Ecosystem Services

A summary of research outputs supported or facilitated by the Environmental Change Programme of the Scottish Government's Portfolio of Strategic Research 2011-2016

Introduction

The 1995 adoption by the *Convention on Biological Diversity* (CBD) of the Ecosystem Approach as its primary framework (Secretariat of the CBD, 2000) stimulated interest in how natural systems deliver ecosystem services to societies around the world. Further stimuli have been the Millennium Ecosystem Assessment (2005) and the UK National Ecosystem Assessment (2011).

In response there has been a very substantial research effort coalescing around improving understanding of: 1) measuring and mapping ecosystem services; 2) how natural systems and their biodiversity deliver ecosystem services; 3) the valuation of ecosystem services; 4) how interactions between people and the environment deliver services; 5) how ecosystem services and the ecosystem approach support sustainable land management. Research in the 2011-2016 Scottish Government Strategic Research Programme addresses these questions, and this booklet summarises its headline findings.

We begin with fundamentals, considering the terminology which has built up around the Ecosystem Approach and ecosystem service concepts (Chapter 1), and the role of biodiversity in regulating ecosystem functions (Chapter 2). Modelling and mapping of ecosystem services starts to demonstrate national-level patterns of service delivery (Chapter 3). However, some services - including cultural services - remain difficult to assess; new approaches are therefore needed (Chapter 4). Valuation of ecosystem services enables the development of natural capital accounts, but there are multiple approaches and a need for context-appropriate methods (Chapter 5).

Case studies explore how approaches to participatory decision-making (in some cases using service mapping and valuation) can help balance multiple demands for services (Chapter 6). Decision-making can be further aided by tools for envisaging how particular policy goals might lead to different configurations of land use (Chapter 7). Considering the Ecosystem Approach overall (which includes ecosystem service assessments), there may be key barriers which impede the uptake of this type of framework (Chapter 8), whilst a considerable challenge at the local scale is understanding how people's interactions with the environment generate ecosystem services (Chapter 9). Two case studies demonstrate how many ecosystem services are co-produced by people and ecosystems, highlighting limitations of existing ecosystem service assessments.

Finally we explore ES delivery by specific ecosystems and management regimes. Considering delivery of water-related services in catchments and peatlands (Chapter 10), we see how 'environmental' policies support Scottish society and the economy. Consideration of service delivery in cropland systems (Chapter 11) shows that - particularly in intensively farmed systems - key supporting services are reduced, but also that data are available to target action for service restoration. Finally we explore nature conservation and ecosystem service delivery (Chapter 12), demonstrating that sites managed for nature conservation overall deliver higher levels of services than non-protected sites, but also highlighting limitations in the data available for assessments.

The work introduced here addresses many of the key challenges of developing and implementing the ecosystem service and Ecosystem Approach concepts and highlights important future directions to progress this field.

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1. Concepts: 'Eco' terminology

Photo Credit: Kirsty Blackstock

Background

Academic, practitioner and policy groups use multiple terms which mention 'ecosystems' or 'ecosystem services'. The meanings and differences between these terms are not always clear. This causes several interrelated problems:

- It can make it harder to reach new audiences: individuals who wish to engage in conversations or processes that use these terms can feel confused or at a disadvantage.
- Partners may struggle to communicate if they are interpreting terms in different ways. If differences go unacknowledged, partners may even work at cross-purposes. This can lead to slow progress, frustration and disappointment.
- Some people wish to use the terms as a contemporary label for pre-existing ways of working. This makes it harder to distinguish the value of using new concepts.

Approach

We reviewed and observed the plethora of terms and meanings currently used by academic, policy and practitioner groups. We identified widely accepted definitions and interconnections between each of the main terms.

Results

The most common terms and their widely-accepted meanings are listed below.

An ***"Ecosystem"*** is a community of living organisms that interact as a system with non-living components of their environment (things like air, water and minerals). Since ecosystems are a network of interactions they can be of any size, but are usually referred to as specific types found in certain places, e.g. Scotland's Caledonian pinewoods. A landscape may contain a mosaic of interconnected ecosystems.

"Ecosystem Services" are the variety of goods and services upon which people depend, and that arise from ecosystems. Ecosystem Services are commonly categorised into *Provisioning* (e.g. water, food production), *Regulating* (e.g. the control of climate and diseases), *Cultural* (e.g. aesthetic values, recreational opportunities), and the underpinning *Supporting* services (e.g. crop pollination). They often arise from actions and interventions by people; therefore it is useful to think of ecosystem services as co-produced by ecosystems and society.

"Ecosystem Services Framework" (sometimes also called 'the ecosystem services approach') is an approach to understanding and describing nature in terms of how it delivers ecosystem services. This contrasts with more 'traditional' ways of describing natural systems in terms of biodiversity and ecological functions. This can structure reports and assessments, such as the UK National Ecosystem Assessment (2011). In recent years this work has been increasingly associated with methods to elicit and report economic values of the benefits that society realises from the natural environment.

"The Ecosystem Approach" (sometimes also called 'an ecosystems approach') is a systemic and participatory approach to ecosystem management. This holistic concept originated with the Convention on Biological Diversity in 2000. It reflects the need for ecosystem-based management: the idea that adaptive management of whole ecosystems is needed, not just of individual species or habitats. It also reflects arguments for stakeholder empowerment, recognising that humans are a part of an ecosystem. It is implemented through 12 complementary and interlinked 'Malawi principles'.

Conclusion

Multiple 'ecosystem' terms are presently in use. Some of these describe ways of understanding or characterising the world – and others are ways of managing or intervening in the world.

Therefore it is important to be clear about the concepts being used, and the rationale for using them, and then to use the terms consistently. To avoid confusion, the terms used should match their definitions and the philosophy underpinning their origins.

Our research suggests that improving understanding of these concepts, and more careful use of terminology, will aid sustainable management of our natural resources.

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The research that this briefing builds on, together with related outputs, are summarised at: http://www.hutton.ac.uk/projects/ecosystemapproachreview

2. Biodiversity and function

Background

Considerable effort has been invested in understanding how the biodiversity of ecosystems is related to the way in which they function, e.g. how productive they are or how resistant they are to invasion by new species. This issue is not just a fundamental question for ecology – it is directly relevant to efforts to reintroduce crop and wider biodiversity into farming systems. However, much of the focus has been on the role of species diversity, and little attention has been given to the potential role of genetic diversity, i.e. the diversity of genotypes within a given species. **The aim of this study was to assess the relative impacts of plant species and genetic diversity on key ecosystem functions, and the mechanisms underlying these impacts.**

Approach

We constructed artificial plant communities in a greenhouse at the James Hutton Institute, Aberdeen. These communities contained a range of diversities of weed species (species diversity treatment) and barley varieties (genetic diversity treatment). We assessed several ecosystem functions including productivity (production of plant biomass by the communities) and invasibility (whether new species sown into the communities could establish), and analysed whether the level of functioning of the communities was related to their underlying levels of diversity.

Results

- Overall, plots with high diversity were more productive (Fig 1).
- Increasing species diversity had a stronger effect on productivity than increasing genetic diversity.
- The effect of increasing species richness operated though selection effects – i.e. with increasing species richness there is a greater chance that the mixture will include a more productive species.
- Increasing the genetic diversity of the barley plants led to increased complementarity – i.e. the different barley varieties complemented each other in terms of their ecological niche leading to improved resource uptake and genuine over-yielding, rather than because one variety became dominant.
- Increasing weed species richness reduced community invasion by new species, but increasing genetic diversity had no effect on invasibility.

