Forestry Commission

Research Note

Ecosystem services and forest management

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The ecosystem services concept helps describe the benefits which humans receive from nature and natural processes in a way that can influence policy and management decision making. The ability of trees, woodlands and forests to provide a wide range of ecosystem services is very much dependent on where they are located and how they are managed. Characterising, assessing and valuing ecosystem services can support forest management in a number of ways. These include demonstrating the human and societal goods and services which trees, woodlands and forests provide; supporting the prioritisation of management activities by articulating forest management outcomes as trade-offs in ecosystem services; and considering whether the configuration and management of woodlands is sufficiently robust to meet potential changes in the future demand for ecosystem services, and is resilient to projected climate change. This Research Note provides an introduction to the ecosystem services framework by explaining the concepts of characterisation, assessment and valuation, and the links to sustainable forest management through the UK Forestry Standard. It presents the findings of a series of workshops, held by Forest Research during 2011, which identified the priority ecosystem services for policy and practice from trees, woodlands and forests as timber and fuel production, carbon sequestration, flood mitigation, water quality, health and recreation, and biodiversity.

Introduction

Forestry in Britain has undergone several shifts in focus over the last century from timber production as the sole objective to multipurpose forestry, sustainable forest management and, most recently, the delivery of ecosystem services. These shifts have been driven by changes in people's attitudes towards and demands from forests, which have been reflected in national regulations and policies, as well as European and global drivers for policy change. Currently, policy makers are concerned with issues of sustainability and multifunctional land use, through safeguarding and protecting the natural environment. This includes meeting biodiversity conservation targets through adherence to the European Habitats Directive, the European Water Framework Directive, and the Convention on Biological Diversity Aichi 2020 targets.

This Note provides an introduction to the ecosystem services framework, describing the main concepts of classification, assessment and valuation, and discusses the links between sustainable forest management and managing for ecosystem services. It presents the findings of a series of workshops which identified the priority ecosystem services from trees, woodlands and forests for policy and practice, for which Forest Research is undertaking ongoing research. Forest management and land-use change affect the supply of ecosystem services – this is demonstrated by considering the wider drivers of change and the management decisions made in response since the beginning of the 20th century. The Note concludes with a discussion of the future challenges for ecosystem services and forest management.

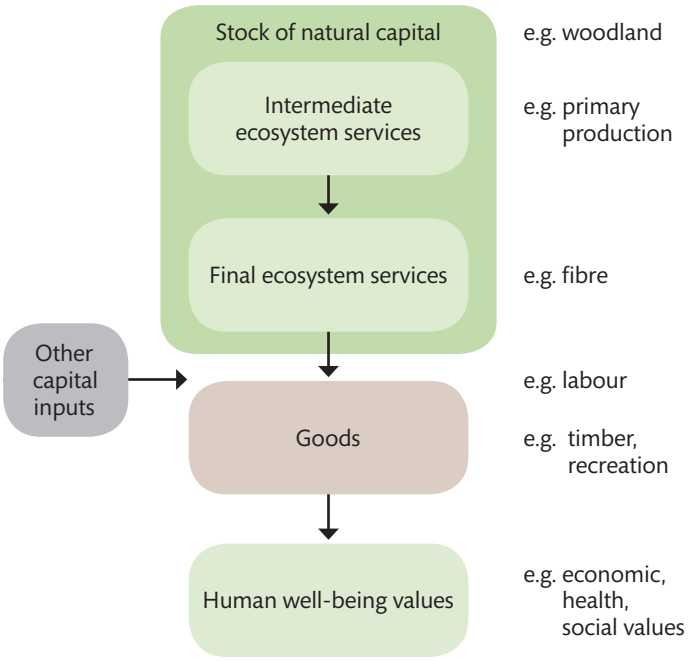
Ecosystem services frameworks

Ecosystem services are the benefits provided by ecosystems that contribute to making human life possible (Mace *et al.*, 2011, p. 16). The term is synonymous with 'ecosystem goods and services'. The ecosystem services framework (also referred to as the ecosystem services approach) assesses the linkages between ecosystem structures and processes and human well-being through the identification and valuation of goods and services*. Final ecosystem services are those which directly contribute to the goods that are valued by people, while intermediate ecosystem services and ecosystem processes underpin the final ecosystem services, but are not directly linked to goods. This is discussed in more detail in the section on Assessing and valuing ecosystem services on page 3.

