universally recognised in policy. It is often adopted at the scale of regional forests, for example the Pacific Northwest of the USA, in the wake of the High Court injunction against logging to protect the northern spotted owl (Bormann, Haynes and Martin, 2007).

In some cases the decision to adopt an AM approach is not taken at policy but at strategic level, and the challenge is to incorporate research lessons into implementation. In the CEC-FRP case, for example, in Ontario (and British Columbia), Canada, there had already been a shift to an ecosystem-based approach to forest management in the 1990s, and a policy shift to increase the proportion of forest under conservation designations. AM thus became a tool to support the forest industry in working within the constraints of policy and regulation, and thereby increased its reliance on science. Great emphasis was placed on research transfer in the CEC-FRP case (Bruemmer, 2008).

In Europe, AFM is encouraged in international-level policy (MCPFE, 2004; MCPFE Liaison Unit Warsaw, UNECE and FAO, 2007; MCPFE *et al*., 2008), and is one of the 12 conceptual linkages between sustainable forest management and the ecosystem approach (PEBLDS Council 2 006). Various MCPFE resolutions are relevant. For example, Resolution V5 highlights the links between Climate Change and Sustainable Forest Management. Resolution H1 on Sustainable Management of Forests in Europe notes:

Forest management should be periodically updated based on forest surveys, assessment of ecological impact and on scientific knowledge and practical experience.

An international project to 'mobilize and integrate the existing scientific knowledge' on Expected Climate Change and Options for European Silviculture (ECHOES) has reported on the status of climate change policy and options for adapting forestry management to climate change, in each participating country. While very few of the country reports mention AFM, most provide and describe research and options for adapting forest management to climate change. The need to change forest management in order to facilitate forest adaptation to climate change is acknowledged, and central to the reports.

Countries that mention that they are using AFM (Slovenia, Estonia) have not done much on-the-ground testing, and those that advise the use of AFM have often not started implementing the strategy (e.g. Spain, Ireland, France, the Netherlands, Finland, Germany). Ireland, Spain and the Netherlands call for further research and guidance or decision support tools, and Forest Research is a partner in a current EU-funded project, MOdels for adaptIVE forest management (MOTIVE), designed to address this.

Whether or not AFM is specified in policy, other aspects of legislation may affect it. Implementing ecosystem management under the current legal system is difficult because the nature of legal systems is stability and certainty, whereas the nature of ecosystems is instability and uncertainty. Laws themselves can be barriers if they promote commodity production for example, or focus on the conservation of a single species (Schultz, 2008). A study in the USA found, however, that three conservation laws all allow for considerable agency discretion in cases of scientific uncertainty, and concludes that AM, while 'something of a new paradigm in public land management' is compatible with the current legal framework (Schultz, 2008).

Allowing risk

We have identified risk aversion as a characteristic of natural resource management organisations. Yet experts in AFM note that:

The future pace of learning and adapting will be determined by the extent to which decision makers can take reasonable risks in the absence of proof. (Bormann, Haynes and Martin, 2007)

For effective adaptation, policies and regulations must be sufficiently flexible to facilitate adaptive co-management, and there needs to be a recognition that mistakes will be made. (Seppälä, Buck and Katila, 2009a)

This appears to be a bottleneck, and it would be valuable to understand better the interactions around attempts to change this. For example, the Forestry Commission in England explicitly recognises this in its draft *Climate Change Action Plan* by committing to an approach to adaptation and mitigation that 'is not risk averse' (Forestry Commission England, in press).

It is important to tease out the ways in which risk is used in official documents. Within the same policy documents, 'risk' can be portrayed as an undesirable factor, or something to be grasped enthusiastically.

Operational guidance

While policy and organisational structure can provide the 'space' in which AM can happen, at the field level there is a need to translate the concepts into practice. Some researchers conclude that low levels of AM implementation are linked to the lack of clear definition of AM and instruction on 'how to do it' (Gosselin, 2009; Gregory, Ohlson and Avrvai, 2006).

One great shortcoming in the literature is the lack of clear, explicit guidelines on how a manager can develop and implement adaptive management; the few papers that address the underlying process usually limit themselves to a general diagram of the steps. As a result, it can be daunting for managers to make the jump from adaptive management as an idea to adaptive management as a practice. (Morghan, Sheley and Svejcar, 2006)

One excellent example is the technical guide produced by the US Department of the Interior (Williams, Szaro and Shapiro, 2009). This provides accessible step-by-step guidance on deciding whether and how to use AFM, measuring success and learning. The technical guide is illustrated with simple examples.

Other sources of practical guidance are the range of recent case studies published in Allan and Stankey (2009) which describe real experiences from temperate countries ranging from Australia to Canada and the UK, in approachable language that avoids too much jargon.

Nevertheless, for most practitioners it will not be easy to make time to absorb this experience, nor work out how to apply it. AM, and its application, is specific to ecological contexts, but also to social, political and institution contexts, and guidance will have to be developed that works within those contexts.

9. Adaptive forest management in Great Britain

Adaptive forest management (AFM)is not a concept that is currently widely applied across Great Britain, and there is virtually no published literature about experiences from this country, using this specific terminology. Nevertheless, there are many valuable starting points to build on. In this section we draw on personal experience of the authors and reviewers, and grey literature, to reflect on the potential contribution of AFM to forestry in Great Britain.

Precedents for adaptive forest management in Great Britain

The 'best practices' that are followed in forestry in Great Britain, developed in the 18th century, are routes to successful establishment and growth, tried and tested over many years. They are based on empirical science built on quantitative and qualitative evidence and knowledge, and provide information and rules in the form of yield tables, thinning regimes etc. Around Europe, the need to adopt AFM is repeatedly highlighted in policy documents, but this is not reflected in practice or reporting of practice.

In recent years, climate change has been acknowledged in forestry policy and standards in Great Britain. For example new climate change guidelines have been produced in the UK Forestry Standard Guidelines on *Forests and Climate Change* (Forestry Commission, in press). These include a section on adaptive management, which states:

Climate change adaptation will require a flexible, reactive and anticipatory approach to management. Detecting change through vigilance and effective monitoring is necessary to inform such an approach. For small, individual woods, published trends and associated guidance may suffice, but for larger forests some form of monitoring could help inform management decisions.

As the risks and uncertainties associated with the changing climate become more obvious and accepted in mainstream thinking, the need to develop new management approaches which address or account for this has arisen.

As yet there has been little systematic research in Britain on adaptation of silviculture or forest management to climate change. The knowledge that has been obtained is largely derived from studies of the potential impacts of projected changes on aspects such as species growth and survival and then providing guidance on measures that might be taken to compensate for such changes (Mason *et al*., 2009).

Nevertheless, silviculture is evolving, and several examples provide insights into the potential for more adaptive approaches. These include continuous cover forestry (CCF), and woodland grazing.

CCF is one result of the growing interest in alternatives to clearfell systems. Technical information produced by the Forestry Commission refers to adaptiveness in this context:

A prerequisite for the successful adoption of CCF is a commitment to a more flexible, adaptive approach to stand management based on an understanding of woodland development over time in a given location. (Mason and Kerr, 2004)

Action following analysis of stand level information is often called 'adaptive management' and is a prerequisite for the successful adoption of continuous cover. (Kerr *et al*., 2002)

Other innovations include woodland grazing, which is now supported through a grant scheme under the Scottish Rural Development Programme, to benefit biodiversity and natural tree regeneration. Because the impacts of grazing are variable, colleagues in Forest Research have developed an innovative and participatory approach to monitoring (Box 9.1), which although not explicitly mentioned in the toolbox, is a form of AFM.

These examples are only two in a much wider picture of change in British silviculture, but one that has not been very fully documented to date.