Conclusions

Changing plant species and genetic diversity within our artificial communities had different effects on ecosystem functions. The larger overall impact of weed species diversity is linked to variation in plant traits: traits vary to a greater extent between different species than between varieties of the same species, shown here using barley. As trait diversity can regulate ecosystem function, introducing a new species can have a greater impact on function than introducing a new variety. However, the limited trait variation between barley varieties may prevent any one variety becoming dominant, thus enabling the weaker – but still positive – complementarity effects.

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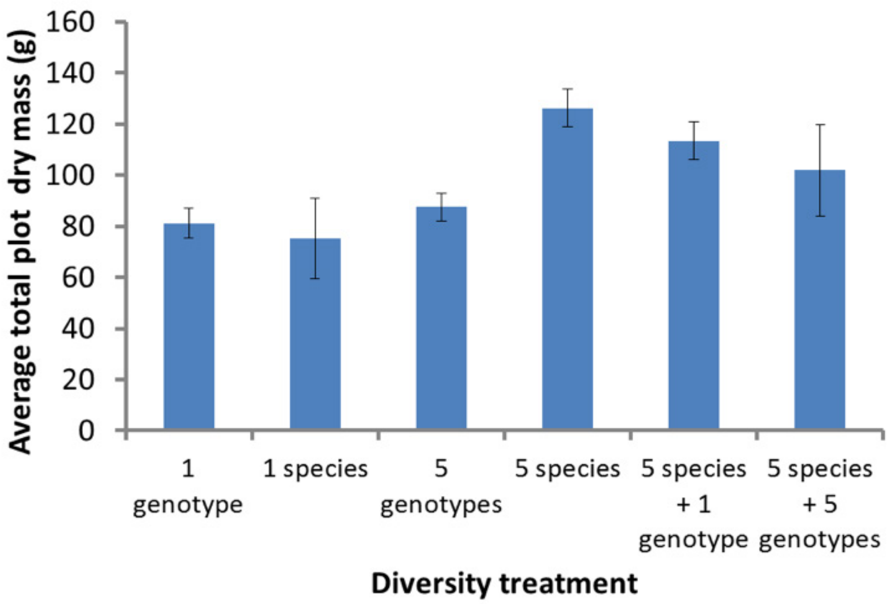

Fig 1: Average total harvested dry biomass (g) of plots with different levels of biodiversity (combinations of genotype and species diversity) within the plots. Error bars show standard errors for the means.

3. Modelling and mapping key ecosystem services

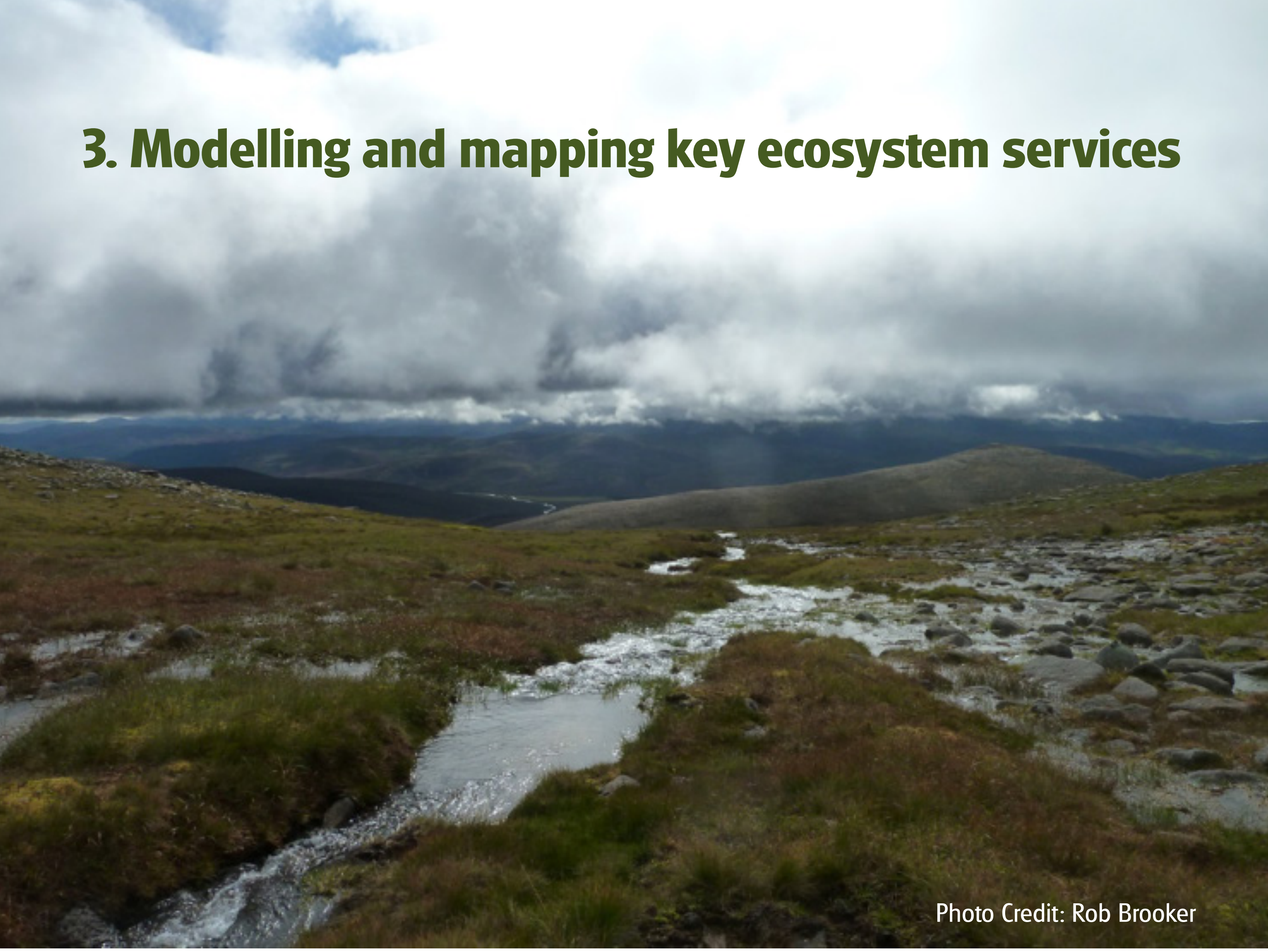

Photo Credit: Rob Brooker

Background

Modelling and mapping ecosystem services is both needed to understand the multiple benefits derived from land, and required by international and national policy goals. For example, Action 5 of the EU Biodiversity Strategy requires member states to "map and assess the state of ecosystems and their services, assess the economic value of such services, and promote the integration of these values", while the Scottish Land Use Strategy calls for land use decisions that maintain the benefits derived from ecosystem services.
The aim of this work was to model and map indicators for selected key ecosystem services.

Approach

Indicators were chosen using an international framework called CICES (Common International Classification for Ecosystem Services). Indicators for Supporting, Provisioning, Regulating and Cultural services were used, each requiring different modelling steps.

Results

Example maps are presented below. Despite each service having its own peculiarities, there is often a visible difference in the spatial pattern of service provision between uplands and lowlands, with contrasting levels of service provision between the two.

Conclusion

These models provide an indication of the natural capital associated with land and can be used to identify areas that provide different combinations of ecosystem services. Further spatial analysis will highlight gaps, and help with the targeting of incentives to land managers to help them deliver multiple benefits from their land.

