

The state of the natural environment

Land use and the future of forestry

**Andy J Moffat¹, Chris P Quine and Helen McKay
Forest Research**

While the Government Office for Science commissioned this review, the views are those of the author(s), are independent of Government, and do not constitute Government policy

¹ Prof. A.J.Moffat, Centre for Forestry and Climate Change, Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH. Email: andy.moffat@forestry.gsi.gov.uk

Introduction

This review will discuss possible changes to land covered by trees. 'Forestry' is taken here to include all trees, woodlands and forests, whether subject to management or not, and the review will include the state and role of trees in the urban landscape. The first part will describe the size, types, defining characteristics and primary uses of the current forested landscape. The second will explore how forestry may change over the next decades, and examine the main drivers behind these possible changes. The contents of this second part are inevitably surrounded by uncertainty and some may be controversial. They are intended to promote discussion and the exploration of policy options. The views are those of the authors and do not represent those of the devolved forestry administrations or the Forestry Commission.

The statutory basis for forestry in the UK is contained in the Forestry Act 1967. This charged the Forestry Commission with 'the general duty of promoting the interests of forestry, the development of afforestation and the production and supply of timber and other forest products'. It also promoted the 'establishment and maintenance...of adequate reserves of growing trees'. However, forestry policy has evolved from one primarily focused on home-grown timber production to one that incorporates multiple objectives. Today it is centred on the principle of 'Sustainable Forest Management' (Forestry Commission, 2009a). This is the global forest industry response to sustainability principles that emerged from the United Nations Conference on Environment and Development (the Rio Earth Summit) in 1992. The Second

Ministerial Conference on the Protection of Forests in Europe in Helsinki, 1993 defined Sustainable Forestry Management as:

‘The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.’

This multifunctional approach to forestry is central to the modern delivery of forestry policy in the UK, both in the management of the public forestry estate (29% of all UK woodland and forest), and in the development of requirements for planning, designing and managing forests for private woodland owners to follow. These are contained in the UK Forestry Standard (Forestry Commission, 2004a) and its supporting Guidelines. The Guidelines also have an important function as the basis of forestry practice for the independent UK Woodland Assurance Standard (UKWAS), which is used for the voluntary independent certification of Sustainable Forestry Management. The public forest estate in Great Britain has been accredited under this scheme since 2000. In 2008, 45% of all UK woodland was certified.

The UK Government devolved responsibility for forestry to Scottish Ministers and the National Assembly for Wales in 1999 as part of a wider programme of constitutional reform. It retained responsibility for forestry in England and for

international issues. Forestry has been fully devolved in Northern Ireland since 1922. A consequence of devolution has been the development of Forestry Strategies for England, Scotland and Wales (Defra, 2007; Scottish Executive, 2006; Welsh Assembly Government, 2009). These set out the priorities and programmes of the devolved administrations for developing and implementing forestry policy over the next few decades, and are distinctly different, reflecting the nature of each country's woodland and forests, and the different priorities put on them.

The current state of forestry

Location, extent and character

Current and historical woodland cover in the UK is given in Table 1. There has been a major expansion of woodland cover during most of the past century. This increase resulted from a purposeful response to the serious inadequacy of domestic timber resources. Woodland now covers nearly 12% of the UK land area, but is low compared to the EU average of 37%.

Table 1. Woodland cover in the UK in hectares and as percentage of total land area

Year	England		Scotland		Wales		Northern Ireland		UK	
	Area (000 ha)	%	Area (000 ha)	%	Area (000 ha)	%	Area (000 ha)	%	Area (000 ha)	%
1924	660	5.1	435	5.6	103	5.0	13	1.0	1211	5.0
1980	948	7.3	920	11.8	241	11.6	67	4.9	2175	9.0
2008	1127	8.7	1342	17.2	285	13.7	87	6.4	2841	11.7

Source: Forestry Commission (2008)

Expansion has focused on faster-growing coniferous species, notably in upland areas in Wales, Scotland and northern England (Table 2), where suitable land was available. Conifers now make up nearly 60% of UK forests. Broadleaved woodland has received more support since the 1980s, as a result of increased interest in woodland as a wildlife habitat and the belief that woodlands composed of native tree species are generally more biodiverse. Britain has only three native conifers, only one of which produces timber. Largely as a response to changes in forestry policy after the enactment of the Wildlife and Countryside (Amendment) Act 1985, the area of broadleaved woodland in Great Britain increased by 34% between 1980 and 1998, with the relative proportion of broadleaves to conifers increasing from 35% to 39% of total forest area (Forestry Commission, 2003). The rate of planting has declined substantially in recent years (Forestry Commission, 2008), mainly due to changes in taxation, but also in part because of the influence of the biodiversity and landscape conservation lobbies.

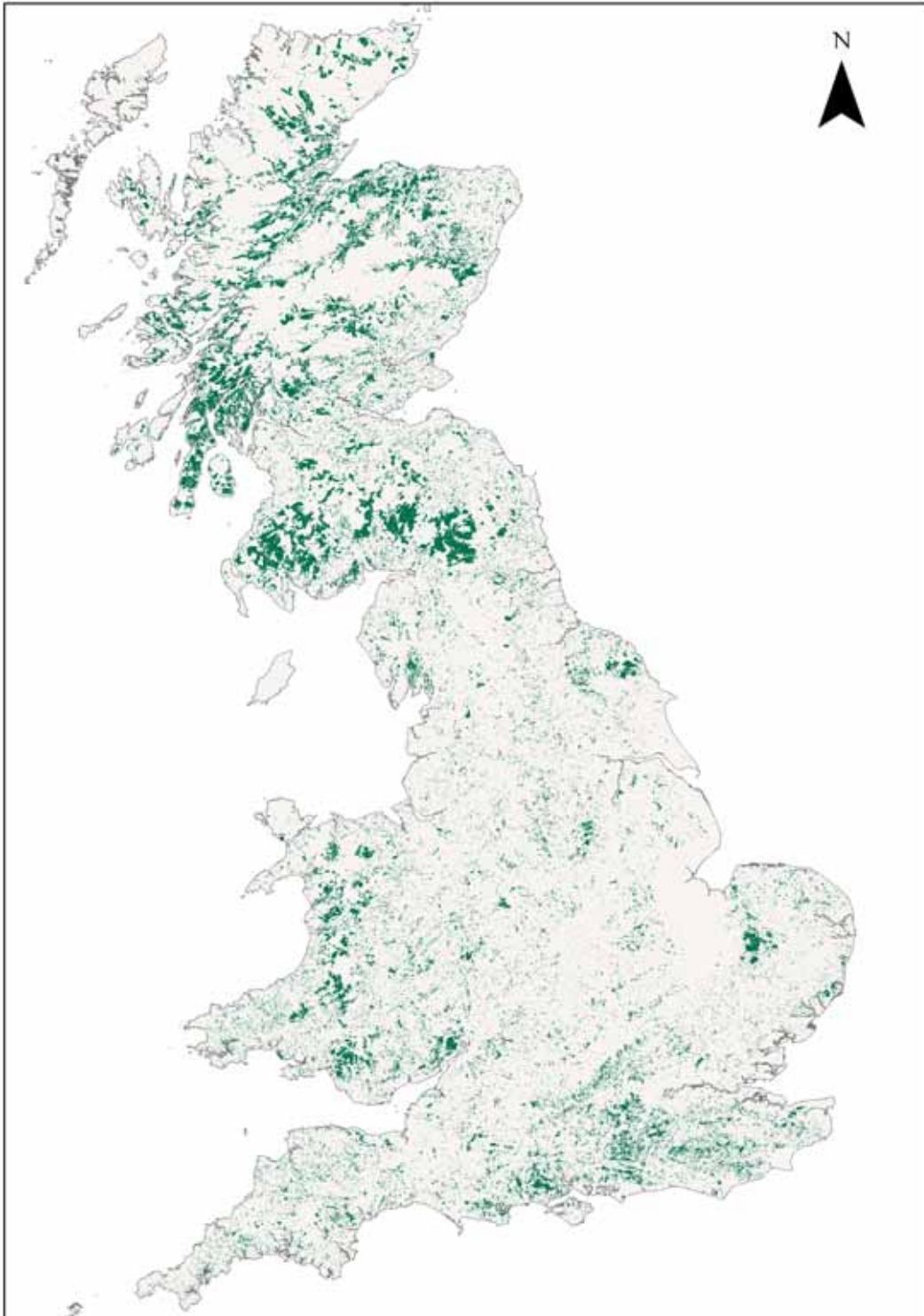
Table 2. Woodland type and ownership in the UK (thousand hectares)