Stakeholder engagement in Great Britain

As discussed in Section 3, successful AFM relies on strong partnerships and networks which encourage stakeholder engagement and ownership of management decisions, and facilitate learning. The particular challenges for stakeholder engagement in Great Britain are partnerships across small-scale units of land use, involvement of the public and communities, and links between scientists and operational staff.

Box 9.1 – Adaptive management of woodland grazing.

Under the woodland grazing element of the Scottish Rural Development Programme, funding applicants are provided with a toolbox that guides managers through an adaptive management (AM) scenario designed to produce a sustainable level of woodland grazing. The toolbox contains both a template management plan and a worked example. Monitoring is recommended twice a year and the same time of year. The method provided, and used by the agencies to check on compliance, is a subjective method based on recording observations of the woodland at 10 stops within each woodland type. At each stop, woodland structure is first assessed as being one of eight types. The level of impact on each of seven indicators of current herbivore impact is then also recorded (from 'very high' to 'absent'). Guidance is provided on how to define the condition of the woodland that is likely to provide the desired natural, or human, heritage outcome. Each time the woodland is monitored, the manager compares the outcome against the desired condition and, if necessary and practicable, adjusts the stock grazing regime accordingly.

This sort of AM allows land managers to focus on the desired outcome rather than the mechanism of achieving it. It also encourages them to understand the impact of their management and gets them used to looking at quite subtle indicators of impact that they might not otherwise spot. The initial grazing regime will almost certainly need to be adjusted in response to woodland condition for two reasons; first we do not have sufficient knowledge to accurately set grazing regimes that will achieve a particular outcome and secondly the impact of grazing animals varies from year to year as weather conditions, and consequently forage production, varies. The best person to do the monitoring and decide on any adjustments needed, is the woodland manager since he or she is on site regularly and is best placed to know what is needed and what is possible.

Source: Helen Armstrong, Forest Research. The toolbox is available at **www.forestresearch.gov.uk/woodlandgrazingtoolbox**

Forestry in Great Britain is spread across a landscape involving multiple stakeholders. Forests and woodlands are relatively small and fragmented, owned under a range of different tenure systems, and managed by multiple sectors and owners. To achieve AM at the landscape scale, these multiple sectors and owners (i.e. stakeholders) necessarily need to collaborate. Some examples are already emerging, such as the New Forest Design Plan (New Forest Association, 2006), but are not always linked to the concept of adaptiveness.

Because of the strong public interest and pressure on woods and forests, AFM in the British context would need to involve communities as well as national and local non-governmental organisations (NGOs) and stakeholder organisations in the development of an AFM approach at the landscape level. A wide range of literature (e.g. Edwards *et al*., 2010), can be synthesised to tell us more about stakeholder expectations and to provide broad objectives within which forest scientists and managers can think about experimenting with new management approaches. Some of these groups will increasingly be the owners and managers of woodland, as a result of ongoing trends in community ownership.

Professional organisations such as the Institute of Chartered Foresters (ICF), the Wessex Silvicultural Group, and many others around the country, as well as special interest groups such as the Continuous Cover Forestry Group, provide valuable forums for debate and discussion among practitioners. There have been trends recently to include other stakeholders in such forums. For example, the annual conference of the ICF in 2011 focused on urban forests, and included town planners; several presentations referred to the need for adaptive management. The professional/public divide is perhaps more challenging. While there are some precedents for consulting local communities about forest planning, there is very little experience in consultations over more technical detail or decision making about silvicultural systems.

Successful AFM also requires researchers and resource managers to work in much closer partnership. Feedback from reviews of the first draft of this report was divided about the extent to which this is already happening. It would be beneficial for Forest Research to carry out a study on learning process within Forest Research and Forest Enterprise, as well as existing information sharing channels both within the Forestry Commission and between the Forestry Commission and other national natural resource management bodies, and other forest practitioners.

Planning and implementation in Great Britain

Forest planning in Great Britain is similar to that in other countries. Planning in public forestry follows a hierarchically structured process with opportunities for public consultation at the tactical level of Forest Design Plan[5], which is based on

[5] This process is described in an accessible way, for Kielder Forest, at www.forestry.gov.uk/forestry/infd-6xjert.

landscape units of 1000–10 000 hectares, revised on a rolling 5-year basis. Larger privately owned areas which are supported with public money, are already subject to Forest Design Plans, while smaller woodlands must have a management plan to qualify for financial support. Many other woodlands have no apparent management plan.

Ongoing research into silvicultural planning and innovation (e.g. Lawrence, 2010a) suggests that there is a need for a more consolidated study of suitable entry points for AFM within existing planning systems, and possible implications for change in management planning processes.

Monitoring in Great Britain

Monitoring is another factor essential to the success of AM. Within the UK there are currently various forestry-related monitoring networks. There is also a wide network of volunteer monitors in the UK; however, these volunteers are more accustomed to reporting biodiversity for the UKBAP (Lawrence, 2010b), and as yet are largely untapped for forestry purposes.

Monitoring for AFM is specific to the sites in which management is being tested, and current practice suggests that there is little adherence to operational guidance (Lawrence, 2010b).

The availability of baseline data varies widely between woodland ownerships. The public or national forest estate is managed through a database of sub-compartments, and other owners with resources to do so will have similar data. One author believes that many woodland sites across the UK will have no baseline data associated with them, despite all of these monitoring networks (Mason *et al*., 2009). In a landscape approach, with collaborations between public and private forestry, it is possible that a good set of baseline data could be amalgamated and deployed.

In the example outlined in Box 9.1, monitoring is used as an intrinsic part of the management strategy. It highlights the use of a simple but highly relevant monitoring system, which allows instant management changes to be applied based on the results.

The introduction of new incentive schemes such as the Woodland Carbon Code will provide opportunities for enhanced use of monitoring. The Woodland Carbon Code sets out the standards for voluntary carbon sequestration projects that incorporate core principles of good carbon management as part of modern sustainable forest management (www.forestry.gov.uk/forestry/INFD-863ffl). Projects to create new woodlands in which they plan to claim the carbon sequestered are required to undertake rigorous 5-yearly monitoring of carbon to enable validation of carbon claims by an independent body. Data collected in these new woodlands could help us to understand changing growth rates in changing climate.

Learning in Great Britain

Experimentation and learning is an integral part of the practice of forest managers who have built up a wealth of professional and locally specific experience and knowledge through a kind of informal action research. We are aware of many instances of innovation in forestry in Great Britain. However, colleagues frequently point out that this experience is not formalised, is not seen as research and is not linked directly to strategic decision making. Much local practice within the Forestry Commission goes undocumented, and because there is little documentation there can be no review, no learning, and restricted ways of changing practice.

Some passive AM is taking place, for example in connection with the Continuous Cover Forestry Group, an independent group with members from both private and public forestry. The group is affiliated to a European network which focuses on 'close-to-nature' forestry and has introduced approaches based on exchange visits to France and Germany (Lawrence, 2008, 2009b). In the state sector, CCF has been implemented in Wales and parts of Scotland and England; however, it is accompanied by varying levels of monitoring that would not meet the criteria of AFM defined here (Lawrence, 2010a).

In other words, forestry in Britain is currently experiencing a considerable amount of innovation. Very little of this innovation is being monitored in a way that allows rigorous learning from the experience; even less is being modelled and compared with forecasts, and lessons are not being effectively shared.

A study of learning pathways and mechanisms in Great Britain would provide useful insights to the amount of capacity building needed to institutionalise the AM process successfully.

Institutionalisation of adaptive forest management in Great Britain

Public forest management in Great Britain has been reliant on hierarchically structured processes, supported by centrally agreed operational guidance, to inform decision making at local scale. The adoption of AFM could therefore require a large shift in both policy and operational aspects of forest management. Forest managers would probably require re-training in experimental approaches and the practices of innovation and experimentation would need to be both fostered and actively encouraged or rewarded.