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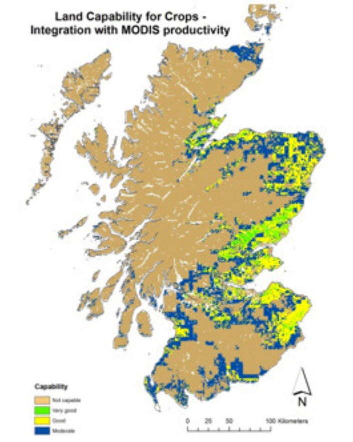
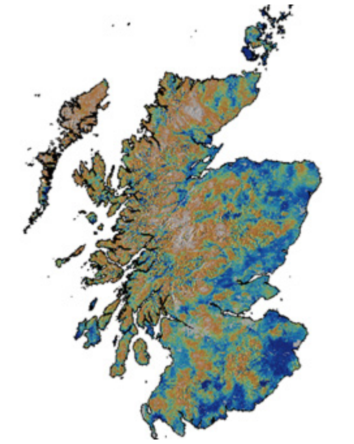
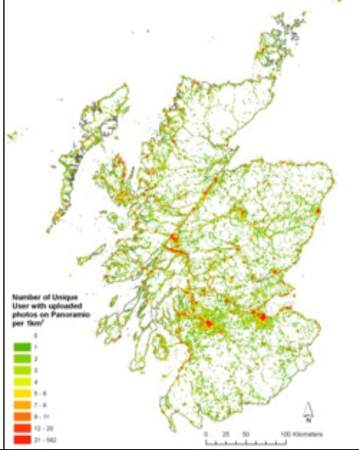
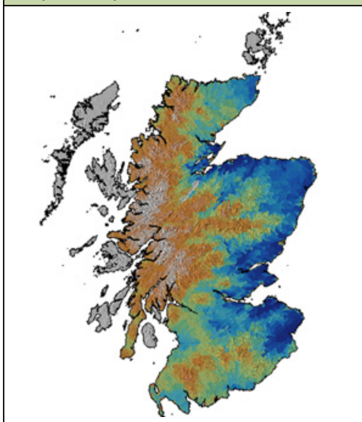
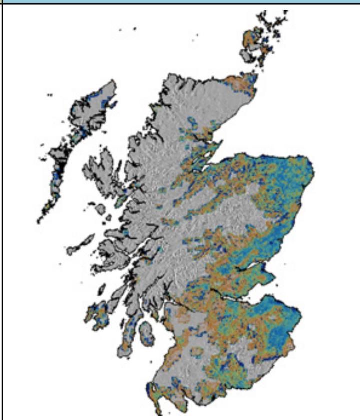
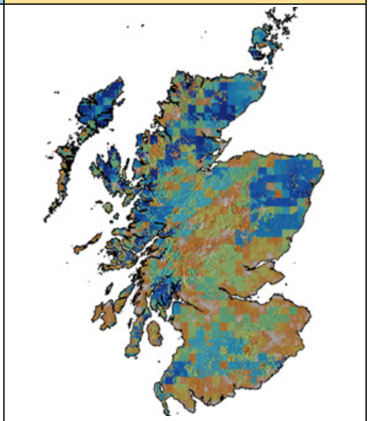
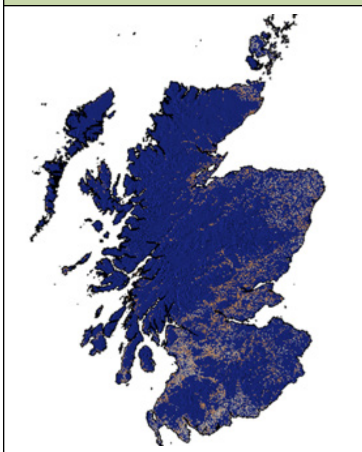
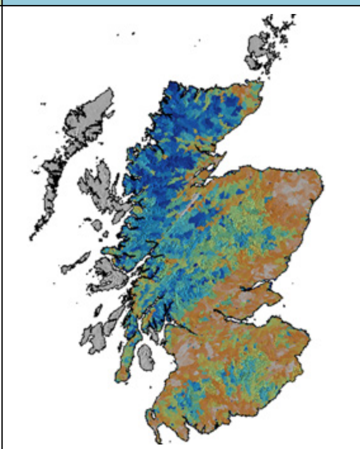
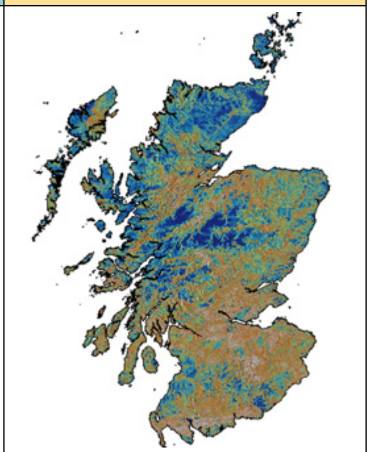
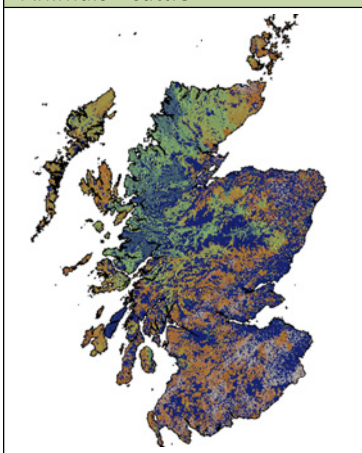
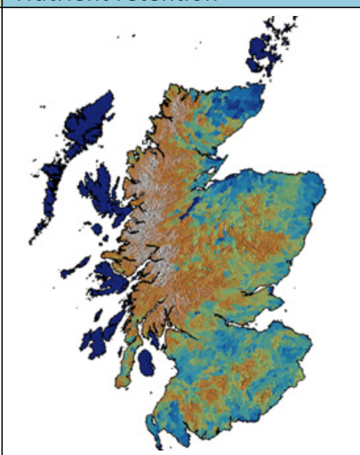
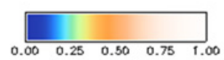
Provisioning	Regulating	Cultural
		
Provisioning - Crops - land capability	Regulating - Soil organic carbon stocks	Cultural -Recreation - individual-user photos
		
Water supply (runoff)	Bumblebees - suitability	Important plant biodiversity areas-distinctiveness
		
Animals - cattle	Nutrient retention	Plant Species richness
		
Animal - sheep	Sediment retention	Legend

4. Mapping cultural ecosystem services

Photo Credit: Rob Brooker

Background

Millennium Ecosystem Assessment (MEA, 2005) ecosystem services (ES; the services, benefits and goods human's obtain from ecosystems) are now widely incorporated into international, national and regional policies and embedded into natural resource management and planning.

Mapping of Provisioning, Supporting and Regulating Services can generally draw on mapping and monitoring traditions in the relevant scientific areas. However, a similar tradition does not yet exist for Cultural Ecosystem Services (CES). The real challenge is that important aspects of CES are not easily captured with traditional mapping techniques, in particular spiritual and symbolic interactions.

The aim of this work was to develop a method for mapping cultural services which will allow inclusion of CES in the ES trade-off analysis and the integration of data for those aspects of CES for which there is currently no effective mapping method in Scotland.

Approach

To create a CES index for Scotland based on CICES (Common International Classification of Ecosystem Services), a simple conceptual model is proposed (Fig 1), with the 1 km grid being the most suitable unit of analysis. The inventory stage identifies suitable indicators and data sources that can measure CES at CICES class level. The indicators are converted to a value per 1 km grid based on an indicator-dependent process. The indicators are then summarised towards a CES index.

The indicators selected for this project to map 'intellectual and representative interactions' are: 1) cultural heritage in the form of listed buildings, scheduled monuments and historic gardens; 2) scientific and educational designated areas represented by SSSIs and SACs; 3) aesthetic values of remote areas (remoteness); 4) specific features (old Caledonian forest); and: 5) woodland recreation/leisure (all woodland areas).