Country	Conifer	Broadleaf	Conifer: Broadleaf ratio	Total woodland
England	366	761	0.48	1127
Scotland	1045	297	3.51	1342
Wales	157	128	1.23	285
Northern Ireland	66	21	3.14	87
UK	1635	1207	1.35	2841

Source: Forestry Commission (2008)

Figure 1 shows where the main wooded areas are in Britain. Some regions such as Cambridgeshire and Lincolnshire, Anglesey and the Scottish Islands have very low woodland cover (less than 1%), but others are comparatively well wooded (e.g. east **Figure 1. Distribution of woods and forests in**

Great Britain in 2000



Source: Forestry Commission (2003)

Galloway (nearly 36%), Surrey (nearly 24%) and south Gwynedd (nearly 20%). Planted forests, mainly of Sitka spruce (49% of all coniferous woodland), are generally larger in Wales and Scotland; in England there are more broadleaved woodlands of smaller size. Well-known public forest areas include the New Forest and Forest of Dean in England, Afan Forest Park in Wales, and Galloway Forest Park in Scotland. Woodland character differs considerably from country to country and from region to region.

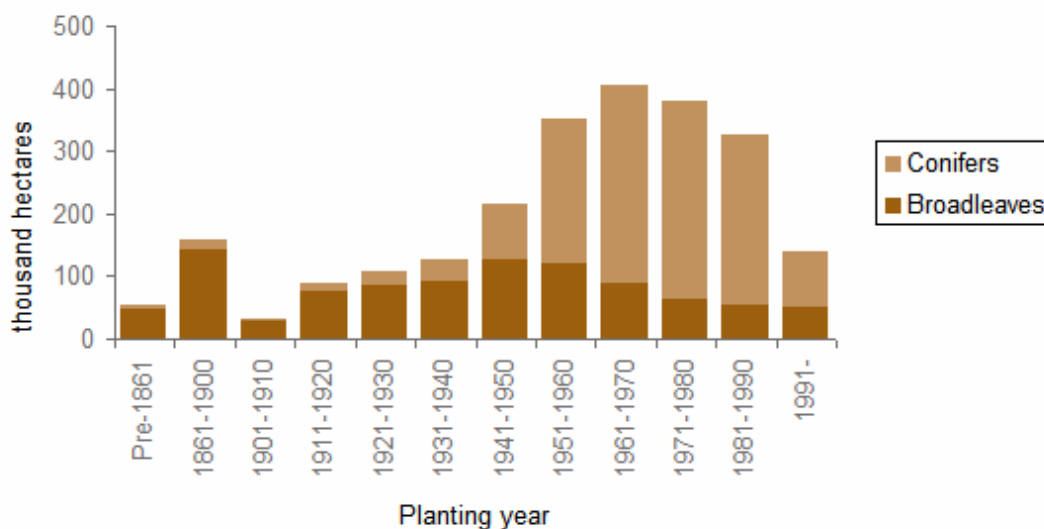
The Forestry Commission and the Northern Ireland Forest Service owned or managed 29% of the total woodland area of the UK in 2008. This proportion ranged from 18% of the woodland area in England to 70% in Northern Ireland. Other owners include traditional estates and investment and management companies (Forestry Commission, 2008). Conservation charities such as The National Trust and the Woodland Trust have also developed to play a significant part in woodland management (with 25,000 and 20,000 hectares respectively) and development of policy in support of Sustainable Forestry Management.

Britain has virtually no virgin forest left, and only a small proportion of its woodland area has a strong legacy of natural forest cover. But approximately 326,000 hectares of 'Ancient and Semi Natural Woodland' (Forestry Commission, 2008) and nearly 551,000 hectares of Ancient Woodland, which has been continuously wooded since at least AD1600 (AD1750 in Scotland), have been conserved. The restoration of 'Plantations on Ancient Woodland Sites' (so-called PAWS) has been a target in recent years. There has also

been some restoration of bog from afforestation (Patterson and Anderson, 2000), and continued pressure for woodland removal from other valued habitats, notably lowland heath. Planted forests are managed primarily using the ‘high forest’ silvicultural system, in which woodland blocks are clearfelled when the tree crop reaches economic maturity. However, alternatives to clearfell, also known as Low Impact Silvicultural Systems and which include Continuous Cover Forestry, are increasingly being implemented.

Figure 2 shows the age distribution according to main tree types. It reflects the significant planting programmes that took place in the second half of the 20th century, which involved both replanting areas felled during WWII and expansion onto marginal agricultural land. However, it also shows that this level of planting has not been sustained in the past 20 years, and that a large proportion of the forest is approaching harvesting age.

Figure 2. Age profile of woodland in GB



Source: Forestry Commission, 2008

Forestry and the economy

Table 3 shows estimated standing timber volumes by woodland type and species, illustrating the predominance of coniferous species. Commercial coniferous species provide the majority of timber stocks. They are all non-native with the exception of Scots pine. Most planted forests and the majority of managed woodlands are predominantly of one or two tree species.

Table 3. Growing stock in 2010 by ownership, type and species (million cubic metres)

Common name	GB Private comml forecast	GB Private non-comm	GB Private over-mature comm	GB Private over-mature non-comm	GB State comml	GB State non-comm	GB Total	NI	UK Total
Sitka spruce	72.9	0.3	3.2	0.0	54.4	0.6	131.4	6.5	137.8
Scots pine	25.8	0.8	8.0	0.7	9.2	0.4	44.9	0.7	45.6
Larch	9.9	0.4	2.6	0.1	5.4	0.3	18.9	0.3	19.2
Lodgepole pine	13.1	0.1	0.1	0.0	8.3	0.2	21.8	0.3	22.1
Norway spruce	10.3	0.2	0.9	0.0	5.7	0.3	17.4	0.5	17.9
Douglas fir	6.2	0.1	1.6	0.0	3.0	0.0	10.9	0.2	11.0
Corsican pine	3.8	0.0	0.6	0.1	4.6	0.1	9.2	0.0	9.3
Other conifers	5.7	1.0	4.9	3.1	2.8	0.2	17.8	0.2	18.0
Total conifers	147.6	2.9	22.0	4.1	93.5	2.2	272.3	8.7	281.0
Oak	15.3	6.0	4.8	0.8	1.1	0.3	28.3	0.4	28.7
Beech	6.8	1.1	6.4	1.1	1.6	0.1	17.2	0.1	17.3
Birch	2.1	3.9	0.7	0.4	0.0	0.3	7.3	0.2	7.5
Ash	4.9	1.4	5.9	2.1	0.0	0.1	14.4	0.1	14.5
Sycamore	2.3	0.9	2.2	0.9	0.1	0.5	6.7	0.1	6.8
Other broadleaves	10.5	8.3	2.4	0.7	0.2	0.6	22.8	0.2	23.1
Total broadleaves	41.9	21.5	22.5	5.9	3.0	1.9	96.7	1.1	97.8
TOTAL	189.5	24.5	44.4	10.1	96.5	4.1	369.0	9.8	378.8

Source: FAO, 2010

Biologically, annual wood production has exceeded the annual harvest for many years. While the Forestry Commission aims to balance the volume harvested with the increment for the public estate, this does not apply to privately-owned woodland. Different types of owners have their own reasons

for not harvesting, which range from the economic and technical to the emotional and attitudinal.