However, current research shows that there is already a considerable amount of innovation going on which is not formally recognised. One important step would be to make this experimentation explicit, and to record it so that experiences can be shared. Clear and functional communication channels could facilitate sharing of both experiments and results (learning), and also provide support for forest managers in the adoption of the AM model.

It is common to complain about the inflexibility of land management agencies and professionals, but both public and private forestry, and the partnerships in which they are involved, have evolved substantially in the last two decades. Any exploration of the potential for moving towards AFM would benefit from building on this change, and drawing on the positive experiences that have supported such change.

10. Conclusions

Summary of key findings

1. **Definitions of adaptive management (AM):** These range from 'learning by doing' to detailed technical specifications of planning, modelling, monitoring, information management and change. We conclude that it is important to keep the full definitions in mind, but that there is much that can be usefully applied to forest management even if it is not (yet) feasible to implement the most systematic and rigorous versions of adaptive forest management (AFM). For example, the development and use of qualitative indicators in woodland grazing allows landowners to adjust management practices at a pragmatic level without using quantitative models and recording systems.

2. **Overall state of knowledge:** We have reviewed a large number of papers, some of which are in turn reviews (e.g. Gregory, Ohlson and Avrvai, 2006; Jacobson *et al*., 2009; Seppälä, Buck and Katila, 2009a). Many of these point out that AM is better known in theory than in practice. However, there are now many examples that also reflect on the steps of doing AM, the roles of different stakeholders and the challenges.

   Most documented experience relates to management of water systems and forests. In the case of forests, there are only a very few examples where the approach has been applied for long enough to comment on the outcomes, although this does not devalue the experience of shorter-term projects.

   There are some examples of high quality social research, which analyses institutional cultures and power dynamics among stakeholders, but there is not yet sufficient evidence to relate recommendations to particular contexts. There is also little evidence of any social analysis of the **process** of doing AFM, and hence guidance on how to facilitate such a process. Processes such as AM are dynamic interactions between people and their environment, and it would be valuable to understand better how the stakeholders co-create their understanding and assessment of the process.

3. **Roles of stakeholders:** Stakeholder engagement is widely considered to be an important part of AM, but the literature does not show consensus on how this is achieved throughout the process. Some authors focus on the scientific challenges, while others emphasise the social. Recent work has made valuable attempts to bring the two together.

   The AFM approach describes methods to involve stakeholders in stages of AFM which may, through sourcing and combining different types of knowledge, provide 'innovative' or 'imaginative' options for forest management, help to resolve conflict, and create an integrated network of organisations and individuals concerned with landscape management.

   What is not clear (and may vary widely between contexts) is which stakeholders need to be involved, how, and at which stages of AFM. Agreement on objectives is clearly important, particularly in public forestry, or private forestry which is providing public benefit. However, it is possible that the AFM process could continue very effectively as an approach operated on behalf of stakeholders by the various professionals in an organisation.

   For AM to be successful, comprehensive channels and support for stakeholder engagement, communication and learning need to be set up and maintained. How stakeholders review processes and agree amended rules of engagement is also open to debate and further experience.

4. **Relevance to British context:** Rather than suggesting that AFM **must** be conducted in the internationally approved fashion, our intention with this review is to open up debate about what can be learnt from international experience, what conditions we see in Great Britain (GB) and what could be tried out next in addressing climate change.

   Within GB there is a great range of woodland types, land-use patterns within which those woodlands are situated, and societal expectations of those woodlands. While much of the AFM literature is based on areas of very extensive publicly owned forest, this is not universally the case. Taking AFM together with wider experience in AM of natural environments, there is plenty of useful material to guide initial attempts at AFM in GB.

   However, the relatively fragmented pattern of land use and ownership, and the high social pressures on semi-natural landscapes, make it particularly important to draw on experience which attempts to combine the right stakeholders and processes, with rigorous science, monitoring and decision making.

5. Priority contexts for AFM: The review makes it clear that AM is not suitable everywhere. If management changes will result in known benefits, there is no need to take an adaptive approach. Where the results of management changes are not known, AM might be desirable but not easily implemented. For example, it is much easier to apply AM in a small area under single ownership and jurisdiction. However, it is in the most challenging situations that AM is most needed.

   In order to prioritise contexts where AFM is most promising, the criteria set out by Gregory, Ohlson and Avrvai (2006) are helpful: scale is feasible; levels of uncertainty do not prohibit interpretation of results; and institutional support exists. In the British context, Forest Research is using vulnerability assessment tools to contribute to this prioritisation. Vulnerability assessment is carried out at a strategic and/or tactical scale. Risk assessment tools are then implemented at a tactical to operational scale.

6. Ownership, motivations and incentives: AM in developed countries is typically carried out by state agencies, with the support of national funds. In the British context, AFM at landscape scale would usually include a range of different kinds of owners, and land uses. Because of the ownership and land-use complexity, there are some challenging questions around motivation and reward for participating in AFM partnerships. It may be worthwhile to build on the research around owners' perceptions and attitudes to woodland management, and effectiveness of grant schemes, currently being conducted in Forest Research.

7. Uncertainty, vulnerability and risk: Literature about AFM often includes discussion about 'uncertainty', 'vulnerability' and 'risk'. These are words which are used in different ways by different authors and stakeholders. To implement AFM, therefore, there needs to be more explicit attention to understanding how these words and concepts are perceived in the forestry context, and in the wider land-use context (in order to include potential land-use change, and small-scale woodlands).

   Some management options which might be tested through AFM could be perceived as 'risky'. However, climate change has created a scenario where forests are considered more vulnerable and management outcomes are no longer certain. Given this situation, more 'risky' methods, such as AFM, may become more politically acceptable.

   Identification of areas particularly vulnerable to the impacts of climate change could provide good entry points for piloting AFM.

8. Learning and organisational culture: In order to develop new management practices, a culture of experimentation and innovation must be fostered and encouraged. An organisational culture that promotes learning is essential to AFM. The implementation of a learning culture in an organisation requires very good communication and the acceptance of regular institutional change. Although natural resource management institutions are often characterised as resistant to learning, there are interesting developments in British forestry. Both public and private forestry practice has developed in the UK, particularly through knowledge sharing in professional associations and special interest groups such as the Continuous Forestry Cover Group. This knowledge sharing is a source of examples and intrinsic experience that can be used to drive any further change, building on existing networks and professional exchange forums. Nevertheless, there is a need to extend such approaches beyond the boundaries of existing professional networks.

9. Operationalising AFM: We have identified a lack of operational guidance as one of the constraints to testing out AFM in Great Britain. It would be most appropriate to develop guidance relevant to the British context, by drawing on and formalising guidance and case studies listed above, local experience and innovation, and efforts to improve the relevance and efficiency of monitoring.

Research priorities in the British forestry context

In the British context the answers to the social and institutional questions highlighted in this review may be different from the solutions in other contexts. These questions are not academic research questions. Instead they are the issues that are most likely to be constraints to the implementation of more AM of UK forests. The research methods will have to be carefully planned to draw on the experiences of practitioners in the UK, and link those to the specific contexts of fragmented ownership, disconnected ecosystems, high population density and changing climatic conditions. This approach will help to answer the significant operational questions of how to learn from experience of

AFM elsewhere and apply it in the most constructive way in the British context.

Based on this approach, the most important research questions are summarised in Table 10.1. For ease of reference, this table links each question to the points summarised in the conclusions section above.

Table 10.1 Research priorities identified through this review.