In the first instance a simple CES index for Scotland was created based on a sum of a limited number of indicators.

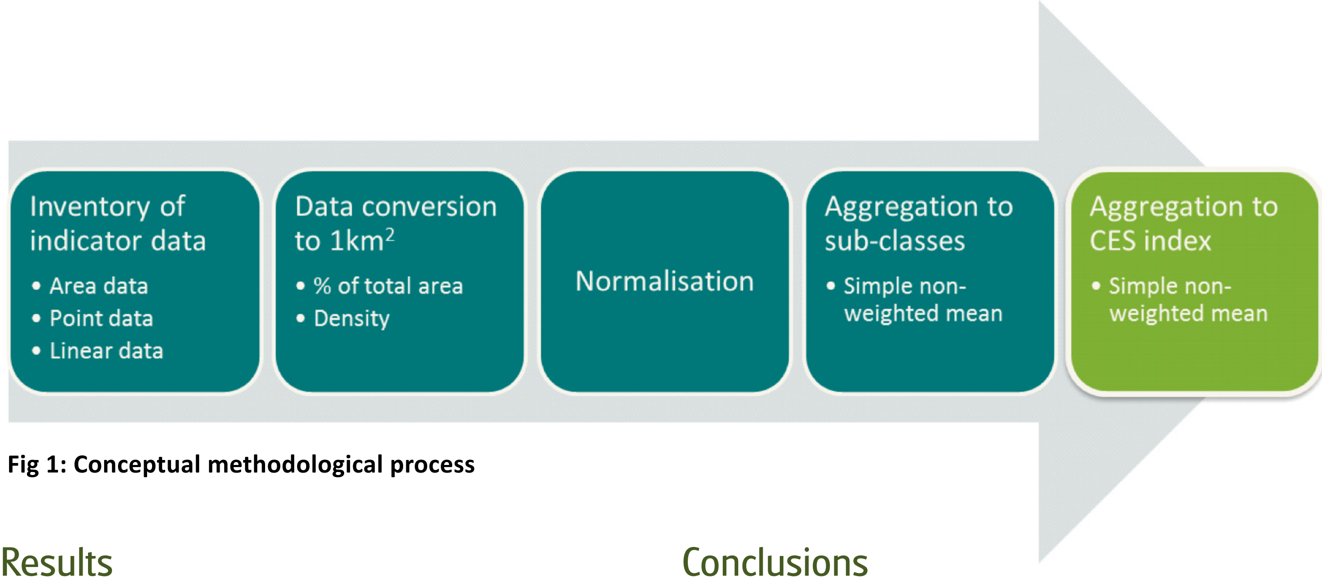


Fig 1: Conceptual methodological process

Results

- Even a very simple sum of the presence of the five broad classes of indicators can start to identify the important areas with known cultural value such as the National Parks, Royal Deeside and the Highlands (Fig 2);
- Current results are limited as they do not yet include important indicators for spiritual and symbolic aspects of CES;
- Interestingly the results show clear concentrations of areas without CES around the national parks, while for the rest of Scotland the absence of CES is more dispersed.

Conclusions

The results from this project are encouraging. A CES index based on a systematic classification process for ES, i.e. CICES, will fulfil an important role in trade-off analysis of ES. However in its current form the CES index is still work in progress. Particularly important 'next steps' are to address the following gaps: 1) the development of new methods to generate data for the most challenging aspects of CES, classified as spiritual, symbolic and other interactions with the environment; 2) a data-supported method for an aggregation of the CES index; 3) validation of the CES index in the context of Scottish landscapes.

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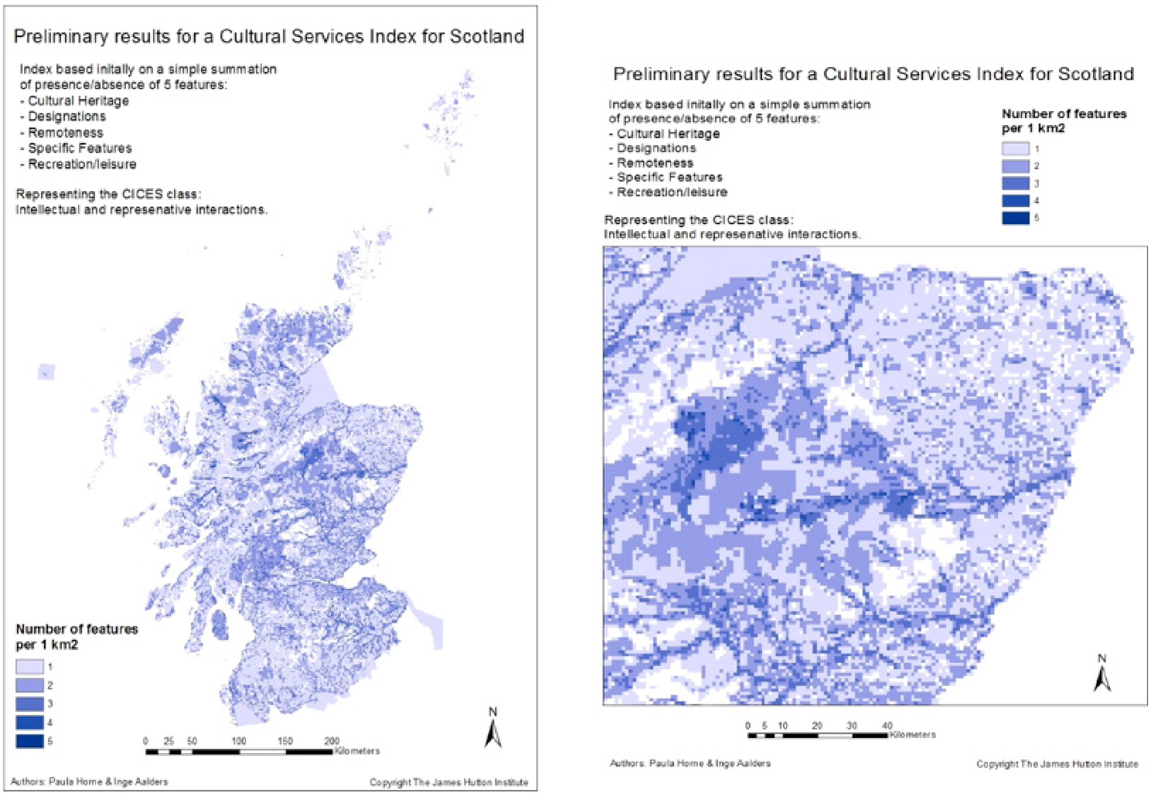

Fig 2: Results of mapping CES based on simple CES index

5. Valuation and natural capital accounting

Background

Ecosystem services provide people with benefits that contribute to our health and well-being. Monetary and non-monetary valuation of these benefits can inform decisions on land use and management. It aids the understanding of trade-offs between ecosystem services where conflicts arise. Valuation allows comparison of multiple ecosystem services where some benefits are marketed goods (food, raw materials), others have values observable through potential costs (climate and natural hazard regulation) or where values are not directly observed (cultural services such as landscape).

Natural capital accounting uses valuation to understand the ‘totality’ of ecosystem service benefits provided by the natural environment. Accounting gives us a better understanding of how ecosystems and benefits change over time, whether benefits are sustainable, and this can guide policy action.

Robust valuations and accounts need an understanding of how natural capital stocks and ecosystem processes work to produce the ecosystem services that we benefit from. This includes reconciling the scales over which ecosystem processes operate with the scales of management action and resulting benefits.

Using a number of case study approaches across different ecosystems we explored issues surrounding ecosystem service valuation and natural capital accounting.