* Goods are the use and non-use outputs from ecosystems that people value, while services are the processes from which the goods are produced.

All ecosystems are characterised by biotic (living organisms) and abiotic components (e.g. climate, soil, rocks) and the biological, geochemical and physical processes (the ecosystem functions) that take place between these components. This stock of living and non-living assets forms the natural capital from which ecosystem services flow. As the quantity and quality (health) of the ecosystem changes, the natural capital changes too, and so will the flow of ecosystem services (Figure 1).

Figure 1 Relationships between natural capital stocks, the flow of ecosystem services and human well-being values. (Based on work by Bateman *et al.*, 2011).



Note: Arrows represent the flows. Many ecosystem goods are not solely attributable to ecosystems; the contribution of other human and capital inputs is represented by the other capital inputs box.

Ecosystem services are considered to be part of the wider Ecosystem Approach to natural resource management, which considers the relationship between people and nature by assessing the impacts of decisions made about the way in which land or other natural resources are used for human well-being now and into the future. The Ecosystem Approach is defined by the Convention on Biological Diversity (2004) as 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way'.

Characterising ecosystem services

Ecosystem assessment is a process for providing decision makers with scientific evidence concerning the causes of ecosystem change, their consequences for human well-being and the potential impacts of alternative management and policy options. In 2005 the Millennium Ecosystem

Assessment, part of the United Nations Environment Programme, made a global assessment of the current understanding of the consequences of human-made ecosystem change for people's well-being. It found that humans have modified ecosystems more in the last 50 years than in any comparable period in history, and more than 60% (15 out of 24) of the ecosystem services assessed were either degraded or used unsustainably as a result of increased natural resource exploitation and the intensification of land use to meet the growing demand for essential goods such as food, water, fibre and fuel.

The first UK National Ecosystem Assessment (UK NEA), conducted between 2009 and 2011, assessed the main broad habitat types in the UK and their current state, the benefits these ecosystems provide for people in terms of goods and services and consequent well-being, and the main drivers of change that affect them (UK NEA, 2011). It concluded that the value of nature, and the ecosystem goods and services provided, are not fully taken into account in decision making. The UK NEA Follow-On project (2014) produced a range of new tools and information for decision makers to address this problem. Table 1 provides a detailed list of the ecosystem services from trees, woodlands and forests using the UK NEA classification typology of provisioning, regulating, cultural and supporting services.

Supply and demand

The supply of ecosystem services takes place at a range of spatial and temporal scales. Forest planning and management decisions which are generally implemented at the local or regional level have impacts on the benefits received regionally, nationally and internationally, as well as locally. For example, providing access to small woodlands for recreation provides health benefits to local people, while the carbon sequestered in the same trees benefits society at large and contributes to national targets to mitigate the emissions of greenhouse gases from the burning of fossil fuels. There is a temporal dimension to the supply and consumption of ecosystem services where there is a lag in the receipt of benefits (e.g. the slow accumulation of peat or soil formation processes will only truly benefit future generations). The human demand for ecosystem services also varies spatially and temporally, and over time there has been a shift in the services that society has demanded (see later section on Drivers of change on page 7). The identification of humans as ecosystem service beneficiaries is a central theme in the ecosystem services framework, as it distinguishes whether an ecological process provides an ecosystem service. The concept of ecosystem services can help planners, managers and policy makers understand how widely the impacts of their decisions may be experienced, by raising awareness of the multiple services that a single landscape unit (such as a forest stand) provides, as well as recognising who the beneficiaries of the services are and where they are located.

Assessing and valuing ecosystem services

The ecosystem services framework can contribute knowledge and evidence to support forest management by integrating data covering a range of environmental processes and making explicit the trade-offs and synergistic effects of any management changes on ecosystem services provision. This can be achieved by carrying out an assessment of ecosystem services supply and demand, which can be undertaken spatially using geographic information systems, possibly followed by a valuation of those services, using either monetary or other quantitative approaches, such as indicators.