Research question	Linked to conclusion number
Prioritising change: • What are suitable entry points in the existing system to introduce AM?	4, 5
Innovation: • In British forestry practice, what innovations are taking place, how are they being monitored, and how is learning linked to that?	3, 4, 7, 8, 9
Scale: • What is the relationship between AFM at strategic, tactical and operational levels? Which comes first, and does change flow upwards or downwards? For example, what difference has the inclusion of a 'risk permissive' strand in Forestry Commission England's Climate Change Action Plan, made to decisions?	5, 9
Communicating the science of risk: • How are 'risk', 'uncertainty' and 'vulnerability' understood by public and private forest managers, and how are these understandings shaped or formalised in organisational structures and culture?	5, 6
Organisational learning cultures: • How do forestry organisations, other partners and individuals in Great Britain learn and adapt? • Specifically, what examples are there of change in forest management practice that are based on organisational learning, and what contributed to that? • What capacity building is needed to institutionalise AFM successfully?	4, 7, 8
Science–practice partnerships: • How do Forest Research/Forestry Commission/other researchers and managers interact, and how can this be improved to facilitate the uptake of AFM in Great Britain?	2, 5, 8
Participatory decision support: • What decision support system or modelling is required in an AFM model in Great Britain? • How do different stakeholders in Great Britain engage with models and decision support tools available to aid in AFM?	3, 8
AFM partnerships: • What can we learn from examples and models of cross-sectoral collaboration and partnerships that would enhance the feasibility of AM at landscape scale? • How can lessons from examples and models of cross-sectoral collaboration and partnerships that enhance the feasibility of AM at the landscape scale be applied to the British context? • What learning mechanisms are most appropriate?	2, 4, 5, 7, 8, 9
Evaluating AFM: • How can the success of AFM be evaluated, building on work to develop indicators of resilience and uncertainty? • What indicators are currently used in British forestry, and could they be used as a starting point for AFM monitoring systems?	5, 6

References

ALLAN, C. and CURTIS, A. (2005). Nipped in the bud: why regional scale adaptive management is not blooming. *Environmental Management* 36, 414–25.

ALLAN, C. and STANKEY, G.H. (eds) (2009). *Adaptive environmental management*. Springer, Dordrecht.

ALLEN, W., BOSCH, O., KILVINGTON, M., BROWN, I. and HARLEY, D. (2001). Monitoring and adaptive management: resolving social and organisational issues to improve information sharing in natural resource management. *Natural Resources Forum* 25, 225–33.

AMBROSE-OJI, B., WALLACE J., LAWRENCE, A. and STEWART, A. (2010). *Forestry Commission working with civil society.* Forest Research, Farnham.

ARGYRIS, C. and SCHÖN, D.A. (1978). *Organizational learning: a theory of action perspective*. Addison Wesley, Wokingham.

ARMITAGE, D.R., PLUMMER, R., BERKES, F. *et al*. (2009). Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment* 7, 95–102.

BALLARD, H.L., STURTEVANT, V., and FERNANDEZ-GIMENEZ, M.E. (2010). Improving forest management through participatory monitoring: a comparative case study of four community-based forestry organizations in the Western United States. In: A. Lawrence ed. *Taking stock of nature: participatory biodiversity assessment for policy and planning*. Cambridge University Press, Cambridge, pp. 266–87.

BATESON, G. (1972). *Steps to an ecology of mind: collected essays in anthropology, psychiatry, evolution, and epistemology*. University of Chicago Press, Chicago.

BELL, F.W., BAKER, J.A., BRUEMMER, G., PINEAU, J. and STINSON, A. (2008a). The Canadian Ecology Centre – Forestry Research Partnership: implementing a research strategy based on an active adaptive management approach. *Forestry Chronicle* 84, 666–77.

BELL, F.W., PARTON, J., STOCKER, N. *et al*. (2008b). Developing a silvicultural framework and definitions for use in forest management planning and practice. *Forestry Chronicle* 84, 678–93.

BERKES, F., COLDING, J. and FOLKE, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10, 1251–62.

BERKES, F., COLDING, J. and FOLKE, C. (eds) (2003). *Navigating social–ecological systems: building resilience for complexity and change.* Cambridge University Press, Cambridge.

BOERBOOM, I.L.G.J. (2010). *Integrating spatial planning and decision support system infrastructure and spatial data infrastructure*. Paper presented at GSDI 12 World Conference Singapore, 19–22 October 2010.

BOLTE, A., AMMER, C., LÖF, M., MADSEN, P., NABUURS, G.J., SCHALL, P., SPATHELF, P. and ROCK, J. (2009). Adaptive forest management in central Europe: climate change impacts, strategies and integrative concept. *Scandinavian Journal of Forest Research* 24, 473–82.

BORCHERS, J.G. (2005). Accepting uncertainty, assessing risk: decision quality in managing wildfire, forest resource values, and new technology. *Forest Ecology and Management* 211, 36–46.

BORMANN, B.T., HAYNES, R.W. and MARTIN, J.R. (2007). Adaptive management of forest ecosystems: did some rubber hit the road? *BioScience* 57, 186–191.

BORMANN, B.T. and KIESTER, A.R. (2004). Options forestry: acting on uncertainty. *Journal of Forestry* 102, 22–7.

BRANDON, A., SPYREAS, G., MOLANO FLORES, B., CARROLL, C. and ELLIS, J. (2003). Can volunteers provide reliable data for forest vegetation surveys? *Natural Areas Journal* 23 (3), 254–62.

BROADMEADOW, M. and RAY, D. (2005). *Climate change and British woodland*. Forest Research, Farnham.

BROOKE, C. (2008). Conservation and adaptation to climate change. *Conservation Biology* 22, 1471–6.

BROWN, H.C.P. (2009). Climate change and Ontario forests: prospects for building institutional adaptive capacity. *Mitigation and Adaptation Strategies for Global Change* 14, 513–36.

BRUEMMER, G. (2008). The forestry research partnership: developing the partnership. *Forestry Chronicle* 84, 648–52.

BUTLER, K.F. and KOONTZ, T.M. (2005). Theory into practice: implementing ecosystem management objectives in the USDA Forest Service. *Environmental Management* 35, 138–50.

CHAPIN III, F.S., TRAINOR, S.F., HUNTINGTON, O., LOVECRAFT, A.L., ZAVALETA, E., NATCHER, D.C., MCGUIRE, A.D., NELSON, J.L., RAY, L., CALEF, M., FRESNO, N., HUNTINGTON, H., RUPP, T.S., DEWILDE, L. and NAYLOR, R.L. (2008). Increasing wildfire in Alaska's boreal forest: pathways to potential solutions of a wicked problem. *BioScience* 8, 531–40.

CHARNLEY, S. (2006). The Northwest Forest Plan as a model for broad-scale ecosystem management: a social perspective. *Conservation Biology* 20, 330–40.

COLFER, C.J.P. (2005). *The complex forest: communities, uncertainty, and adaptive collaborative management.* Resources for the Future, Washington, DC.

COMMONWEALTH OF AUSTRALIA (1992, revised 1995). *National Forest Policy Statement: a new focus for Australia's forests*. Commonwealth of Australia, Canberra.

CONROY, M.J., BARKER, R.J., DILLINGHAM, P.W., FLETCHER, D., GORMLEY, A.M. and WESTBROOKE, I.M. (2008). Application of decision theory to conservation management: recovery of Hector's dolphin. *Wildlife Research* 35, 93–102.

CROWE, K.A. and PARKER, W.H. (2008). Using portfolio theory to guide reforestation and restoration under climate change scenarios. *Climatic Change* 89, 355–70.

DAFF (2009). *National Climate Change and Commercial Forestry Action Plan, 2009–2012*. Australian Government, Department of Agriculture, Fisheries and Forestry (DAFF), Canberra.

D'EON, R. (2008). *Adaptive management: learning from doing in the face of uncertainty*. SFM Network No. 29. University of Alberta, Edmonton.

DREVER, R. (2000). *Ecological principles for sustainable forestry on BC's coast: a cut above*. The David Suzuki Foundation. Vancouver.

DUNCAN, D.H. and WINTLE, B.A. (2008). Towards adaptive management of native vegetation in regional landscapes. In: I. Bishop, K. Lowell, D. Duncan, C. Pettit, W. Cartwright and D. Pullar eds. *Landscape analysis and visualisation. Spatial models for natural resource management and planning, lecture notes in geoinformation and cartography*. Springer, Berlin, Chapter 9, pp. 15–182.