UK production of roundwood, defined as stemwood more than 7 centimetres in diameter, totalled 9.0 million m³ wood raw material equivalent underbark (WRME) in 2007. A further 54.1 million m³ WRME of wood and wood products were imported to the UK in that year, while 6.6 million m³ WRME were exported. These figures exclude recycled wood and recovered paper. The main markets for timber and wood-based products are construction, pallets and packaging, furniture, fencing and outdoor use markets. In addition, there is a wide selection of other markets, ranging from the manufacturing of kitchen utensils, picture frames and toys to ladders and transport components. More recently, bioenergy has emerged as a potential significant market on an industrial, commercial and domestic scale.

A substantial wood processing industry has been established, and the UK is a significant exporter of wood-based products. But the UK is also a major importer of wood-based products, fourth in the world in value terms behind the US, China and Japan. The Gross Value Added for forestry and primary wood processing, the difference between the value of outputs and the value of intermediate consumption, was over £2.1 billion in 2007 (Forestry Commission, 2009b). This excludes secondary wood processing industries, which are mainly based on imported materials.

In 2007, 42,000 people were employed in the UK forestry and primary wood processing sectors (Forestry Commission, 2009b). Of these, the 13,000 in the forestry, logging and related services plus another 12,000 in sawmilling and 5,000 producing panels are largely reliant on home-grown resources.

Forestry and the environment

Forests provide a wide range of ecosystem goods and services. This role is reflected in the definition of Sustainable Forestry Management, and the Ecosystems Approach adopted by the Millennium Ecosystem Assessment (World Research Institute, 2003). Defra and other government departments increasingly value this approach. Table 4 gives a brief list of the services considered most important, and in the following section, some of those considered most relevant to land use are briefly described.

Table 4. Types of UK Forest Ecosystem Service, based on framework from Millennium Ecosystem Assessment

Ecosystem Service provided by woodlands	Examples of goods and benefits	Key references
Provisioning Services		
Trees as a source of timber	Provision of raw timber materials for use in commercial and domestic enterprises; provision of chips for boards and pulp for paper. Use of timber as an alternative for other building materials such as steel and concrete in order to reduce use of fossil fuels and enhance building standards.	Forestry Commission, 2003; Suttie et al., 2009
Trees as a source of bio/woodfuel	Timber products (e.g. harvesting residues, stumps and roots, recycled wood) as fuel for heat and power	McKay et al., 2003; Ireland et al., 2004

	plants, as domestic firewood, for biochar and as raw material for processed hydrocarbon fuels.	
Non-timber forest products	Non-timber forest products (NTFPs) for commercial and domestic use, for example meat, berries, honey, fungi and medicinal derivatives and drugs.	Martin et al., 2006
Regulating Services		
Purification – Pollution control	Capture of atmospheric pollutants in tree canopies and consequent reduced exposure for humans, crops, buildings etc. Woodland cover to stabilise contaminated brownfield land and hinder the pathways between source and receptors. Because of minimal use of pesticides and fertilisers, woodlands managed under sustainable principles also offer benefits of water quality.	NEG TAP, 2001
Hazard regulation – soil protection	Tree cover can offer protection from soil erosion and slope failure. Forest management will reduce exposure to chemicals and pesticides and likelihood of soil compaction compared to agriculture.	Moffat, 1991; Nisbet et al., 2008
Hazard regulation – flood and water protection	Woodlands moderate rainfall events and river and stream hydrographs, delaying and reducing flood events.	
Climate regulation – carbon sequestration	Woodlands and their soils are important reserves of terrestrial carbon, and timber products can also be considered.	Morison et al., 2008; Lorenz and Lal, 2009
Climate regulation – avoidance of climate stress	Tree cover can help dampen the climatic effects experienced in the open, thus protecting soils, animals and humans from extremes of temperature and UV light.	Mason et al., 2009
Cultural Services		
Meaningful places – social cohesion, personal strength	Trees and woodlands are valuable for personal enlightenment, and as places or catalysts for social activity and cohesion.	O'Brien, 2006
Meaningful places – education	Forests are increasingly harnessed for their educational value.	O'Brien and Murray, 2007
Meaningful places – inspiration for the arts	Trees have been perpetual motifs in fine art, and influenced many other art forms.	Phythian, 1907; Hohl, 1998

Socially valued landscapes – recreation and tourism	Many forests are open to the public for the enjoyment of outdoor pursuits and recreational activities. Their access facilitates exercise and benefits human health and longevity.	Woodland Trust, 2004; O'Brien and Morris, 2009
Socially valued landscapes – historic environment, amenity	Trees and woodlands increase the diversity of landscape character; their existence provides a link with the past when man's existence was more closely linked to woodlands and their products; woodlands reduce the rate of, or eliminate the need for, cultivation, a significant cause of archaeological destruction.	Rackham, 1976; Smout, 2002; Crow, 2004
Supporting Services		
Soil formation, nutrient cycling, water cycling, oxygen production	Forests facilitate soil formation and other biogeochemical processes essential to life.	Fisher and Binkley, 2000
Biodiversity	Forests, including plantations, provide habitat for a wide range of fauna and flora.	Humphrey et al., 2003

Source: World Research Institute, 2003. Figures rounded.

The distribution of woodland and forest across different soil types is shown in Table 5. It shows that there has been a predisposition to retain and establish coniferous woodland on more acidic, infertile and poorly drained soils, mainly because other commercial species do not thrive on these soil types.

Broadleaved woodlands occur much more on more fertile brown earth soil types. Forest soils can contain more carbon than the trees, particularly the organic-rich soils common in the upland areas of the UK. Forest soil carbon stocks in each main soil group are given in Table 6, based on a recently completed survey of forest soils in Great Britain.

Table 5. Soil types under GB forests

<i>Soil Type</i>	Soil (%)	Conifer (%)	Broadleaves (%)
Brown Earths	30.9	21.4	43.7
Podzols and Ironpans	6.3	15.5	9.5
Surface water gleys	19.4	11.3	23.1
Ground-water gleys	5.2	0.7	3.1
Peaty gleys/podzols	15.7	37.0	5.2
Deep peats	5.9	10.6	1.3
Rankers and rendzinas	5.6	3.5	14.2
Other	11.0	0.0	0.0

Source: Morison et al., 2008

Table 6. Mean soil carbon stocks to 80 cm depth (Mt CO₂ equivalent ha⁻¹) averaged for soil type, country and forest type