Monetary valuation can establish a common metric to integrate data for a range of ecosystem services and support cost–benefit decision making. However, it is more straightforward to calculate the benefits for certain ecosystem services which fit into traditional economic markets, such as timber and woodfuel, than for the benefits which do not currently have commercial markets (i.e. non-market benefits) such as biodiversity and recreation. Many ecosystem services have traditionally held little or no commercial value and are regarded as 'free goods'. For such services, a broader range of social science tools and valuation methods involving a wide range of stakeholders are needed to understand their value to society. Payments for ecosystem services are a range of mechanisms, including public and voluntary payment schemes as well as newly emerging markets, to compensate resource owners for the provision of ecosystem services. These may act as an incentive for the value of ecosystem services to be considered in forest management decision making.

When valuing ecosystem services it becomes necessary to distinguish between the intermediate and final ecosystem services from which people derive various goods and services to avoid double counting (see Figure 1). Intermediate services are the ecosystem functions that have a supporting or regulatory role in a system and an indirect effect on human well-being, whereas final services directly contribute to the goods that people value. For example, within a forest ecosystem primary production is the intermediate supporting service which results from the ecological processes of photosynthesis and plant nutrient and water intake, fibre is the final ecosystem service and timber is one of the goods which people value. This separation is necessary to avoid double counting and joint production when valuing the goods and services derived from

Table 1 Examples of the ecosystem services from trees, woodlands and forests in the UK (adapted from the UK NEA, 2011).

Provisioning services: direct use products derived from forest ecosystems	
Fibre and fuel products	Timber for construction, veneers and flooring; wood chip for board, pulp for paper; timber products for woodfuel, including stumps and roots, and harvesting residue.
Non-timber forest products (NTFPs)	Products such as food products derived from plants (tree fruit, berries, foliage, syrup and nuts as well as edible products from plants other than trees – like fungi), wild deer or livestock raised in woodland or forest settings in agro-forestry systems; beverages; craft, ornamental and gardening materials such as bark chips for play areas, poles, stakes and fencing; toys, medicinal products and chemicals derived from gums, resins, waxes, oils and fatty acids.
Water supply	The provision of water through the interception of rain, mist and fog, which is then transferred to the soil and into a watercourse and groundwater. Woody debris creates dams in watercourses that increases storage and slows the water flow (contributing to flood hazard reduction, a regulating service).
Genetic resources	Seed orchards of locally adapted provenances provide genetic resources for British growing conditions.
Biodiversity	Forests that are managed to deliver particular types of diversity and species assemblages, for example through Biodiversity Action Plans and agri-environment schemes, providing habitats for rare, protected and priority species including red squirrels and rare butterfly or bird species.
Regulating services: regulatory functions that forest ecosystems provide	
Climate regulation	Carbon capture and storage (sequestration); protection from or moderation of the effects of extreme temperature, wind, ultra-violet light and precipitation, such as shelter for people or livestock, protection for fish through regulating water temperatures in streams.
Hazard regulation	Protection from soil erosion and slope failure (depending on forest management practices, see later section); rainfall interception moderates flooding by delaying and attenuating peak river flows.
Detoxification and purification of soils, air and water (including noise)	Trees are able to capture and absorb (scavenge) pollution, including diffuse pollution, from soils, water and the atmosphere, improving the quality of each. However, those pollutants may then be transferred into the water supply. Trees, woodlands and forests can therefore have both positive purifying and negative impacts on water quality that are species, site and management dependent. Belts of trees can act as noise buffers to reduce noise pollution (noise abatement), providing health benefits.
Disease and pest regulation	Woodlands with high biodiversity tend to exhibit increased age and tree species structure. These structural components have been shown to reduce the damaging effect of some pests and pathogens in woodlands. A meta-analysis comparison of single species and mixed forests (comprised of taxonomically more distant species) showed a significant reduction in plant material loss (herbivory) from mixed woodland compared to single species woodlands (Jactel and Brockerhoff, 2007). It is thought that the reduction of host trees and niches in mixed woodlands causes the effect. In mixed woodlands, the risk of damage to any specific tree species is spread across more pathogens, and the potential for damage to the stand is reduced.
Pollination	Trees, woodlands and forests provide habitat for pollinator species.
Cultural services: non-material well-being benefits which people gain from ecosystems*	
Health	The health benefits identified are: physical well-being, involving some form of physical activity, action or movement; mental restoration from spending time in woodlands; escape and freedom, allowing people to gain physical and mental distance from sources of anxiety or everyday life; and enjoyment and fun from recreational and leisure activities undertaken in woodlands and forests.
Nature/landscape connections	These are the benefits people describe from sensory stimulation and feelings of connection to both the landscape and wildlife, including biodiversity and the well-being benefits from gathering NTFPs.
Education and learning	The types of benefit range from formal learning through Forest Schools to personal development gained through volunteering and apprenticeships. Studies show the long-term educational importance of connecting children and young people with nature.
Economy	Woodlands and forests can contribute to local livelihoods through generating employment, both directly through timber production, forest-based recreation and other enterprises including NTFP gathering, and indirectly to local economies, for example businesses supporting the associated tourist industry.
Social development and connections	Activities undertaken within forests can strengthen existing social relationships, while organised activities within forest environments can create the opportunity for new relationships, including people's involvement with volunteer groups and community forests (social capital).
Symbolic, cultural and spiritual significance	This includes use and non-use values, through cultural or historical associations, such as connections to historical or folk figures like Robin Hood and associations of evergreen foliage with Christmas.