EDWARDS, D., JAY, M., JENSEN, F., LUCAS, B., MARZANO, M., MONTAGNE, C., PEACE, A. and WEISS, G. (2010). *Public preferences for silvicultural attributes of European forests. EFORWOOD deliverable D2.3.3*. 89 pp. Forest Research, Farnham.

ELMQVIST, T., COLDING, J., BARTHEL, S., BORGSTROM, S., DUIT, A., LUNDBERG, J., ANDERSSON, E., AHRNE, K., ERNSTSON, H., FOLKE, C. and BENGTSSON, J. (2004). The dynamics of social–ecological systems in urban landscapes – Stockholm and the National Urban Park, Sweden. *Annals of the New York Academy of Sciences* 1023, 308–22.

ENGEL, S.R. and VOSHELL, J.R. (2002). Volunteer biological monitoring: can it accurately assess the ecological condition of streams? *American Entomologist* 48 (3), 164–77.

ESPIGARES, T., ZAFRA-CALVO, N. and RODRÍGUEZ, M.Á. (2008). What do we call adaptive management? A general characterization from a global sample. *Web Ecology* 8, 1–13.

FAILING, L., GREGORY, R. and HARSTONE, M. (2007). Integrating science and local knowledge in environmental risk management: a decision-focused approach. *Ecological Economics* 64, 47–60.

FARRELL, E.P., FUHRER, E., RYAN, D., ANDERSSON, F., HUTTL, R. and PIUSSI, P. (2000). European forest ecosystems: building the future on the legacy of the past. *Forest Ecology and Management* 132, 5–20.

FAZEY, I., FAZEY, J.A., SALISBURY, J.G., LINDENMAYER, D. and DOVERS, S. (2006). The nature and role of experiential knowledge for environmental conservation. *Environmental Conservation* 33, 1–10.

FORESTRY COMMISSION (in press). *Forests and Climate Change*. UK Forestry Standard Guidelines. Forestry Commission, Edinburgh.

FORESTRY COMMISSION ENGLAND (in press). *Climate Change Action Plan.* Forestry Commission England, Bristol.

FRITTAION, C.M., DUINKER, P.N. and GRANT, J.L. (2011). Suspending disbelief: influencing engagement in scenarios of forest futures. *Technological Forecasting and Social Change* 78 (3), 421–30.

FÜRST, C., LORZ, C., VACIK, H., POTOCIC, N. and MAKESCHIN, F. (2009). How to support forest management in a world of change: results of some regional studies. *Environmental Management*, 46 (6), 941–52.

FUNTOWICZ, S.O. and RAVETZ, J.R. (1994). Uncertainty, complexity and post-normal science. *Environmental Toxicology and Chemistry* 13, 1881–5.

GLÜCK, P. and RAYNER, J. (2009). Governance and policies for adaptation. In: R. Seppälä, A. Buck and P. Katila eds. *Adaptation of forests and people to climate change – a global assessment report*. IUFRO World Series Volume 22. IUFRO, Helsinki, pp. 187–210.

GOSSELIN, F. (2009). Management on the basis of the best scientific data or integration of ecological research within management? Lessons learned from the Northern spotted owl saga on the connection between research and management in conservation biology. *Biodiversity and Conservation* 18, 777–93.

GOUGH, A.D., INNES, J.L. and ALLEN, S.D. (2008). Development of common indicators of sustainable forest management. *Ecological Indicators* 8, 425–30.

GREGORY, R.S. (2002). Incorporating value trade-offs into community-based environmental risk decisions. *Environmental Values* 11, 461–88.

GREGORY, R., OHLSON, D. and AVRVAI, J. (2006). Deconstructing adaptive management: criteria for applications to environmental management. *Ecological Applications* 16, 2411–25.

GUNN, E.A. (2005). *Sustainable forest management: control, adaptive management, hierarchical planning*. USDA Forest Service – General Technical Report PNW: 7–14

GUTRICH, J., DONOVAN, D., FINUCANE, M., FOCHT, W, HITZHUSEN, F., MANOPIMOKE, S., MCCAULEY, D., NORTON, B., SABATIER, P., SALZMAN, J. and SASMITAWIDJAJA, V. (2005). Science in the public process of ecosystem management: lessons from Hawaii, Southeast Asia, Africa and the US Mainland. *Journal of Environmental Management* **76**, 197–209.

HARRISON, C., BURGESS, J. and CLARK, J. (1998). Discounted knowledges: farmers' and residents' understanding of nature conservation goals and policies. *Journal of Environmental Management* **54**, 305–20.

HOBBS, N.T. (2003). Challenges and opportunities in integrating ecological knowledge across scales. *Forest Ecology and Management* **181**, 223–38.

HOKAJÄRVI, R., HUJALA, T., LESKINEN, L.A. and TIKKANEN, J. (2009). Effectiveness of sermon policy instruments: forest management planning practices applying the activity theory approach. *Silva Fennica* **43**, 889–906.

HOLLING, C.S. (1978). *Adaptive environmental management and assessment*. Wiley, Chichester.

HOOGSTRA, M.A. and SCHANZ, H. (2008). The future orientation of foresters: an exploratory research among Dutch foresters into the prerequisite for strategic planning in forestry. *Forest Policy and Economics* **10**, 220–9.

HOOGSTRA, M.A. and SCHANZ, H. (2009). Future orientation and planning in forestry: a comparison of forest managers' planning horizons in Germany and the Netherlands. *European Journal of Forest Research* **128**, 1–11.

HUBACEK, K. and REED, M. (2009). Lessons learned from a computer-assisted participatory planning and management process in the Peak District National Park, England. In: C. Allan and G.H. Stankey eds. *Adaptive environmental management*. Springer, Dordrecht pp. 189–202.

HULL, R.B. and ASHTON, S. (2008). Forest cooperatives revisited. *Journal of Forestry* **106**, 100–5.

INNES, J., JOYCE, L.A, KELLOMÄKI, S., LOUMAN, B., OGDEN, A., PARROTTA, J.A., THOMPSON, I., AYRES, M., ONG, C., SANTOSO, H., SOHNGEN, B. and WREFORD, A. (2009). Management for Adaptation. In: R. Seppälä, A. Buck and P. Katila eds. *Adaptation of forests and people to climate change – a global assessment report*. IUFRO World Series Volume 22. IUFRO, Helsinki, pp. 149–200.

JACOBSON, C., HUGHEY, K.F.D, ALLEN, W.J., RIXECKER, S. and CARTER, R.W. (2009). Toward more reflexive use of adaptive management. *Society and Natural Resources* **22**, 484–95.

JULIUS, S.H., WEST, J.M., BLATE, G.M., BARON, J.S., GRIFFITH, B., JOYCE, L.A., KAREIVA, P., KELLER, B.D., PALMER, M.A., PETERSON, C.H. and SCOTT, J.M. (2008). Executive summary. In: CCSP ed. *Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A report by the US Climate Change Science Program and the Subcommittee on Global Change Research*. US Environmental Protection Agency, Washington, DC, pp. 1.1–1.6.

KEOUGH, H.L. and BLAHNA, D.J. (2006). Achieving integrative, collaborative ecosystem management. *Conservation Biology* **20**, 1373–82.

KERR, G., MASON, B., BOSWELL, R. and POMMERENING, A. (2002). *Monitoring the transformation of even-aged stands to continuous cover management*. Forest Research, Farnham.

KIMMINS, J.P. (2008). From science to stewardship: harnessing forest ecology in the service of society. *Forest Ecology and Management* **256**, 1625–35.

KIMMINS, J.P., REMPEL, R.S., WELHAM, C.V.J., SEELY, B. and VAN REES, K.C.J. (2007). Biophysical sustainability, process-based monitoring and forest ecosystem management decision support systems. *The Forestry Chronicle* **83**, 502–14.