Approach

The interactions of biophysical processes and management that produce ecosystem service benefits have been considered in the contexts of land and water ecosystems. Appropriate scales and approaches for valuation have been considered in the context of forest ecosystem services.

Natural capital accounting has been assessed in the contexts of water, through grey water footprints and soil natural capital. Grey water footprint refers to the assimilation of pollutants by water bodies; this contrasts with blue or green water footprints which consider the volume of freshwater needed to sustain production and consumption (Fig 1). Soil natural capital accounting was considered in the context of increasing organic matter content of arable soils.

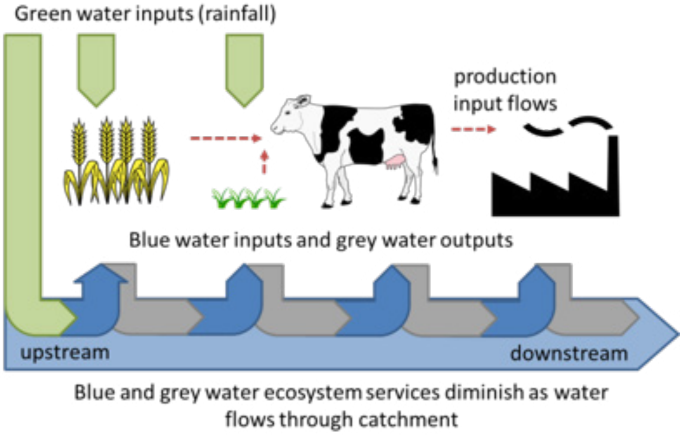

Fig 1: Green, blue and grey water footprint concepts. Human uses benefit and impact on ecosystem services at different stages.

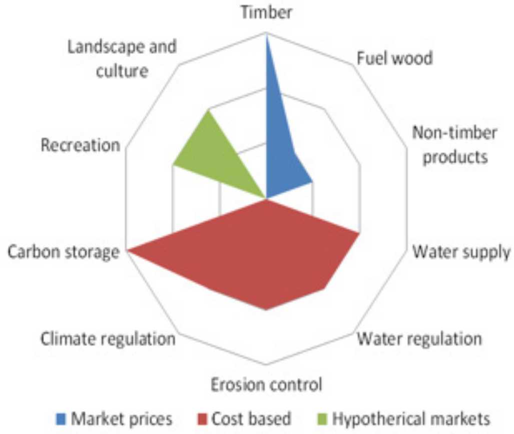

Fig 2: Scale (distance from centre: local, regional, global) and monetary valuation approaches for multiple forest benefits

Results

- Ecosystems provide benefits over multiple scales creating challenges for valuation. Valuation methods cannot easily accommodate all scales and benefits (Fig 2). Mixed approaches including deliberative and non-monetary methods can be appropriate.
- Participatory modelling approaches such as Bayesian Networks can help researchers and stakeholders develop a joint understanding of how ecosystem processes contribute to services and benefits that can be valued.
- A grey water footprint study showed the relevance of considering a number of pollutants (e.g. arsenic, lead and mercury) that pose a threat to ecosystem sustainability and health, indicating that natural background concentrations are also an important driver of grey water footprint.
- Soil natural capital accounting is hampered by infrequent collection of indicator data. Soil management contributes to ecosystem services but its impacts on natural capital condition may be good or bad. These impacts are key to soil sustainability and need to be recognised when valuing benefits.

Conclusions

There is no one 'best' approach to valuation. Methods should be appropriate for the context and scale at which services are provided.

The grey water footprint study showed a relatively simple method to analyse water quality data and define hotspots to target policy.

Challenges remain in developing natural capital accounts. We need biophysical data that reflect changes in condition over time, and that can be linked to both management actions and benefits that can be valued.

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6. Approaches for more integrated and participatory decision-making

Background

There is increasing recognition that our ecosystems provide multiple benefits at multiple scales. Making decisions about the way we manage our natural resources is becoming more complex because we need to reconcile private objectives for maintaining livelihoods, whilst ensuring the delivery of public goods and services which are resilient to change. This necessitates land managers considering the consequences of their decisions in a more integrated and holistic way. **Here we tested a number of approaches designed to inform land use decisions and take into account drivers of change.**

Approach

- Exploring local engagement in the Land Use Strategy (as part of the Regional Land Use pilots) using Multi-Criteria Decision Analysis (MCDA) to: i) to evaluate land-use scenarios; and: ii) engage local individuals in thinking more widely about the consequences of different futures on goods and services.
- Examining the usefulness of scenarios and 3-D visualisation for strategic planning on a private estate; i.e. how to achieve economic sustainability whilst enhancing the environment and encouraging participation.

Results

The majority of participants found the approaches very useful in helping them to consider the impacts of decisions on land-use change in a more integrated, holistic way. They also allowed diverse perspectives and opinions to be aired and listened to, and this was greatly valued.

People were happy to engage in the evaluation of a narrative-based scenario using MCDA but they were sceptical of modelled projections of change. The analysis demonstrated where there was common ground and where there were differences in opinion, allowing a more nuanced and less polarised debate[1] (Fig 1).

[1] http://www.hutton.ac.uk/sites/default/files/files/snc/FINAL%20Huntly%20third%20workshop%20report%2030-3-15.pdf

On the estate, exploratory (hypothetical) scenarios were considered inappropriate for local community engagement, for fear of generating misunderstandings. The estate therefore opted for a targeted scenario approach. In addition, differences in opinion on future governance (a key driver) highlighted the need for more facilitated debate about the institutional arrangements before engaging further with the community. However, the study clearly demonstrated the benefits of involving a broader stakeholder base in evaluating scenarios, sharing information and the creation of innovative solutions.

Conclusions

Making decisions about land use in a more integrated and participatory way has clear benefits. However, the time and resources needed to work in such a way should not be underestimated. Building the capacity of both local communities and organisations (public and private) with regards to governance, knowledge and engagement is paramount if these approaches are to be mainstreamed.

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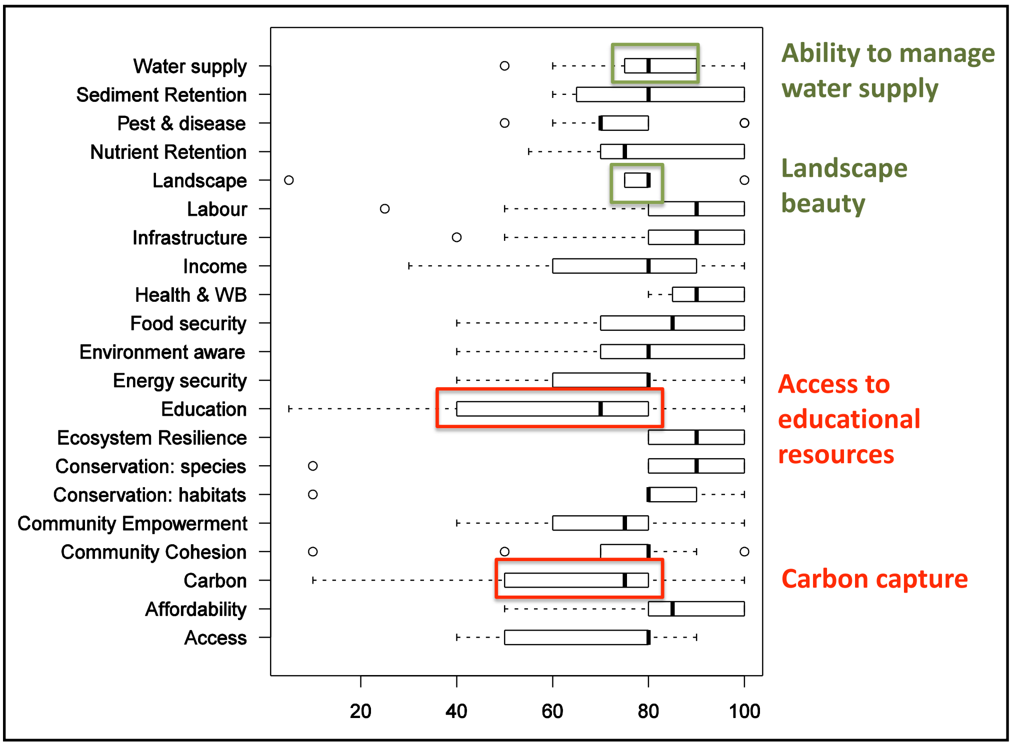

Fig 1: Ranking of different criteria used to assess scenario options. Criteria are ranked from 0-100 in terms of importance. Narrow bars indicate agreement among participants over the relative importance of a criterion (see green boxes as examples). Wide bars indicate criteria were there was a wide range of opinions over how important the criterion is (see red boxes as examples).