* These examples are explained in more detail in O'Brien and Morris, 2014.

Supporting services: ecosystem processes that support and underpin Provisioning, Regulating and Cultural services	
Primary production	The fixation of carbon dioxide by photosynthesis produces organic matter, resulting in plant growth and oxygen production.
Soil formation	The breakdown of the underlying geology by roots and microbial fauna (mineral weathering) and the accumulation of organic matter from leaf litter within the soil layer.
Nutrient cycling	As with other forms of vegetation, trees, woodlands and forests enhance the cycling of nutrients between the leaf litter and the soil, as well as the interception of atmospheric compounds by the canopy, which provides essential nutrients to the soil, such as nitrogen required for primary production.
Water cycling	In addition to the provisioning service that forests provide society through the capture and supply of water, they have an important role in the wider hydrological cycle through moisture interception and transpiration.
Biodiversity	Biodiversity and the associated genetic variation within locally adapted species and provenances can support flora and fauna that contributes to woodland dynamics, including providing habitats for pollinators and below-ground flora and fauna that maintain the decomposition processes underpinning soil formation and nutrient cycling.

ecosystems, and it is not intended to signify that intermediate services have less importance.

The provision of ecosystem services may also depend on the stock of human capital (knowledge, skills and experience). Many ecosystem services are not solely attributable to ecosystems, and can accrue as a result of other human and capital inputs (see Figure 1), such as labour, transportation and processing, which are required to deliver ecosystem services. These capital inputs add value to the final ecosystem service, and so the economic value of goods such as timber is not always solely attributable to ecosystem function.

Priority ecosystem services from Britain's trees, woodlands and forests

The identification of priority ecosystem services from Britain's public forest estate was carried out to focus research on the development of new tools and methods for quantifying and valuing ecosystem services. Forest Research conducted workshops with Forestry Commission staff in each of the countries during 2011. The attendees were asked to apportion 10 units across the list of ecosystem services in any combination they wished, for example ten units on one single ecosystem service; five on one unit, and one unit on each of a further five ecosystem services; or they could spread the ten units across ten different ecosystem services. A weighted mean from all the workshops was calculated for each of the ecosystem services in the list. The prioritised results showed consistency across the countries (see Table 2) and identified the top six ecosystem services from Britain's trees, woodlands and forests as: production (fibre and fuel), climate mitigation: carbon, flood mitigation, water quality, recreation/health and biodiversity. This list is being used by Forest Research to develop appropriate ecosystem services indicators to support forest management. The list may also be used by forest managers to assess the contribution their woodlands and forests make towards delivering the goods and services that society requires, including meeting policy objectives, such as climate change mitigation and public health benefits.