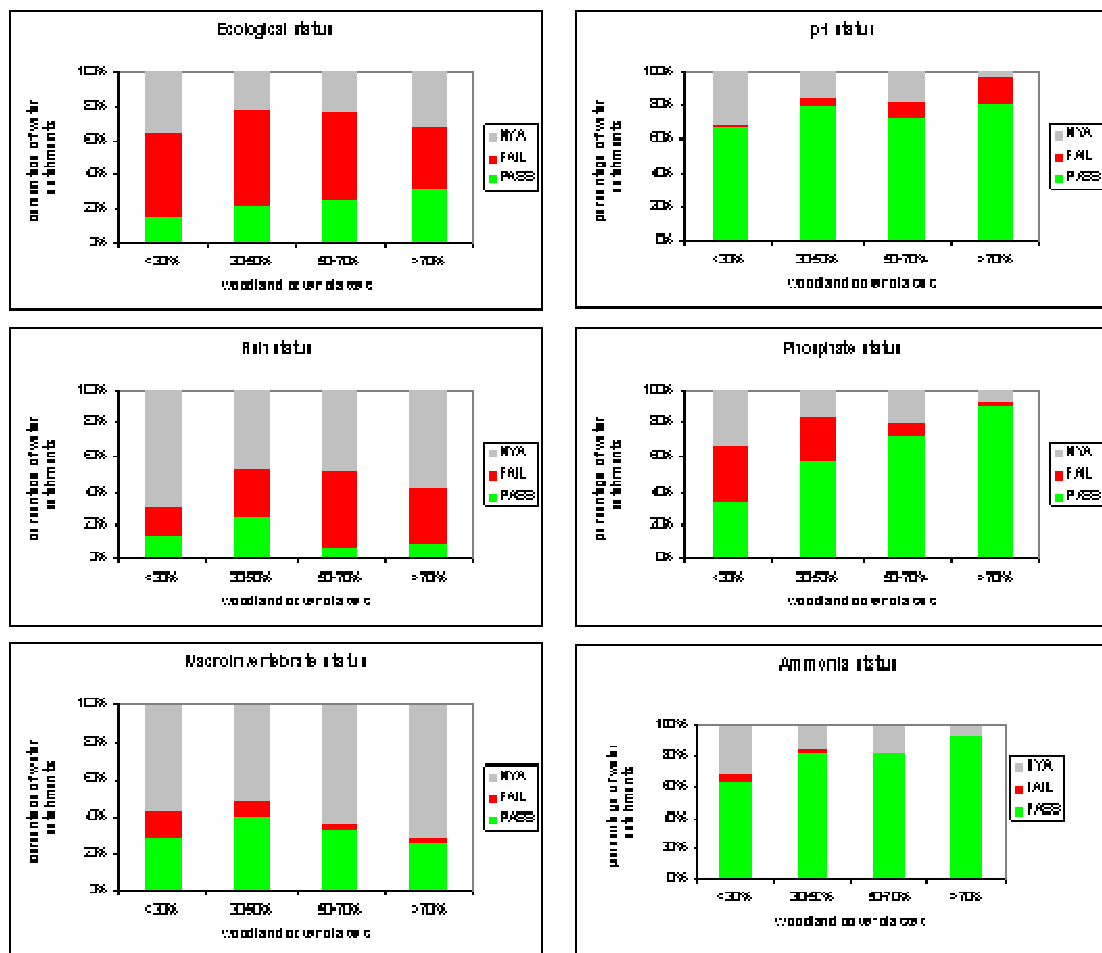
Soil type	England		Wales		Scotland	
	Coniferous	Broadleaves	Coniferous	Broadleaves	Coniferous	Broadleaves
Brown earths	71.6	135.1	39.1	34.2	70.6	36.6
Podzols and ironpans	28.0	20.1	21.9	0.3	84.2	25.0
Surface water gleys	40.2	91.9	5.0	9.9	58.8	16.7
Ground water gleys	6.1	15.3	0.4	1.2	0.0	0.0
Peaty gleys	63.2	9.3	26.2	4.7	636.4	42.4
Deep peats	38.1	12.6	18.8	0.8	231.7	6.4
Rankers and rendzinas	22.6	73.1	4.2	2.3	9.2	1.1
Total	269.8	357.3	115.6	53.4	1091.1	128.3

Source: Vanguelova et al., in prep.

Forests and the way that they are managed can have profound effects on surface and ground waters. Well-located, designed and managed forests help to protect water and the wider environment, moderate surface water flow and support the flora and fauna that depend on this important habitat. In contrast, poor planning and management can contribute to water shortage and water pollution, including increased acidification, siltation and nutrient enrichment (Nisbet et al., 2008). For England and Wales, Figure 3 shows some indicators of water quality that vary with the degree of land covered by woodland and

forest. For those datasets that are reasonably complete, there is good evidence to suggest that woodlands can maintain water quality, especially from eutrophication. However, acidity remains an issue in some upland catchments, largely due to the scavenging effect on atmospheric pollution that forests exhibit.

Figure 3. Indicators to describe water quality in catchments in England and Wales



Source: Data kindly provided by the Forestry Commission and Environment Agency. NYA = not yet assessed.

UK forests are important ecosystems for wildlife habitat. Table 7 shows that planted forests can be significantly biodiverse. They make a major

contribution to the conservation and enhancement of biodiversity in woodland itself and in open habitats. Over 200,000 hectares of UK woodland are under various types of statutory protection, principally for the diverse range of species and habitats they support. Biodiversity has been enhanced by: increasing the range of species planted; the amount of open space; the treatment of riparian zones; and the provision of deadwood. Forests are important habitats for a number of rare and iconic species, e.g. the red squirrel and the capercaillie. Targeted management has been developed to assist their survival (Ray and Broome, 2007). There is evidence that woodland birds have fared better than farmland birds over the past decade (Defra, 2009a), but there are still concerns over the provision of suitable woodland structures for key species. Major issues are the neglect of management, and the impact of increasing deer populations on the ground and shrub layers (Gill and Fuller, 2007; Quine et al., 2007).

Table 7. Total number of invertebrates, fungi, lichens, vascular plants and songbird species recorded in various forest/climate zones

	Lowland		Upland	
	Scots pine	Oak	Sitka spruce	Oak
Canopy invertebrates	81	66	47	31
Sub-canopy invertebrates	220	95	114	84
Ground invertebrates	75	41	52	37
Deadwood invertebrates	24	8	23	2
Fungi	249	181	232	127
Lichens	29	51	46	102
Bryophytes	35	37	54	60
Vascular plants	34	55	40	60

Songbirds	25	0	15	0
Totals	772	534	623	503

Source: Humphrey et al., 2003

Forestry for people

Forests are now regarded as important for delivering on many government agendas, such as improving quality of life, tackling social exclusion, and promoting sustainable lifestyles (O'Brien, 2003). Increasing urbanisation and the impact of Community Forests have brought the public benefits of forests into sharp focus in recent years, and this trend is likely to continue.

In 1990, Community Forests were established in England to demonstrate the potential contribution of environmental improvement to economic and social regeneration. Over 10,000 hectares of new woodland have been established and more than 27,000 hectares of existing woodland have been brought under management. This regeneration approach was also taken in 2003 by the North West Development Agency and the Forestry Commission. They used £59 million of funding, in two phases, for the Newlands (New Economic Environments through Woodlands) regeneration programme (North West Regional Development Agency, 2007). Major contributions have been made to government agendas including quality of life, health, community cohesion, and addressing climate change through a focus on public benefit (Nail, 2008; Lawrence et al., 2009).

Forests, including urban forests, have a key role in the delivery of 'green health' benefits, by providing restorative post-stress environments (Mitchell

and Popham, 2008; Maas et al., 2009). People have significant cultural and social attachments to trees and woods, and value them as components of the UK landscape (Tsouvalis, 2000). Trees and woods also have a key role in the delivery of wider recreation opportunities, both formal and informal. Forests are increasingly popular as destinations for sport, leisure and tourism (Martin, 2007). The number of people in the UK who say they have visited forests in the past few years has risen from 67% in 2003 and 65% in 2005 to 77% in 2009 (Jamieson and Diggins, 2009). Forests are also seen as having an important role in environmental education, with potential for contributing to the public understanding of climate change (Lovell and O'Brien, 2009). There is a strong connection in many people's minds between forests and climate change mitigation. In many UK regions, forests are integral to the rural economy and social enterprise. They are key visible and cultural components of the landscape and offer considerable potential for the exploration of participatory planning and governance (Edwards et al., 2009).

There have been several studies intended to explore, and where possible quantify, the actual impact that forestry is making on people's lives. Box 1 contains some pertinent findings for Scotland. These studies show that by direct and indirect means, UK woodlands and forests are delivering significant economic and social benefits.

Box 1.