Fig 2: Participants revising a scenario following its evaluation. Areas evaluated as needing improvement included: greater community involvement; sufficient and sustainable sources of funding; and reducing conflicts and impacts of users.

7. Aberdeenshire Regional Land Use Pilot: A web-based spatial tool to support land use decision making

Background

To investigate the application of Scotland's Land Use Strategy at a regional scale, two pilot projects were carried out to consider existing and future land uses in a collective and integrated way. The aim was *"to create a framework which summarises policy and environmental information for users and indicates where particular types of land use change might be beneficial or detrimental in line with policy goals and climate change mitigation/adaption".*

Approach

We developed an interactive web-based mapping tool that allows users to explore the consequences of following different policy priorities on land use change and the consequences for ecosystem service delivery. The tool also incorporates how land capability for agriculture will change under a medium climate change scenario for 2050.

Each land parcel (pixel) is scored against 22 criteria relating to policy goals including biodiversity, carbon, water management, safeguarding food production and recreation.

The tool allows the user to explore how changing the weighting of the different criteria leads to different configurations of land use change using woodland expansion as a lens (Fig 1).

The consequences of these different configurations for sediment retention, nutrient retention and carbon storage can also be viewed.

Results

The maps rank areas according to their suitability for a proposed change such as woodland expansion, taking into account how any change could provide other benefits such as recreation opportunities or reduce problems such as water quality issues. For example, users can visualise the most suitable areas for broadleaved woodland expansion if water management is prioritised, as well as the consequences for sediment and nutrient export (Fig 2).

The results show that:

a) Achieving policy targets for woodland expansion may only involve a relatively small area of Aberdeenshire (Fig 2).

b) Even with woodland expansion there is an overall decline in ecosystem service delivery - mainly attributable to the potential expansion of prime agricultural land under predicted climate change.

The tool is freely available at http://rlup.hutton.ac.uk/.

Conclusions

The tool prompts users to think about potential change and its implications by visualising, in a relatively simple way, large amounts of data and complex calculations that link land, water, access, carbon and biodiversity issues.

It demonstrates how a strategic approach could help planners to target support to areas where land use change could deliver multiple benefits. However, due to limitations in the resolution of the available data, implementing this at a local level also requires engagement with local knowledge about the practical constraints and opportunities.

We aim to develop the approach to explore wider land use change options, building on the current woodland and prime agricultural land expansion focus.

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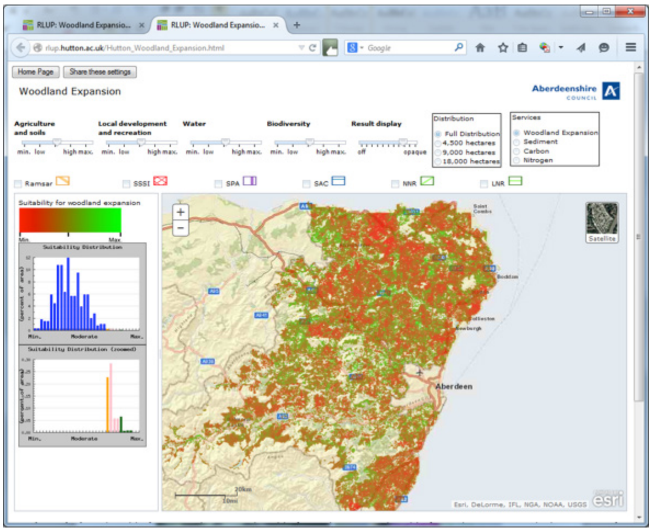

Fig 1: A screenshot of the RLUP tool showing the how the suitability for woodland expansion varies across Aberdeenshire (green and red are most and red least suitable, respectively) by scoring each pixel against 22 different policy related criteria that represent the constraints and opportunities relating to woodland planting.

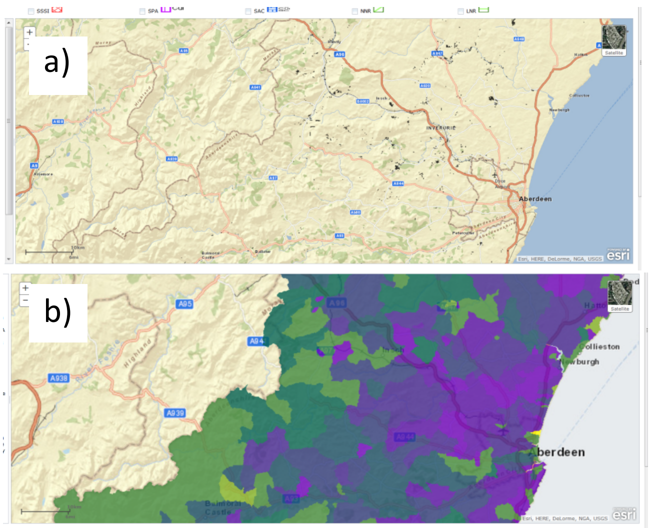

Fig 2: a) A screenshot from the RLUP tool that indicates the 9000ha of land (small black polygons) with the highest suitability for woodland expansion in Aberdeenshire taking into account policy priorities such as water management and safeguarding food production; b) a map of the predicted sediment export from the sub-catchments under the woodland expansion scenario shown in a).

8. Delivering ecosystem services at a national scale: institutions and governance

Photo Credit: Kerry Waylen

Background

Public, private and third sector organisations are starting to explore how the concepts of ecosystem services and the Ecosystem Approach might help them manage our environment in order to deliver integrated benefits to society. Application of the Ecosystem Approach is gaining traction across Europe and within Scotland as one way to ensure we deliver multiple benefits from land and water. It is important to understand the interplay of actors and actions that shape environmental management, and to identify potential barriers to implementing new management concepts like the Ecosystem Approach. **This research set out to illustrate the benefits and challenges of applying the Ecosystem Approach and identify where there are 'sticking points' to overcome.**

Approach

The research used multiple qualitative methods to assess 24 UK case studies that had implemented the Ecosystem Approach. The first challenge was to identify those genuinely implementing an Ecosystem Approach, as some projects using the terminology were not consistent with our definition, whilst others were not using the term yet had a similar ethos. We then undertook a review of published project documentation complemented by in-depth interviews with project officers. These data were qualitatively analysed and the results peer-checked by our interviewees.