Forest management

The ability of trees, woodlands and forests to provide ecosystem services is dependent on both the type of management and the location of wooded patches in the landscape, since different forest management systems and woodland types lead to differing outcomes. For example, the climate change mitigation benefits resulting from carbon sequestered in the trees and soil is dependent on silvicultural operations such as site preparation, species choice and harvesting methods. Ecosystem service bundles are discussed in the research literature as a collection of services that are regularly provided together through the interaction of a forest management system on a forest type. For example, a mosaic of irregular-aged patch stands of short rotation silviculture in conifer forests leads to regular biomass harvest and an emphasis on biodiversity associated with the stand initiation phase prior to canopy closure, but with corresponding trade-offs of reduced recreational value of the stands and a lack of later successional stage biodiversity due to the absence of older trees and low species and structural diversity. Compare this to stands of mixed broadleaved trees managed using a shelterwood system. Here the tree species and structural diversity is greater, leading to a greater range of biodiversity and recreational values. Water demands by the forest will be seasonal but more stable through time compared to fell–restock rotation systems, and water quality is also likely

Table 2 Summary of the ecosystem services from trees, woodlands and forests showing the priority ecosystem services for Britain's public forest estate identified during workshops held by Forest Research during 2011.

Ecosystem service		Priority services*			
		England	Scotland	Wales	Great Britain
Provisioning	Fibre	■	■	■	■
	Fuel	■	■	■	■
	Non-timber forest products (e.g. food, animals, craft)				
	Water supply/storage				■
	Genetic resources				
	Biodiversity				
Regulating	Climate regulation: mitigation (e.g. carbon)	■	■	■	■
	Climate regulation: moderation (e.g. shade)				
	Flood protection	■	■	■	■
	Soil protection		■		■
	Noise reduction				
	Water quality	■	■	■	■
	Air quality				
	Soil quality				
	Disease and pest regulation				
	Pollination				
Cultural	Health	■	■	■	■
	Nature/landscape connections, biodiversity	■	■	■	
	Education and learning			■	
	Economy	■	■	■	■
	Social development				
	Cultural significance				
Supporting	Primary production (including oxygen production)		■		■
	Soil formation				
	Nutrient cycling		■		■
	Water cycling		■		■
	Biodiversity	■	■	■	

* As defined by the Forestry Commission in Great Britain, England, Scotland and Wales. The shaded boxes represent the highest scoring services at each of the workshops.

to be more stable through time compared to the regular disturbance of fell–restock systems. But there is a corresponding trade-off of lower biomass production.

Sustainable forest management is a recognised method of managing forests according to the Ecosystem Approach, and is a key component of forest certification schemes. Table 3 shows links between the ecosystem services catalogue (Table 1) for forestry in Britain and the related UK Forestry Standard Requirements and Guidelines covering the different aspects of sustainable forest management (Forestry Commission, 2011). The Requirements and Guidelines provide the framework and guidance for meeting the UK Forestry Standard. This in turn helps towards the UK's delivery on European and international agreements on sustainable forest management.

At the landscape scale, the broad habitat land cover of conifer, broadleaved and mixed woodlands are located alongside freshwater, cropland (arable and pasture), greenspace, grassland, moorland and other habitats. When making decisions at the landscape scale, land-use change and changes in forest management will have some level of impact on ecosystem services provision – see the Drivers of change section on page 7. These impacts can be quantified by comparing the value of different land cover and land-use management systems to people. For this to happen there must be a consistency in the terminology of both the natural capital value and the ecosystem services flows to people, to help improve decisions affecting land use and management. The UK NEA showed that the adoption of multipurpose sustainable forest management had served the UK forestry

sector well. Quine, Bailey and Watts (2013) considered these issues and concluded that the adoption of ecosystem services is consistent with forestry's use of sustainable forest management, although they acknowledge that this is a single-sector approach to land use.