- Total employment in the Scottish forestry sector is estimated to be 13,200 Full-Time Equivalent (FTE) jobs.
- Employment due to spending from tourism and recreation attributable to woodland is estimated to be around 17,900 FTE jobs.
- The total Gross Value Added (GVA) associated with Scottish timber is estimated to be around £460 million at 2007/08 prices, or 0.5% of the total GVA for the Scottish economy.
- The GVA of visitor spending attributable to woodland visits is estimated to be £209 million at 2007/08 prices.
- Between 56% and 41% of Scottish adults visited Scottish woodlands, equating to 2.3 and 1.7 million people, in 2005/06 and 2006/7 respectively.
- In 2006/07, an estimated 64% of Scottish children made a total of 11.6 million visits to Scottish woodlands.
- An estimated 95% of the Scottish adult population agrees or strongly agrees that woodlands in Scotland are an important part of the country's natural and cultural heritage.
- Around 65% of the Scottish adult population is estimated to agree or strongly agree that woodlands are good places to meet with friends and family.
- There are 1,418 scheduled ancient monuments located in Scottish forests.

Source: Edwards et al., 2009

Emerging issues

The multifunctional nature of forestry in the UK means that it is constantly subject to a large range of drivers and pressures for change. This section outlines what we consider to be the principal future drivers, reviews evidence about how the sector has been responding to them, and suggests institutional changes that will be required to facilitate further travel in the right direction.

Climate change

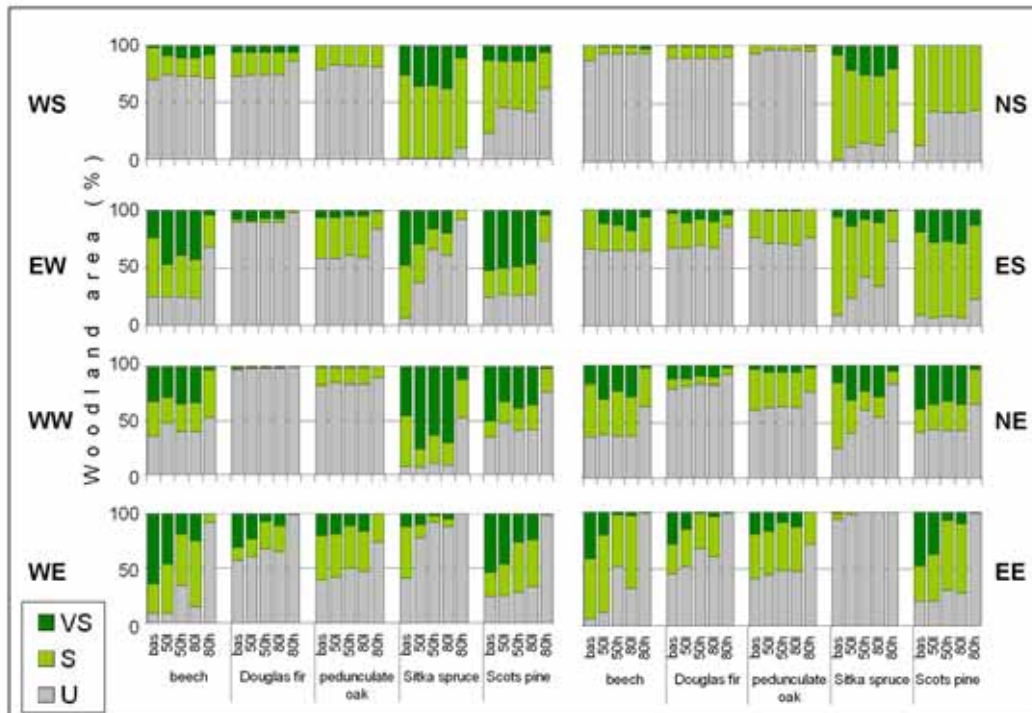
Climate change adaptation

Since the UN Conference on Environment and Development (the Rio Earth Summit) in 1992, the forestry sector, led by the Forestry Commission, has adopted a strong focus on climate change. With the advent of domestic projection scenarios for climate change (by UK Climate Impacts Programme – UKCIP – from 1998), it has been possible to explore the implication of projected changes in temperature and rainfall on the suitability and growth of a range of tree species grown commercially in the UK, using the Forestry Commission Ecological Site Classification (Pyatt et al., 2001; Ray et al., 2002). Using the UKCIP02 scenarios (Hulme et al., 2002), Figure 4 gives some insights into species suitability under the low² and high³ socio-economic scenarios for 2050 and 2080. Britain is divided into eight regions, and the suitability of five major commercial tree species has been assessed to give an average suitability across each region in its entirety.

² Clean and efficient technologies; reduction in material use; global solutions to economic, social and environmental sustainability; improved equity; population peaks mid-century

³ Very rapid economic growth; population peaks mid-century; social, cultural and economic convergence among regions; market mechanisms dominate; reliance on fossil fuels

Figure 4. Change in the suitability of five important forest tree species with UKCIP02 scenario by UK region



VS = very suitable; S = suitable; U = unsuitable. WS = West Scotland, EW = East Wales; WW = West Wales; WE = West England; NS = North Scotland; ES = East Scotland; NE = North England; EE = East England

Figure 4 shows that the likely tree response varies considerably across Great Britain. In east and west England, the class of very suitable declines for every species compared to the baseline climate. But in west and east Scotland, there is a projected increase in the area that is very suitable for some of the species studied. Overall, the signs are that in the south of England and in parts of east Scotland, it is highly likely that climate change will cause a decline in the suitability of species on many traditional site types. This is mainly due to increased drought stress, and it is likely to lead to reductions in the quality as well as quantity of timber derived from the traditional species currently considered suitable.

The impact of projections such as that described above is significant. These scenarios are based on best practice modelling methods and make use of the best available knowledge on the climatic and soil requirements of commercial tree species. Climate Change Guidelines are currently being finalised by the Forestry Commission and will be published in 2010 (Forestry Commission, in press). They will require forest managers to give due regard to species suitability predictions when establishing or replanting forests, and will encourage more species diversity in planting designs. A major implication of this scientific analysis is that in particular areas of the country, the future climate will be unsuitable for several of the types of native species growing there at present. The composition and nature of these woodlands will inevitably change and adaptation will be required to manage them sustainably. Increasing attention is being given to the use of non-native tree species which currently grow in climatic conditions predicted to occur later in this century, such as *Eucalyptus*, *Nothofagus* and Calabrian pine. Adaptation strategies for the forestry sector will support this approach across Government (e.g. Kirby, 2009), and it seems inevitable that the nature of woodlands will continue to change in this century as it did in the previous one.

Biosecurity and extreme abiotic events

In recent years, British trees, woodlands and forests have experienced significant attacks, mainly by pathological and bacterial microbes and insect pests, but also by mammals such as the grey squirrel, rabbit and various deer species. The population dynamics of these damaging agents will inevitably

change over the next few decades, partly as a result of climate change, but also due to changes in forest demographics, management and wider land use matters. In addition, it is now appreciated that the international plant and timber trade poses a real risk through the importation of new pests and diseases. There are considerable uncertainties in predicting precise effects: much depends on random or near-random processes. Nevertheless, we can say with some confidence that increased temperature will facilitate the reproduction and survival of insect, mammal and fungal pests and extend their range, whilst drought stress will increase the susceptibility of some tree species to damaging attack. It is likely that woods and forests will succumb to existing and new pests and diseases in the next decades, although to an unknown extent. Forestry policies and practices to prevent or mitigate these effects include tree protection and population control for mammals, woodland management to optimise phytosanitary conditions and reduce the risk of attack in forest stands, and biosecurity to hinder or prevent the arrival or dispersal of new pests and diseases. These will need to develop in line with risk and consequence. A new biosecurity strategy for forestry is currently being developed by the Forestry Commission, which will consider the plant trade and how to manage the risks more effectively.

Climate projections are only just beginning to address the possible shifts in frequency of extreme events such as storms and droughts. Such events can shape forestry and influence management methods. Ultimately, they can affect the technical feasibility of a range of uses for forests. Their unpredictability makes them difficult to embed in futures thinking. But clearly,

catastrophic storms and intense droughts (like novel pests or diseases) can substantially alter the perceived value of forests as well as forestry practices. Forest research and future forestry planning will have to accommodate the uncertainty of extreme events, through a combination of good adaptive and contingency management.