KIMMINS, J.P., WELHAM, C., SEELY, B., MEITNER, M., REMPEL, R. and SULLIVAN, T. (2005). Science in forestry: why does it sometimes disappoint or even fail us? *Forestry Chronicle* **81**, 723–34.

KIRBY, K., QUINE, C. and BROWN, N. (2009). The adaptation of UK forests and woodlands to climate change. In: D.J. Read, P.H. Freer-Smith, J.I.L. Morison, N. Hanley, C.C. West and P. Snowdon eds. *Combating climate change – a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change*. The Stationery Office, Edinburgh, pp. 164–79.

KITTREDGE, D.B. (2005). The cooperation of private forest owners on scales larger than one individual property: international examples and potential application in the United States. *Forest Policy and Economics* **7**, 671–88.

KOONTZ, T.M. and BODINE, J. (2008). Implementing ecosystem management in public agencies: lessons from the U.S. Bureau of Land Management and the Forest Service. *Conservation Biology* **22**, 60–9.

LAND AND WATER AUSTRALIA (2005). *2005–2010 Strategic R&D Plan*. Land and Water Australia. Canberra.

LANE, M.B. and MCDONALD, G. (2002). Towards a general model of forest management through time: evidence from Australia, USA and Canada. *Land Use Policy* **19**, 193–206.

LAWRENCE, A. (2006). 'No personal motive?' Volunteers, biodiversity and the false dichotomies of participation. *Ethics, Place and Environment* **9**, 279–98.

LAWRENCE, A. (2008). But is it science? A day with the CCFG at Stourhead (Western) Estate, Wiltshire. *CCFG Newsletter* **28**, 16–17.

LAWRENCE, A. (2009a). The first cuckoo in winter: phenology, recording, credibility and meaning in Britain. *Global Environmental Change* **19**, 173–79.

LAWRENCE, A. (2009b). *How ideas spread in forestry: the case of continuous cover*. Seminar at Newton Rigg, Cumbria University, 26 February 2009. Forest Research, UK. Available from the author.

LAWRENCE, A. (2010a). *LISS implementation in Wales: organisational structure and culture. Internal report*. Forest Research. Available from the author.

LAWRENCE, A. (2010b). The personal and political of volunteers' data: towards a national biodiversity database for the UK. In: A. Lawrence ed. *Taking stock of nature: participatory biodiversity assessment for policy and planning*. Cambridge University Press, Cambridge, pp. 251–65.

LAWRENCE, A. (ed.) (2010c). *Taking stock of nature: participatory biodiversity assessment for policy planning and practice*. Cambridge University Press, Cambridge.

LAWRENCE, A., KINHAL, G., LUINTEL, H., MOLTENO, S. and GILLETT, S. (2007). Participatory science for sustainable wild harvests – a methods handbook. University of Oxford, Oxford.

LAWRENCE, A. and STEWART, A. (2011). Sustainable forestry decisions: on the interface between technology and participation. *Mathematical and Computational Forestry & Natural Sciences* 3, [on-line] 42-52.

LINDENMAYER, D.B. and LIKENS, G.E. (2009). Adaptive monitoring: a new paradigm for long-term research and monitoring. *Trends in Ecology and Evolution* 24, 482–6.

LINKOV, I., SATTERSTROM, F.K., KIKER, G., BATCHELOR, C., BRIDGES, T. and FERGUSON, E. (2006). From comparative risk assessment to multi-criteria decision analysis and adaptive management: recent developments and applications. *Environment International* 32, 1072–93.

LUDWIG, D., HILBORN, R. and WATERS, C. (1993). Uncertainty, resource exploitation and conservation. Lessons from history. *Science* 260, 17–36.

MCAFEE, B.J., MALOUIN, C. and FLETCHER, N. (2006). Achieving forest biodiversity outcomes across scales, jurisdictions and sectors with cycles of adaptive management integrated through criteria and indicators. *Forestry Chronicle* 82, 321–34.

MCALPINE, C.A., SPIES, T.A., NORMAN, P. and PETERSON, A. (2007). Conserving forest biodiversity across multiple land ownerships: lessons from the Northwest Forest Plan and the Southeast Queensland regional forests agreement (Australia). *Biological Conservation* 134, 580–92.

MACDONALD, G.B. and RICE, J.A. (2004). An active adaptive management case study in Ontario boreal mixedwood stands. *Forestry Chronicle* 80, 391–400.

MCKINNON, G.A. and WEBBER, S.L. (2005). Climate change impacts and adaptation in Canada: is the forest sector prepared? *Forestry Chronicle* 81, 653–54.

MCPHERSON, S., BELL, F.W., LEACH, J., STREET, P. and STINSON, A. (2008). Applying research for enhanced productivity on the Canadian Ecology Centre –Forestry Research Partnership forests. *Forestry Chronicle* 84, 653–65.

MANRING, S.L. and PEARSALL, S. (2005). Creating an adaptive ecosystem management network among stakeholders of the lower Roanoke River, North Carolina, USA. *Ecology and Society* 10 (2), art. 16.

MANSON, S.M. (2001). Simplifying complexity: a review of complexity theory. *Geoforum* 32, 405–14.

MASON, B. and KERR, G. (2004). *Transforming even-aged conifer stands to continuous cover management*. Forest Research, Farnham.

MASON, B., NIJNIK, M., RAY, D., BROADMEADOW, M. and SLEE, B. (2009). *ECHOES Country Report: United Kingdom*. ECHOES, Paris.

MATTA, J., ALAVALAPATI, J., KERR, J. and MERCER, E. (2005). Agency perspectives on transition to participatory forest management: a case study from Tamil Nadu, India. *Society and Natural Resources* 18, 859–70.

MCPFE (2004). *Sustainable forest management and the ecosystem approach: outcome of the MCPFE and EfE/PEBLDS ad hoc Working Group on Development of the Pan-European Understanding of the linkage between the Ecosystem Approach and Sustainable Forest Management*. MCPFE. Ministerial Conference on the Protection of Forests in Europe, Oslo.

MCPFE LIAISON UNIT WARSAW, UNECE and FAO (2007). *State of Europe's forests 2007: The MCPFE Report on Sustainable Forest Management in Europe*. MCPFE, UNECE, FAO.

MCPFE, UNECE/FAO, EFI and EfE/PEBLDS (2008). *Sustainable forest management in the Pan-European region – achievements, challenges and planned actions in relation to issues to be addressed at UNFF8*. MCPFE, UNECE/FAO, EFI, EfE/PEBLDS.

MENDOZA, G.A. and DALTON, W.J. (2005). Multi-stakeholder assessment of forest sustainability: multi-criteria analysis and the case of the Ontario forest assessment system. *Forestry Chronicle* 81, 222–28.

MENDOZA, G.A. and PRABHU, R. (2000). Development of a methodology for selecting criteria and indicators of sustainable forest management: a case study on participatory assessment. *Environmental Management* 26, 659–73.

MENDOZA, G.A. and PRABHU, R. (2003). Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management. *Forest Ecology and Management* 174, 329–43.

MENDOZA, G.A. and PRABHU, R. (2006). Participatory modeling and analysis for sustainable forest management: Overview of soft system dynamics models and application. *Forest Policy and Economics* 9 (2), 179–96.

MORGHAN, K.J.R., SHELEY, R.L. and SVEJCAR, T.J. (2006). Successful adaptive management – the integration of research and management. *Rangeland Ecology and Management* 59, 216–19.

MURRAY, C. and MARMOREK, D. (2003). *Adaptive management: a science-based approach to managing* *ecosystems in the face of uncertainty*. In: Fifth International Conference of Science and Management of Protected Areas: Making Ecosystem Based Management Work, Victoria, British Columbia, 2003.