Drivers of change

The changes that have shaped UK forests in the past can be described in terms of changes to ecosystem services supply and demand using a modified Driver–Pressure–State–Impact–Response (DPSIR) framework which has been adapted to assess the impacts of environmental change drivers on ecosystem services provision (Figure 2). DPSIR is an internationally recognised* method to connect human activities to the state of the environment in environmental decision making that was developed in the 1990s by the European Environment Agency. The Framework for Ecosystem Services Provision connects drivers of change (e.g. socio-economic, world markets, international, European and national commitments) to the pressures within the forestry sector (UK Forestry Standard, supporting forestry guidelines and forest policy) and helps to identify how alternative response options may change drivers, pressures and state for a particular system. Pressure produces change in the state of

* The DPSIR framework is a development of the OECD (1994) Pressure–State–Response framework for connecting human activities to the state of the environment that is being applied by the European Environment Agency and US Environment Protection Agency.

Table 3 Maintaining ecosystem goods and services delivery through sustainable forest management, using the UK Forestry Standard Requirements and Guidelines.

Ecosystem service		UK Forestry Standard Requirements and Guidelines																						
		General			Biodiversity			Climate change			Historic environment			Landscape			People			Soil			Water		
Provisioning	Fibre		Y							G															
	Fuel		Y							G															
	Non-timber forest products		Y	G				G		G															
	Water supply/ storage		Y	G				G		G													R	Y	G
	Genetic resources		Y																						
	Biodiversity		Y	G	R	Y		G		G		Y							G	R			R		Y
Regulating	Climate regulation: mitigation								Y	G															
	Climate regulation: moderation								Y	G															G
	Flood protection						G		Y	G													R	Y	G
	Soil protection			G			G		Y	G										R	Y	G		Y	G
	Noise reduction																								
	Water quality			G			G		Y	G										R	Y		R	Y	G
	Air quality																								
	Soil quality			G			G		Y	G										R	Y	G		Y	G
	Disease and pest regulation	R	Y	G			G			G															G
	Pollination																								
Cultural	Health		Y	G									G				R	Y	G						
	Nature/landscape connections, biodiversity		Y	G	R	Y	G			G		Y	G		Y	G		Y	G	R			R	Y	G
	Education and learning																	Y	G						
	Economy																	Y	G						
	Social development																R		G						
	Cultural significance			G							R	Y	G		Y	G			G						
Supporting	Primary production																								
	Soil formation																			R	Y	G			
	Nutrient cycling			G			G													R	Y	G			
	Water cycling			G			G			G										R	Y	G	R	Y	G
	Biodiversity		Y	G	R	Y	G			G		Y							G	R			R	Y	G

R UKFS Requirements (legal) Y UKFS Requirements (good forestry practice) G UKFS Guidelines

the current or future natural capital (change in the woodland area, the forest types, open ground) and the beneficiaries of the ecosystem services that flow from natural capital. Changes in the state of the trees, woodlands and forests and the ecosystem service beneficiaries impact on the quality, quantity and mix of ecosystem services and their value and synergy. Such changes may prompt a response in forest management and/or forest policy, acting as a pressure that alters the state of the natural capital, as well as wider policy responses that affect the drivers of change.

Since the start of the 20th century, forest policy and management has undergone a succession of changes as different goods and services have been required, notably resulting in an increase in the forest cover (the natural capital stock) from 4.7% in 1905 to 12.9% by 2014 (Forestry Commission, 2014). The low woodland cover at the start of the 20th century was the result of a combination of human and climatic drivers applying unsustainable pressure on the forest stock such that timber imports were required to replace the shortfall in domestic supply.

Twentieth century wars disrupted the trade routes, placing greater extraction pressure on UK forests to supply fibre and timber, and consequently reducing the natural capital stock further. The impact on ecosystem services was an increase in timber supply (provisioning service) at the expense of regulating, cultural and supporting services. In response the government from 1919 to 1957 sought to establish a strategic timber reserve and support rural economies (by job creation) through a programme of state-funded afforestation by the Forestry Commission (which was established in 1919) and a range of financial incentives to encourage planting and forest management by private landowners.