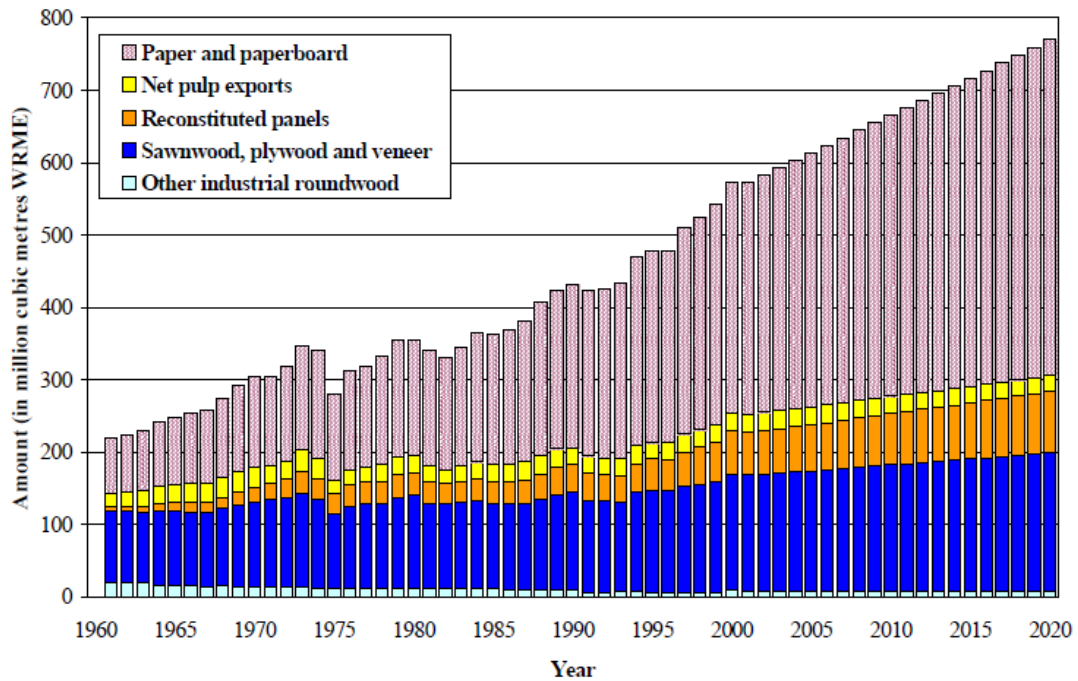
Changing markets

Forestry markets and production

Projections of the consumption and production of forest products up to 2020 for Western Europe (Becker et al., 2006) have suggested a steady future growth for all major types of wood product, especially paper and paperboard (Figure 5). Although markets for timber and timber products have suffered during the recent recession (UNECE Timber Committee, 2009), timber prices in the UK have subsequently stabilised and harvesting activity has resumed as a result of the weakness of sterling and a significant increase in demand for bioenergy (IPD, 2009). At the time of writing, there is no evidence to suggest major shifts in behaviour or technology in response to the 2008 financial downturn, so the projections of Becker and his colleagues are expected to hold, albeit with a delay of few years.

There are strategic reasons why the nature and size of the UK's future domestic timber resource will need to be addressed (Lawson and Hemery, 2008). These now include the need for national forest cover that continues to provide a sink for atmospheric carbon dioxide (Read et al., 2009).

Figure 5. Development of wood consumption in western Europe until 2020



Source: Becker et al., 2006

In the UK, potential softwood availability in the United Kingdom is predicted to increase over the next 15 years from 12 million m³ per year in the period 2007–2011, peaking in the period 2017–2021 at just over 14 million m³ per year (Halsall et al., 2006). A major exercise is under way to refine and increase the certainty of these predictions by means of an updated woodland map, revised information on management intentions, and measurement of a significant sample of privately-owned woodland. Options to meet the anticipated gap between potential demand and domestic supply include releasing the ‘wood bank’ that has built up over recent decades and mainly in

privately-owned woodland, increasing the woodland area, and changing to species with greater growth rates. Of these, the last two can have an immediate but limited effect. Barriers to harvesting differ between different types of private owner, making detailed predictions of future supply across the UK uncertain. Further uncertainty is introduced by the possibility of catastrophic change such as the possible mortality of an important commercial species due to a new pest or disease. On balance we concur with Lawson and Hemery (2008) who concluded that the increase in demand for conventional wood products will not be met from standing timber resources because of the many impediments to bringing timber to market. The UK will increasingly need to rely on imported supplies.

Sawn timber can contribute to climate change mitigation by replacing materials with high embedded energy such as steel and concrete. It also has inherent insulating properties. These advantages have been recognised in theory (Burnett, 2006) but have yet to be translated into increasing demand. However, we anticipate that the Government's Code for Sustainable Homes (Department of Communities and Local Government, 2006), which sets a pathway for all new homes to be zero-carbon by 2016, will draw attention to both of these advantages and should strengthen the market for construction timber.

Demand for wood energy in the EU is projected at about 260 million m³ in 2010, up from about 160 million m³ in 2003. If EU Member States are to meet the targets for renewable energy based on the EU Biomass Action Plan, there

will need to be an increase in harvesting intensity, possibly including the recovery of branchwood, stumps and roots, an increase in thinning activity, and an expansion of the area used for wood production. Across Europe there is a need to increase the responsiveness of woodland owners to the opportunities they now have for contributing to wood supply. Traditional market mechanisms may not be enough to increase supply from these sources, and new policy instruments are likely to be required. These could include fixed prices, taxation, investment subsidies and green certificates (Thornley and Cooper, 2008). Certainly, opportunities under the EU Rural Development Regulation (RDR) and the Common Agricultural Policy (CAP) Single Payment Schemes need to be exploited more intensively (Silcock and Manley, 2008) to encourage further tree planting on agricultural land. This will require work by several government departments and the European Commission in time for the new programmes in 2013 (Standing Forestry Committee ad hoc Working Group II, 2008).

As a means of capturing atmospheric carbon dioxide, the cost-effectiveness of woodland creation has to be placed in the context of other abatement strategies. Marginal abatement cost curves have been derived for various land use sectors (Moran et al., 2008), and Matthews and Broadmeadow (2009) have expanded this analysis to explore a range of woodland creation options. Their work shows the potential for woodland creation to meet climate change objectives cost-effectively, and identifies where grant aid or other financial initiatives might be required to achieve such a programme. However,

it is important to recall that woodland creation delivers abatement in the medium to longer term rather than immediately.

Woodland expansion will almost certainly require private as well as public finance. Innovative incentive and regulatory mechanisms will need to be developed (Pareto Consulting, 2008). For example, work to identify how producers can benefit from the take-up of atmospheric carbon dioxide has begun with the recent publication of a draft *Code of Good Practice for Forest Carbon Projects* (Forestry Commission, 2009c). The Code sets out a Design Standard for projects that aim to sequester carbon through woodland creation and to generate voluntary emission reductions for the purposes of demonstration or sale. Although the removal of carbon units associated with projects under this Standard cannot contribute to an organisation's emissions trading account under the EU Emission Trading System or towards carbon reduction commitments, it would quantify them and allow reporting as part of a wider corporate social responsibility programme. Other financial mechanisms are currently being explored, and will be needed if woodland expansion and increased timber production is to take place.

A major uncertainty in predicting how the UK may respond to the need for timber in the 21st century is the influence of demand from the rest of the world, in particular quickly-developing countries such as China and India (Flynn et al., undated; Fuller, undated).

Biomass energy

The recent focus on bioenergy (e.g. DECC, 2009a, 2009b) has shown the strategic need to consider renewable energy as a safeguard against uncertain energy provision from overseas suppliers, and as a form of climate change mitigation. Government projections suggest that around 30% of the UK renewable energy target could come from bioenergy. Energy from woody biomass has significant potential. All three devolved forestry strategies in Britain support the increased use of biomass production from existing woodlands and the planting of dedicated crops such as short-rotation forestry and short-rotation coppice to grow appropriate boiler feedstocks.