MURRAY, C. and MARMOREK, D.R. (2004). *Adaptive management: a spoonful of rigour helps the uncertainty go down*. In: 16th International Annual Meeting of the Society for Ecological Restoration, Victoria, British Columbia, Canada, 2004.

NABUURS, G.J., MASERA, O. *et al*. (2007). *Forestry*. In: Working Group III Report 'Mitigation of Climate Change', Chapter 9. IPCC Fourth Assessment Report, Intergovernmental Panel on Climate Change, Geneva.

NEW FOREST ASSOCIATION (2006). T*he New Forest Design Plan: recovering lost landscapes.* New Forest Association.

NEWMAN, C., BUESCHING, C.D. and MACDONALD, D.W. (2003). Validating mammal monitoring methods and assessing the performance of volunteers in wildlife conservation – '*Sed quis custodiet ipsos custodies?' Biological Conservation* 113, 189–97.

NORTON, B.G. and STEINEMANN, A.C. (2001). Environmental values and adaptive management. *Environmental Values* 10, 473–506.

OGDEN, A.E. and INNES, J. (2007). Incorporating climate change adaptation considerations into forest management planning in the boreal forest. *International Forestry Review* 9, 713–33.

OGDEN, A.E. and INNES, J.L. (2009). Adapting to climate change in the southwest Yukon: locally identified research and monitoring needs to support decision making on sustainable forest management. *Arctic* 62, 159–74.

OHLSON, D.W, MCKINNON, G.A. and HIRSCH, K.G. (2005). A structured decision-making approach to climate change adaptation in the forest sector. *Forestry Chronicle* 81, 97–103.

OLIVER, C.D. and LARSON, B.C. (1996). *Forest stand dynamics*, updated edition. John Wiley & Sons, New York.

OLSSON, P. and FOLKE, C. (2001). Local ecological knowledge and institutional dynamics for ecosystem management: a study of Lake Racken Watershed, Sweden. *Ecosystems* 4, 85–104.

OLSSON, P. FOLKE, C. and HAHN, T. (2004). Social–ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. *Ecology and Society* 9 (4), art. 2.

PARKINS, J.R. (2006). De-centering environmental governance: a short history and analysis of democratic processes in the forest sector of Alberta, Canada. *Policy Sciences* 39, 183–203.

PARKINS, J.R. (2008). The metagovernance of climate change: institutional adaptation to the Mountain Pine Beetle epidemic in BC. *Journal of Rural Community Development* 3, 7–26.

PARKINS, J.R. (2010). The problem with trust: insights from advisory committees in the forest sector of Alberta. *Society and Natural Resources* 23, 822–36.

PARKINS, J.R., STEDMAN, R.C. and VARGHESE, J. (2001). Moving towards local-level indicators of sustainability in forest-based communities: a mixed-method approach. *Social Indicators Research* 56, 43–72.

PEBLDS COUNCIL (2006). *Pan-European Biological and Landscape Diversity Strategy: Joint statement on the MCPFE/ PEBLDS on Sustainable Forest Management and the Ecosystem Approach*. PEBLDS, Brussels.

PLUMMER, R. and ARMITAGE, D.R. (2007). A resilience-based framework for evaluating adaptive co-management: linking ecology, economy and society in a complex world. *Ecological Economics* 61, 62–74.

PYKÄLÄINEN, J., HILTUNEN, V. and LESKINEN, P. (2007). Complementary use of voting methods and interactive utility analysis in participatory strategic forest planning: Experiences gained from western Finland. *Canadian Journal of Forest Research* 37, 853–65.

RAVETZ, J.R. (2006). Post-normal science and the complexity of transitions towards sustainability. *Ecological Complexity* 3, 275–84.

RAY, D. (2008). *Impacts of climate change on forests in Scotland – a preliminary synopsis of spatial modelling research*. Forestry Commission Research Note 101, Edinburgh.

RAYNER, J. and GLUECK, P. (2009). *Policy options for the adaptation of forests to impacts of climate change*. Presentation at the 8th session of the United Nations Forum on Forests , New York, 22 April 2009. Available at www.iufro.org/download/file/4494/4496/Unff-present-rayner.pdf

READ, D.J., FREER-SMITH, P.H., MORISON, J.I.L., HANLEY, N., WEST, C.C. and SNOWDON, P. (eds) (2009). *Combating climate change – a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change*. The Stationery Office, Edinburgh.

REED, M.G. and VARGHESE, J. (2007). Gender representation on Canadian forest sector advisory committees. *Forestry Chronicle* 83, 515–25.

ROUILLARD, D. and MOORE, T. (2008). Patching together the future of forest modelling: implementing a spatial model in the 2009 Romeo malette forest management plan. *Forestry Chronicle* 84, 718–30.

ROUTMAN, K. (2007). *Forest communities and the Northwest Forest Plan: what socioeconomic monitoring can tell us*. USDA Forest Service Pacific Northwest Research Station. Portland, Oregon.

SCHANZ, H. and OTTITSCH, A. (2004). Netherlands – forest policy paragon or NFP failure? In: D. Humphreys ed., *Forests for the future: national forest programmes in Europe*

– *country reports from COST Action E19*. Office for Official Publications of the European Communities, Luxembourg, pp. 193–206.

SCHULTZ, C. 2008. Responding to scientific uncertainty in U.S. forest policy. *Environmental Science and Policy* 11, 253–71.

SEPPÄLÄ, R., BUCK, A. and KATILA, P. (eds) (2009a). *Adaptation of forests and people to climate change – a global assessment report*. IUFRO. Available at www.iufro.org/download/file/4486/4496/Policy_Brief_ENG_final.pdf

SEPPÄLÄ, R., BUCK, A. and KATILA, P. (2009b). *Making forests fit for climate change: a global view of climate-change impacts on forests and people and options for adaptation*. IUFRO. Available at www.iufro.org/download/file/4486/4496/Policy_Brief_ENG_final.pdf

SHEPPARD, S.R.J. and MEITNER, M. (2005). Using multi-criteria analysis and visualisation for sustainable forest management planning with stakeholder groups. *Forest Ecology and Management* 207, 171–87.

SIRY, J.P., CUBBAGE, F.W. and AHMED, M.R. (2005). Sustainable forest management: global trends and opportunities. *Forest Policy and Economics* 7, 551–61.

SMITH, G.K.M. and JOHNSON, J.E. (2007). Breaking trail through mountains – forest policy implementation case studies. *Forestry Chronicle* 83, 699–707.

SOULÉ, M.E. (1985). What is conservation biology? *BioScience* 35, 727–34.

SPITTLEHOUSE, D.L. (2005). Integrating climate change adaptation into forest management. *Forestry Chronicle* 81, 691–95.

STANKEY, G.H., BORMANN, B.T., RYAN, C., SHINDLER, B., STURTEVANT, V., CLARK, R.N. and PHILPOT C. (2003). Adaptive management and the Northwest Forest Plan: rhetoric and reality. *Journal of Forestry* 101, 40–6.

SWART, R., BIESBROEK, R., BINNERUP, S., CARTER, T.R., COWAN, C., HENRICHS, T., LOQUEN, S., MELA, H., MORECROFT, M., REESE, M. and REY, D. (2009). *Europe adapts to climate change: comparing national adaptation strategies*. Partnership for European Environmental Research, Helsinki.

SWART, R. and RAES, F. (2007). Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies? *Climate Policy* 7, 288–303.

SWEDEEN, P. (2006). Post-normal science in practice: a Q study of the potential for sustainable forestry in Washington State, USA. *Ecological Economics* 57, 190–208.

TENGO, M. and BELFRAGE, K. (2004). Local management practices for dealing with change and uncertainty: a cross-scale comparison of cases in Sweden and Tanzania. *Ecology and Society* 9 (3), Art. 4.