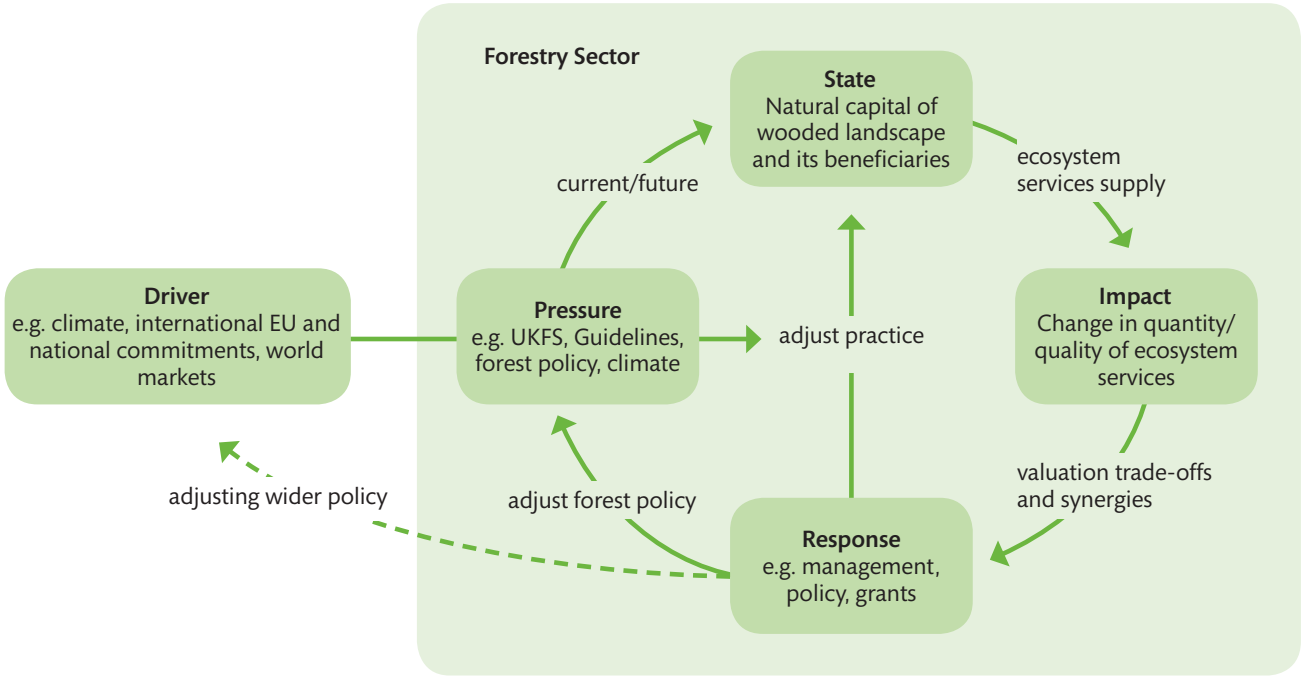
After 1957*, UK forest policy shifted more to production forestry to realise the economic value of timber by supplying a newly emerging domestic wood processing industry. Pressure to intensify and increase yields brought about changes in forest management, notably species selection and site preparation. The spatial distribution of forests also changed, as there were large increases in upland conifer plantations in Scotland and Wales. Over this period, provisioning and regulating services increased but cultural services declined, notably the aesthetic values of the landscape and biodiversity provision through loss of habitats for rare and protected species, as well as from land-use and land cover change.

Gradually legislation and forest policy responded to public attitudes and demands for an increased conservation and recreation focus. Successive drivers shifted forest policy away from timber production to multipurpose forestry during the 1980s, such as the 1985 Broadleaves Policy, so that forests were increasingly managed to provide cultural as well as provisioning ecosystem services, although the rate of new planting decreased.

Today the key drivers of change for woodlands and forests identified by the UK NEA are climate change and invasive species, and habitat change due to either land-use change or a deterioration in habitat condition. There is renewed pressure to

* The Zuckermann Report published in 1957 reported that the requirement for a national strategic timber reserve had disappeared with the advent of the nuclear age, and recommended that end users for forest products be actively sought.

Figure 2 The Framework for Ecosystem Services Provision for the forestry sector (adapted from Rounsevell, Dawson and Harrison, 2010).



plant woodlands and manage land to supply multiple benefits while ensuring the sustainable use of natural capital. Recently, financial instruments have favoured the planting of broadleaved woodlands, and this is having an impact on the future supply of timber to other economic sectors. Species choice and changes in woodland management systems have also affected the rate of carbon sequestration as a regulating service.