The British landscape is likely to be affected by the growth of these woody plantations (Rothamsted Research, 2008), provided fiscal incentives are attractive to landowners and an industry develops to utilise these materials. Woody biomass will form a significant proportion of the fuel powering a future 'decarbonised' energy sector, especially in terms of heat generation. It is likely that this will drive substantial increases in management activity across the British natural and cultural landscapes, with practices such as coppicing returning strongly. Growth in this sector is likely to make less familiar tree species such as willow, and non-native species such as eucalyptus, more prominent.

Powers in the Energy Act 2008 allow the setting up of a Renewable Heat Incentive (RHI) in recognition of the fact that heat generated from renewable sources accounts for only 0.6% of total heat demand but may need to rise to 12% to hit the UK's binding EU targets. Support for renewable heat is

expected to accelerate the strong current growth in small-scale and community heat-only systems. Government policy to promote the growth of renewable electricity from biomass has met with mixed results to date (Thornley and Cooper, 2008), but it is likely to increase as a result of international and European obligations such as the Renewable Energy Directive, the EU Emission Trading System and the domestic Renewables Obligation, which will be extended to at least 2037.

There may be competition for land between the woody biomass and the food production sectors (Defra, 2009b). Change in land use to support biomass production is likely to be tested increasingly against sustainability principles. This approach is already well developed in the traditional forestry sector (DECC, 2009b). Nevertheless, it seems likely that large quantities of biomass will continue to be imported into the UK for energy (Perry and Rosillo-Calle, 2008) unless the internal market is suitably supported over the long term and dedicated supply chains are established.

Tree breeding and technological development

The products of tree breeding could have a major impact on future forestry. Over the coming 40 years, gains from the use of selected seed sources could yield an extra 25% more timber per hectare (Lee and Matthews, 2004) than areas planted 15 years ago, before the benefits of tree breeding became generally available. Stands of trees from new seed stock will also produce better-quality timber. With further advances in tree breeding, quality and

quantity gains will increase yet further for newly planted forests established with the most up-to-date improved stock.

Between 70% and 80% of all Sitka spruce and Scots pine planted in the UK today is the result of genetic improvement. Further progress will undoubtedly be made through higher selection intensities, and more accurate selection of the best individuals for the trait under selection (and at an earlier age) using DNA marker technology. Laboratory screening means that improved material can be released to the forest quicker, from about 25 years today to 10 years in the future.

There are further potential gains to be had by deploying the best individuals over large areas by the use of clonal forestry. This involves reducing diversity so that nearly all the trees are fit for end use at their rotation age. Clones are chosen for their adaptation to a known range of site types. However, this practice can fail to align with policies to increase diversity. Commercial practice is to use a number of different clones to balance the desire for greater performance and uniformity with biodiversity. If there are plans to use a single clone over a wide area, this dichotomy will need to be resolved.

There is currently a presumption against the use of genetically modified (GM) technology in UK forestry. However, this may change as the benefits and risk of GM become better understood for agricultural crops. It is unlikely that GM technology will make a large impact in forestry; but equally, it seems improbable that GM will not be part of forest crops 50 to 60 years from now

(Gartland and Oliver, 2006; Gartland and Gartland, 2008). Nevertheless, there remains significant opposition to this technology (e.g. Convention on Biological Diversity, 2008), and its rate of uptake is obviously uncertain. Risk management in this area needs further thought. For example, there need to be better ways of weighing the benefits of clonal and GM developments, such as their potential to reduce the use of pesticides and herbicides, against the concerns they raise for biosecurity, including the susceptibility of monocultures.

Other technologies are already indicating the value of woody biomass for biofuel generation. Biomass to liquid technologies, including those for the production of 'second generation'⁴ biofuel', are developing rapidly and are likely to be more mature and financially viable by mid-century. Interest in biofuels has slowed down after the decision to adjust targets for the proportion of biofuels blended with fossil fuel, but is likely to pick up again as the recession recedes and oil demand and oil prices go up. The scale of the resource required to support a future UK biofuels industry is probably beyond the scope of UK forestry as it exists today.

Societal demands

Health and wellbeing

There is an increasing body of evidence to demonstrate the wellbeing benefits of forests, woodlands and trees, and a greater recognition of ways in which

⁴ This would use biomass high in celluloses and lignin sourced from woody material and non-food parts of food crops, such as stems, leaves and husks, non-food crops and cereals that bear little grain, and industry waste such as wood chips, skins and pulp

they can deliver on wider government agendas that go well beyond what was previously considered as 'forestry'. The trend towards greater investment in forests as environments for health and wellbeing, education and recreation is likely to continue (Royal Commission on Environmental Pollution, 2007; Konijnedijk, 2008; Nail, 2008). The World Health Organization (2009) regards mental ill-health as a major global issue for the next 20 years, and the challenge during this time is to implement what is already relatively well understood from research – that trees, woodlands and forests provide significant restorative opportunities for an increasingly urbanised population. The importance of green space, woods and trees for health is now outlined in current health strategies such as 'Be active, be healthy' (Department of Health, 2009) and 'Healthy lives, brighter futures' (Department of Health; Department for Children, Schools and the Family, 2009). One of the Marmot review task groups on health inequalities talks about the importance of investment in quality green space, including tree planting in residential areas to promote health and reduce health inequalities (Marmot, 2009). Taken together with concerns about the disconnection of a broad range of the population from nature (Louv, 2005), these and other health issues could lead to a greater focus on trees and woodlands near to people. In UK urban areas, the health consequences of intense 'heat islands' could be managed by planting more 'shade trees', a principle already widely used around the world.

Community development and capacity

Changes to the transport system intended to reduce carbon emissions could combine with government policies to resist and reverse sedentary lifestyles in

ways that will mean a bigger role for green infrastructure, including trees and woodlands. They could form part of pleasant transport networks for walking, cycling and skating (Commission for Architecture and the Built Environment, 2009). A low-carbon economy will also encourage people to spend holidays at home rather than abroad, and there may be an increasing demand for forest-related tourism (Welsh Assembly Government, 2002).

The trend towards greater demands from community groups for involvement in woodland management and decision-making is likely to continue. Forests and woodlands could also form a focus for volunteering, and for community and public engagement in changing and improving local spaces and community life (O'Brien et al., 2008). In addition, opportunities could be taken to promote the relationship between individuals, communities and the natural environment, strengthening environmental behavioural change at the local and community level.

Interactions with other land uses

The right tree in the right place

All three devolved forestry strategies reflect the need to manage existing woods and forests, and expand woodland cover, in response to modern needs and priorities. Changing social and environmental objectives have already done much to influence woodland management in recent decades. This trend is likely to continue, in line with environmental pressures such as climate change, and the need to optimise the balance of delivery of appropriate ecosystem services. The Water Framework Directive, in

particular, requires a much more integrated approach to catchment management (Environment Agency, 2008). In the urban environment, the importance of trees and woods will grow as the climate changes. They will be an important part of the 'green infrastructure' and will be needed to help modify the microclimate. The realisation of these benefits will require attention to the location of woodlands (e.g. Woodland Trust, 2004) and will need to be provided for through the planning system.

Research, particularly the development of appropriate ecophysiological, biogeochemical and forest management models, is already providing the means to explore these issues. These models need to be further developed, and should be integrated into a better understanding of the social and economic impact of forests and woodlands. Such research will allow the trade-offs in the delivery of ecosystem services to be studied, by allowing existing woodlands to develop along certain paths and for new ones to be created in the best places. The resilience of the landscape in withstanding and adapting to the effects of climate change can be evaluated by using this kind of spatial planning process to facilitate better integration between forests and land used for agriculture. Scotland intends to produce an integrated land use strategy by 2011, and its extension across the rest of Great Britain seems possible in coming decades. Nevertheless, land use optimisation and integration are unlikely unless fiscal support measures are integrated too.