Results

- National leaders (public, private and third sector) must support those who manage and use particular ecosystems to think systemically and plan for the long term.
- The legacy of the past may create three types of 'sticking points' (Fig 1).
- Firstly, many existing policies, strategies, targets and delivery actions are a product of historical thinking about individual issues or problems, whereas an Ecosystem Approach requires connecting these issues together. Implementing the Ecosystem Approach may require more flexible and dynamic approaches that may be at odds with fixed statutory targets or designations.
- Secondly, sticking points can also be caused by informal rules, norms and behaviours that arise due to people's training and the way they are rewarded in their organisations; these explain why people can find it difficult to think holistically or trust non-scientific knowledge.
- Finally, the ability to change and manage in new ways may be resisted by those whose interests are served by the *status quo*. However, one of the benefits of the Ecosystem Approach is to seek more sustainable partnership solutions.

Full results can be found at http://www.hutton.ac.uk/projects/ecosystemapproachreview and in Waylen et al., (2015) http://www.ecologyandsociety.org/vol20/iss2/art21/ (open access).

Conclusion

National and international support is needed to implement new ecosystem concepts. It can be difficult to adopt new approaches that foster holistic, long-term and transdisciplinary working. Therefore, encouragement and rewards are needed for individuals and organisations that invest in partnership working processes, and sufficient resources (human and financial) are needed to allow innovation to be implemented and evaluated. This will assist in capturing and communicating the benefits of doing things differently; and this information can be used to influence the main sources of advice, regulation and incentives for those managing our environment.

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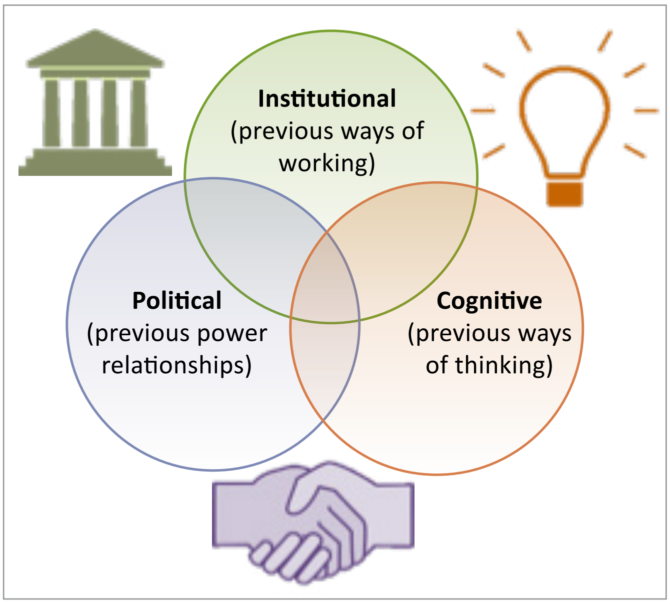

Fig 1: Three types of sticking points

9. Ecosystem services at a local scale

Background

Recent large scale initiatives such as the UK National Ecosystem Assessment (2011) and its Follow-On (2014) have provided useful broad-scale overviews of ecosystems and ecosystem services. However, large scale perspectives tend to favour a focus on services which can be mapped and assessed based on biophysical features or economic indicators. Such assessments often imply or even require a representation of services as readily provided by ecosystems, without any human involvement.

While this is useful for policy and decision-making purposes (e.g., in the context of Sustainable Development Goal 15.9 ‘integrate ecosystem values into planning’), it risks missing important processes and values. **We examined ecosystem services and benefits at a lower level of scale, and examined how people contribute to the generation of ecosystem services in their interactions with the environment.**

Approach

Two empirical studies aimed to assess ecosystem services at the local level, drawing on the perceptions of a wide variety of stakeholders and users of the ecosystems in question.

- Study A: 46 qualitative interviews focusing on a mixed woodland/agricultural estate in Fife
- Study B: Two sets of three workshops each, held in two areas in Aberdeenshire as part of the Rural Land Use Pilot.

Results

- The extent of the human role in the generation of benefits from ecosystems was striking (e.g. planting trees; turning a tree into timber, fuel, or a piece of art; managing a riverbed for flood retention).
- Ecosystem services were thus best described as co-produced by people and ecosystems. These processes of co-production and the attribution of meaning (co-construction) were informed

by the identities and capabilities of the people involved (Fig 1).

- While most maps and inventories of ES focus on individual, final services such as food production, participants emphasised how benefits flowed on through networks. For example, crops produce income for the farmer, local jobs on the farm and in processing industries, and thereby help maintain vibrant local communities as well as contributing to the national economy and food security.
- Benefit flows that are usually seen as cultural ecosystem services were often not separate from other services but an integral part of these, and added meaning and value to them (e.g. wood fuel as a symbol of local self-sufficiency and sustainability).

Conclusion

Many ecosystem services are not readily 'provided' by ecosystems, but are co-produced by people and ecosystems. This implies limitations of coarse assessments that build on purely physical ecosystem structures as indicators of benefits. Local, contextualised studies are needed to complement such large-scale inventories.

Cultural ecosystem services connected to other services (e.g. provisioning) need to be recognised alongside more 'traditional' cultural ecosystem services such as recreation.

Methods for ecosystem service assessments need to be developed further to take the complexity and interconnected character of services and benefits into account to complement inventories of individual ecosystem services.

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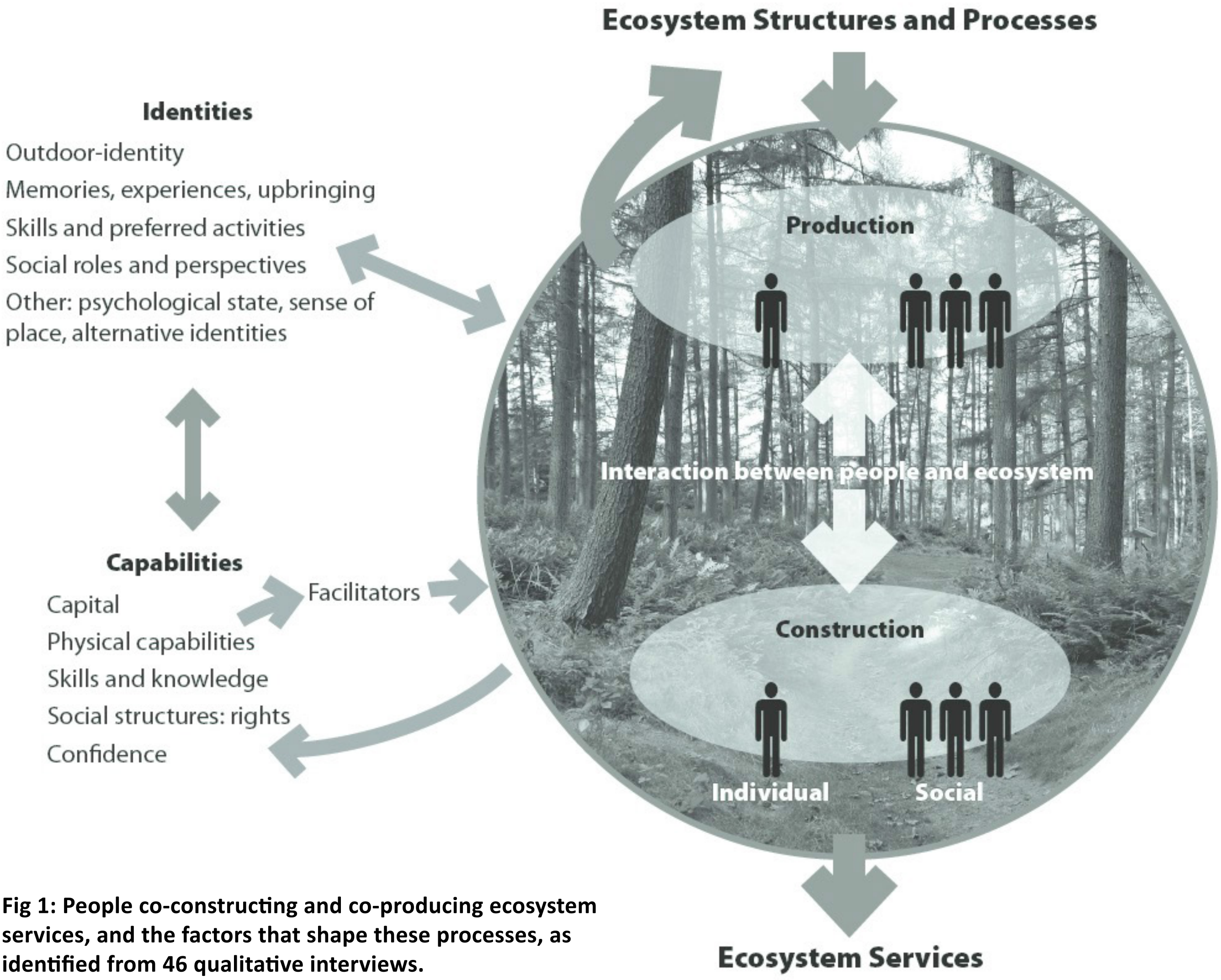