Future challenges

The UK NEA found that in future the management of ecosystem services will need to be resilient and adaptive to societal, environmental and land-use changes. Forest management can be supported to achieve this by understanding the drivers and pressures of change, their impacts on ecosystem supply and demand and the response options that are available to managers and decision makers. This includes the use of scenario analysis* to test the potential impact of alternative management approaches on ecosystem services (Ray *et al*., 2014), including for a range of climate change projections. It seems likely that the valuation of services will become more prominent and may lead to new funding streams that pay for trees, woodlands and forests in the right place for the right ecosystem service delivery reason (Quine, Bailey and Watts, 2013). However, the forest industry in Britain must take care that the easily valued goods and services from forests (such as timber and carbon) do not overly influence management system priorities in the delivery of ecosystem services, and that in adapting forests to climate change we consider a longer term sustainable view rather than just short-term adaptive management approaches.

Conclusions

The adoption of ecosystem services in forestry should provide consistency in the assessment and valuation of the human benefits of trees, woodlands and forests. This is important because forestry in Britain has long been undervalued, and forced to produce timber on some of the poorest site types. There is considerable tension in land-use planning, with farmers opposed to woodland expansion on better quality farmland, and some sporting estates and non-government organisations opposed to woodland expansion on moorland and heathland. The ecosystem services framework is able to provide a mechanism to assess the human benefits of woodland, pasture, arable land, moorland, wetland, freshwater and urban development in the right place for the right reasons. In using the ecosystem services framework, a more quantitative approach to land-use issues including land-use change should emerge, along with a more transparent rationale for stakeholder involvement in planning decisions at local, regional and national levels.

* A scenario is a plausible and often simplified storyline describing how the future may develop based on a set of coherent and internally consistent assumptions about key driving forces.

References

BATEMAN, I.J., MACE, G.M., FEZZI, C., ATKINSON, G. and TURNER, K. (2011). Economic analysis for ecosystem service assessments. *Environmental and Resource Economics* **48** (2), 177–218.

FORESTRY COMMISSION (2011). *The UK Forestry Standard: The governments' approach to sustainable forestry*. Forestry Commission, Edinburgh.

FORESTRY COMMISSION (2014). *Forestry Statistics 2014*. Forestry Commission, Edinburgh.

JACTEL, H. and BROCKERHOFF, E.G. (2007). Tree diversity reduces herbivory by forest insects. *Ecology Letters* **10** (9), 835–48.

MACE, G.M., BATEMAN, I., ALBON, S., BALMFORD, A., BROWN, C., CHURCH, A., HAINES-YOUNG, R., PRETTY, J.N., TURNER, K., VIRA, B. and WINN, J. (2011). Chapter 2: Conceptual framework and methodology. In: *UK National Ecosystem Assessment: Technical Report*. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge.

O'BRIEN, L. and MORRIS, J. (2014). Well-being for all? The social distribution of benefits gained from woodlands and forests in Britain. *Local Environment* **19** (4), 356–83.

QUINE, C.P., BAILEY, S.A. and WATTS, K. (2013). Sustainable forest management in a time of ecosystem services frameworks: common ground and consequences. *The Journal of Applied Ecology* **50** (4), 863–7.

RAY, D., BATHGATE, S., MOSELEY, D., TAYLOR, P., NICOLL, B., PIZZIRANI, S. and GARDINER, B. (2014). Comparing the provision of ecosystem services in plantation forests under alternative climate change adaptation management options in Wales. *Regional Environmental Change*. 2014.

ROUNSEVELL, M.D.A., DAWSON, T.P. and HARRISON, P.A. (2010). A conceptual framework to assess the effects of environmental change on ecosystem services. *Biodiversity and Conservation* **19** (10), 2823–42.

UK NATIONAL ECOSYSTEM ASSESSMENT (2011). The *UK National Ecosystem Assessment: Synthesis of the key findings*. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge.

UK NATIONAL ECOSYSTEM ASSESSMENT FOLLOW-ON (2014). *The UK National Ecosystem Assessment Follow-on: Synthesis of the key findings*. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge.

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