Woodland expansion is seen as important in fighting climate change (DECC, 2009a; 2009b; Read et al., 2009), mainly because of the ability of woodlands

to sequester carbon from the atmosphere, but also for their role in helping society adapt to the changes that will be needed in people's lives. In terms of carbon capture, woodlands planted since 1990, coupled to an enhanced woodland creation programme of around 23,000 hectares per year over the next 40 years, could, by the 2050s, be delivering emissions abatement equivalent to 10% of total greenhouse gas emissions at that time (Read et al., 2009). Recently, both the UK and Scottish Governments have made commitments to supporting a significant expansion in woodland cover over the next decades, mainly in support of climate change mitigation objectives (DECC, 2009a, 2009b; Scottish Government, 2009). In Scotland it has been estimated that some 84% of the land area currently has the biological potential for tree cover, whilst 33% of Scotland is identified as being suitable for trees from both a biological and a land use planning perspective (Towers et al., 2006).

The challenges set by the various forestry strategies are seen as demanding, and will be challenged by some who see woodland expansion as a threat to landscape character, wildlife habitat or even food production (with an increasing rhetoric of food security). An ecosystems approach should facilitate dialogue and negotiation between relevant stakeholders. It seems likely that work will explore and further develop markets and market mechanisms for forest ecosystem services that are currently subject to market failure. To date, most work on the economics of forest carbon has been done by Valatin (2009). He has reviewed methods for valuing carbon over time, examined approaches for dealing with risk, and considered approaches to extending

standards developed for forestry to broader voluntary carbon markets in the UK. However, the impact of climate change on total forest ecosystem carbon depends on a complex range of management decisions on adaptation policy, and it will take more work to explore the consequences for carbon value.

Work has also been undertaken to explore the value of woodlands in flood mitigation. Nisbet and Thomas (2008) have produced a summary of British and foreign cost benefit analysis studies related to woodland planting and the protection of water resources. The overall contribution of forest biodiversity and recreation has been monetised through contingent valuation studies such as Willis et al. (2003). However, none of these studies have yet examined the impact of climate change on market or non-market value or revenue.

Given multiple and diversifying woodland ownership, and the variable level of woodland planning and management objectives, it is a major challenge to find appropriate fiscal and other incentives to encourage woodland planting and change of land use. The provision of an effective and auditable carbon trading scheme seems the most likely catalyst at present.

Integration across the landscape

There are increasing pressures to consider woodland and forests as components of the wider landscape, not just as a separate and distinct land use, and it is probable that these will continue. The regulatory requirements of the Water Framework Directive, and the need for more effective spatial planning at the farm level in order to meet increasing sustainability objectives,

all require those involved in woodland planning and management to consider the wider environment. Trees and woods are increasingly recognised for their role in flood management and in water quality enhancement, but they can only be effective if they are placed strategically in the landscape. Habitat connectivity is another increasingly important driver for considering land use at this scale. The concept of 'Working trees for agriculture' (USDA National Agroforestry Center, 2008) is one that facilitates the appropriate integration of trees and woodlands into a landscape, whether intimately as in agroforestry systems, in strategically placed belts or blocks, or both.

Support for these approaches is coming from domestic forestry strategies and from those promoting the revision of broader financial instruments such as the Retail Distribution Review (RDR) and Common Agricultural Policy (CAP). Forestry has suffered in the past from being seen as a competitor or a hindrance to important rural policies, such as the maintenance and enhancement of wildlife habitat and biodiversity or the preservation of landscape character. These policies have been driven in part by international agreements and obligations such as the Convention on Biological Diversity and the European Landscape Convention. It is likely that agricultural and forestry policy will grow closer together and that financial support mechanisms that work at the landscape level will be developed. Operationally, it is possible that a rural advisory extension service will be required, to support both landowners seeking to adapt to the demands of a changing climate and the regulatory environment that will accompany it.

Discussion

Devolved country forestry strategies point to the need to instil confidence in both producers and industrial consumers, by means of the development of a long-term vision. It is also recognised that agricultural and forestry policy should be brought closer together (Swales et al., 2006), and that funding and incentive schemes need to be more integrated. The forestry sector has suffered from being much smaller than agriculture in both the UK and in most of continental Europe, and its political profile has been comparatively low. Progress in CAP reform has been slow (HM Treasury, 2005) and there has been a relatively small increase in productive woodland area in the UK for several years. Nevertheless, the importance of woods and forests in supplying a wide range of ecosystem services relevant to national and European agendas for climate change adaptation and mitigation suggests that there is a real opportunity over the next few decades to improve this position.

As the UK moves to embrace a low-carbon, and increasingly uncertain, global economy, it is clear that the strategic need for a greater forest area in the UK is increasingly understood. However, the step change in woodland expansion, and in the effectiveness of woodland management, that is needed to deliver the range of services required calls for a broader understanding and acceptance of the relevance of woods and forests in the rural landscape.

Central government and the devolved administrations are responsible for translating country forestry strategies into action on the ground and on the part of the institutions and industrial partners that are needed to support them. Barriers to woodland expansion and exploitation, in particular economic ones, must be addressed, and non-market benefits must be monetised where possible.

Sustainability will remain at the heart of forestry policy. It is also likely that this concept will be reinforced and expanded in other land use sectors, including bioenergy, as we accept the need to manage all land as much for the medium and long term as for what it can deliver on an annual cycle. The forestry sector can be expected to influence this direction of travel – indeed, forestry is unusual in being a productive land cover that can also contribute significantly to biodiversity, recreation and other policy objectives. There will be a need to reconsider the balance of delivery of ecosystem services within ‘multifunctional forestry’, and to accommodate existing policies alongside those that seek to focus on carbon. Negotiations will be needed with those focused on the extensification or ‘re-wilding’ of the countryside to support biodiversity and landscape. These should take place in the context of holistic land use at a landscape spatial scale and a dynamic temporal scale incorporating short-, medium- and long-term objectives. We are optimistic that a common understanding of forest adaptation will develop between the industrial forestry sector and those responsible for upholding the concept of sustainability through certification processes.

There is a growing realisation that many aspects of 20th century forestry are exportable into the 21st; for example, well-managed plantation forestry, and it is possible that in the next decades, there will be a convergence of attitudes towards land management based on sound science. In addition, there will be a blurring of the distinction between planted and regenerated forests and woods and between native and non-native tree species. Some remaining taboo areas such as GM technology and nativeness will need revisiting, although GM should be seen as only one type of biotechnology that is likely to demonstrate its value in both the agricultural and silvicultural sectors. The continual evolution of ideas about woodland management in the face of changing environmental, economic and social pressures will inevitably impact on the British landscape in future decades.

Climate change will also impose considerable change on the health, appearance, biodiversity and functionality of existing woods and forests. This will provide a real opportunity to manage and redesign woods and forests for perceived and predicted future needs. Adaptation is a central requirement of sustainability in a changing world, and it is likely to be used to maximise delivery as much as possible. In some parts of the UK, especially in the south and east, woodland and forest will look very different in 50 years' time, a result of changing tree species and silvicultural management.

Evidence-informed policy is likely to remain at the heart of future forestry strategy, but the urgent need for adaptive policy and practice is increasingly recognised. Scientists will need to be more flexible and responsive, and will

have to work more closely with both land use policy-makers and operational foresters to achieve sustainable solutions in the face of continual environmental change. Scientific uncertainty will need to be managed, and land use planning and silvicultural practices that recognise this must be adopted.

Better communication will be at the heart of forest adaptation in the future. As well as improved technical information, the acute need to manage land resources in the future will require spatially explicit decision support tools. These should allow the understanding gained at the plot or site scale to be turned into outputs at the point, local and regional scale, and should facilitate the exploration of land management options in order to optimise the use to which land is put (Gregory and Ingram, 2000). Modelling will become an increasingly important research, communication and delivery tool.

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