TITTLER, R., MESSIER, C. and BURTON, P.J. (2001). Hierarchical forest management planning and sustainable forest management in the boreal forest. *Forestry Chronicle* 77, 998–1005.

TULER, S. and WEBLER, T. (2010). How preferences for public participation are linked to perceptions of the context, preferences for outcomes and individual characteristics. *Environmental Management* 46, 254–67.

VAINIKAINEN, N., KANGAS, A. and KANGAS, J. (2008). Empirical study on voting power in participatory forest planning. *Journal of Environmental Management* 88, 173–80.

VAN GOSSUM, P., LUYSSAERT, S., SERBRUYNS, I. and MORTIER, F. (2005). Forest groups as support to private forest owners in developing close-to-nature management. *Forest Policy and Economics* 7, 589–601.

WALTERS, C.J. (1986). *Adaptive management of renewable resources.* McGraw Hill, New York.

WALTERS, C.J. and. HILBORN, R. (1978). Ecological optimization and adaptive management. *Annual Review of Ecology and Systematics* 9, 157–88.

WILLIAMS, B.K., SZARO, R.C. and. SHAPIRO, C.D. (2009). *Adaptive management*. The US Department of the Interior Technical Guide, Washington DC.

WILLIAMSON, T.B., PARKINS, J.R. and MCFARLANE, B.L. (2005). Perceptions of climate change forest-based risk to forest ecosystems and communities. *Forestry Chronicle* 81, 710–16.

WOLF, S.A. and HUFNAGL-EICHINER, S. (2007). External resources and development of forest landowner. *Society & Natural Resources* 20, 675–88.

Appendix

Questions to help stakeholders review an adaptive management process

Jacobsen *et al.* (2009) include the following checklist of questions in their table 1, to help stakeholders review their adaptive management process:

Step 1: Buy in and goal setting

- Do you have a shared vision for your project and a set of goals to match?
- Are the ecological boundaries of management clearly defined?
- Do goals consider ecological and social aspects of the management context?
- Are goals aimed at managing uncertainty?
- Have both social and ecological benchmarks for success been created?
- Have relevant stakeholders been identified and provision made to involve them?
- Have communication networks been identified and a process for communication been established?
- Do you have adequate capacity for your project? (people, resources, institutional support)

Step 2: Model building

- Has a model of the system being managed been developed?
- Have relevant sources of knowledge been identified and drawn together to use in the model?
- Have uncertainties in knowledge and assumptions in the model been acknowledged?
- Have issues associated with both temporal and spatial scales been considered (e.g. lag effects)?
- Is the model translatable for stakeholders and policymakers?

Step 3: Action

- Have management options been identified that meet goals, and are they stated as hypotheses?
- Have predictions been developed for each option?
- Have stakeholders been included in decision making?
- Have the risks and trade-offs between different management options been considered?
- Have ecological imperatives been considered equitably with economic and social imperatives?
- Have management actions been designed as experiments, and are they recognised as such?
- Have the limitations of methods been recognised?
- Has focus been given to biological significance?
- Have compromise and constraint been accepted?
- Has an appropriate running time been considered for experiments?

Step 4: Monitoring

- Is monitoring conducted systematically and in relation to hypotheses?
- Are short- and long-term responses monitored?
- Are appropriate criteria used in indicator selection?
- Have stakeholders been given an opportunity to be involved?
- Has data been collected so that management processes can be evaluated?

Step 5: Feedback

- Is evaluation conducted systematically and in relation to goals?
- Are both process and experimental lessons documented?
- Is the management process transparent?
- Is the process iterative?
- Is evaluation completed in relation to the timing of ecological processes?
- Are failures and unexpected results treated as learning exercises?
- Are both social and ecological uncertainties evaluated?
- Has the appropriateness of goals been evaluated?
- Are management and learning processes evaluated?
- Are practitioners and organisations reflexive?

Glossary

Abbreviations and acronyms

- **AEM**: Adaptive ecosystem management
- **AFM**: Adaptive forest management
- **AM**: Adaptive management
- **CCF**: Continuous cover forestry
- **CEC-FRP:** Canadian Ecology Centre – Forestry Research Partnership
- **DAFF**: Department for Agriculture, Fisheries and Forestry (Australia)
- **DSS**: Decision support systems
- **ECHOES**: Expected Climate Change and Options for European Silviculture
- **FAO**: Food and Agriculture Organization
- **GB**: Great Britain
- **IUFRO**: International Union of Forest Research Organization
- **MCPFE**: Ministerial Conference on the Protection of Forests in Europe (now known as Forest Europe)
- **NGO**: Non-governmental organisation
- **PEBLDS**: Pan-European Biological and Landscape Diversity Strategy
- **R&D**: Research and development
- **UKFS**: UK Forestry Standard
- **UNECE**: United Nations Economic Commission for Europe

Definitions of related terms

Adaptation

In this context it is common to use the term 'adaptiveness' to refer to an ongoing process, and 'adaptation' to refer to a one-off outcome. Adaptation, in forestry, is not simply a matter of choosing the right species for a predicted climate, because 'the right species' is a moving goal. The climate (and other aspects of the social–ecological context) will continue to evolve, and therefore an AM approach is needed that allows for structured evolution of resource management.

Adaptive capacity

The ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities or to cope with the consequences (Swart *et al*., 2009).

Complexity

A term used far more commonly than it is defined (Manson, 2001) – widely used in ecological sciences to refer to systems in which the 'whole is more than the sum of the parts'.

Resilience

(1) The ability of a system to absorb or buffer disturbances and still maintain its core attributes; (2) the ability of the system to self-organise; and (3) the capacity for learning and adaptation in the context of change (Berkes, Colding and Folke, 2003).

The capacity of a system to re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks. It does not refer just to being persistent or robust to disturbance. It is also about the opportunities that disturbance opens up in terms of recombination of involved structure and processes, renewal of the system and emergence of new trajectories. (Plummer and Armitage, 2007)

Risk

The possibility of suffering harm or loss (OED). In this case, risk can be viewed in several directions: in the context of climate change there is significant risk involved if alternatives are not explored, and the effects are not monitored. However, the risk of experimental interventions causing harm, has inhibited AM efforts in North America (Bormann, Haynes and Martin, 2007). While AM is considered 'risky' in terms of management, through using AM the potential to discover management systems that reduce vulnerability and increase adaptive capacity and resilience is increased.

Uncertainty

The problem of not having knowledge or information about the current state and dynamics of a system, and hence not knowing how the system will respond to a chosen decision (Conroy *et al*., 2008). In the context of forestry, uncertainty comes from not knowing the scale and impact of climate change, unknown social and economic contexts and unknown levels of vulnerability of forest ecosystems (Walters, 1997 ; Bormann, Haynes and Martin, 2007).

[In the case of AM,] *uncertainty covers a wide range of phenomena relating to the outcomes of a plan, the assumptions that underlie management interventions, the values associated with the anticipated consequences, and a variety of institutional responses.* (Gregory, Ohlson and Avrvai, 2006)

Vulnerability

The state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt (Spittlehouse, 2005).

Adaptive forest management is a systematic process for continually improving forest management, in conditions of complexity and uncertainty, by learning from the outcomes of experiments and operational practice. Adaptive management has often been proposed as a suitable approach for dealing with uncertainty and complexity in natural systems, particularly in relation to climate change.

Some of the most significant challenges for implementing adaptive management are social and institutional. This study reviews published evidence, to assess international experience in adaptive forest management and its implications for woodland management in the UK. While much can be learnt from other countries, the pressures on land, high public expectations, fragmented habitats and ownership structures require a particularly collaborative approach in the UK. Characteristics of the UK context, including longstanding experience with partnership working, and a thriving culture of forestry knowledge networks, are promising aspects for a more adaptive approach to forestry.

Forestry Commission

Silvan House
231 Corstorphine Road
Edinburgh
EH12 7AT

www.forestry.gov.uk