Fig 1: People co-constructing and co-producing ecosystem services, and the factors that shape these processes, as identified from 46 qualitative interviews.

10. Ecosystem Services from Catchments and Peatlands

Photo Credit: Kirsty Blackstock

Background

In Scotland and across Europe there is increasing interest in using the concept of ecosystem services to deliver the Water Framework Directive, particularly through its use in the River Basin Management Planning cycle. Improved delivery of water quality and quantity using an ecosystem services-based approach will also deliver to flood risk management and drinking water policies. Conversely, restoration of terrestrial habitats, particularly peatlands and riparian woodlands, will improve the delivery of water ecosystem services. Whilst Scotland's water is perceived as clean and abundant, only 62% of its waterbodies (rivers, lochs, estuaries, coasts and ground-waters) are considered to meet good ecological status. **Our research considered the benefits and challenges of using the concepts of ecosystem services to deliver improved catchment management.**

Approach

The research used literature reviews and the application of conceptual frameworks to existing data to analyse the delivery of ecosystem services and the ability to use an ecosystem services-based approach (Fig 1) to implement river basin management planning. The focus of the work was at the national level (Scotland) with focussed case-studies on: (a) the benefits of peatland restoration in Aberdeenshire and Lewis; and: (b) valuing catchment management interventions in two NE catchments.

[1] Source: http://www.environment.scotland.gov.uk/get-interactive/data/water-body-classification/)

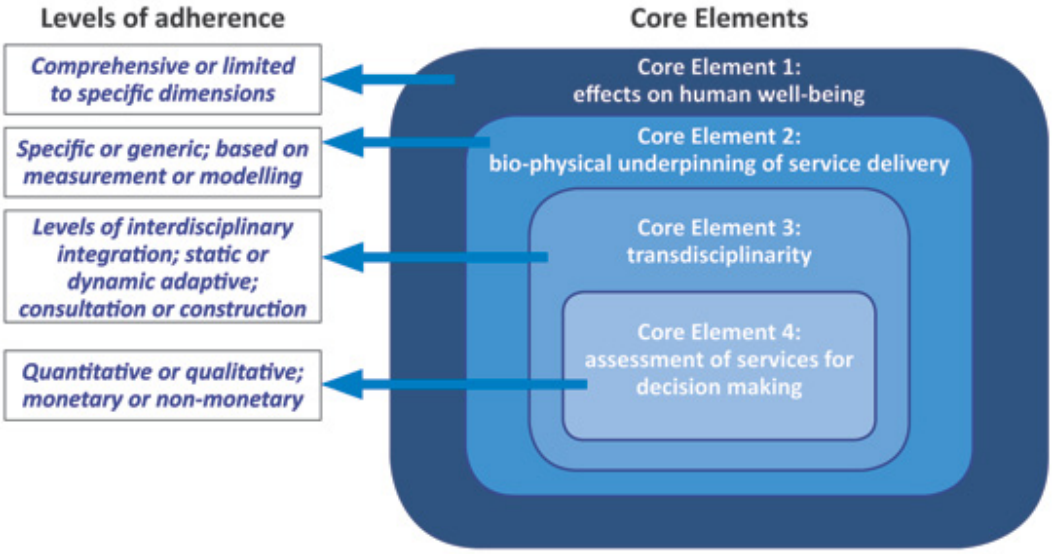

Fig 1: Nested core elements characterising the ecosystem services-based approach applied in our study, reprinted with permission from Martin-Ortega et al (2014)[2]

Results

- Scottish waterbodies provide a wide range of ecosystem services, from provisioning (drinking and irrigation water, renewable energy); through regulation and maintenance of the hydrological cycle; to cultural (providing recreational, educational and spiritual opportunities)[3].

- Existing approaches tend to focus on direct services provided by the water body itself. The additional consideration of ecosystem services from catchment management affecting the water body can enhance the delivery of services and associated benefits.

- There is evidence that peatland restoration and following best practice for riparian management will reduce sediment load and improve water quality; however the science is still uncertain given the variability in how different settings respond to measures[4].

- Most focus tends to be on delivering the 4th core element (assessment of services for decision-making) in Fig 1, but achieving the ethos of the Water Framework Directive as a 'sustainability directive' requires all four elements to be delivered.

- Managing ecosystem services from water and peatlands is not simply a technical issue of monitoring and measuring ecological changes but requires engaging a range of stakeholders in adaptively managing the land and water, including all those who use and enjoy them.

Conclusion

The ecosystem services-based approach can help illustrate how human well-being is dependent on ecological health. In turn, this can illustrate how delivering 'environmental' policies is actually about supporting Scottish society and its economy. A number of scientific challenges remain, including how to monitor and map ecosystem services as part of a complex, varied and changing system; how to support decision-making taking account of a range of values and preferences; and how to work with uncertainty.

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[2] Martin-Ortega J, Jorda-Capdevila D, Glenk K and Holsted K.L (2014) What defines ecosystem services-based approaches? In Water ecosystem services: a global perspective, Cambridge University Press: Cambridge pp3-15.

[3] See http://www.sepa.org.uk/data-visualisation/benefits-of-the-water-environment/ for more information.

[4] For results see Martin-Ortega (2014) http://www.sciencedirect.com/science/article/pii/S2212041614000655

11. Ecosystem services from croplands

Background

The lowland agriculture of Scotland is based on grain from cereals such as oat, barley and wheat and grass from pasture. Intensification in the 20th century moved production from deficit to surplus but had negative effects on many supporting and regulating services. By the mid-1990s, the rise in yield of most crops had levelled for reasons that were not clear. There were questions therefore as to whether the croplands would continue to be high yielding and whether reported declines in biodiversity and system function could be halted and reversed. **The internal condition of arable-grass cropland in Scotland was therefore examined over the five years from 2011-2016 with a view to understanding its present state and future potential.**

Approach

A suite of around 100 indicators was defined for assessing the status of arable-grass cropland. The indicators covered growth and yield, agronomic inputs, carbon and nitrogen cycles, weeds and wild plants, invertebrates, soil biophysical status and landscape features. A site network of more than 50 farms in the east of Scotland was used to assess the status of fields of differing intensity, including those that had changed relatively little during intensification and those that had become reliant on very high inputs of fertiliser and pesticide. Areas of concern and potential were identified and then tested in the rotations at the Centre for Sustainable Cropping, Dundee.

Results

- The estimated potential yield of the main crops is presently about 1.5 times the national average. Previous analyses of yield gaps largely failed to recognize soil degradation as a potential contributor. However, our major field surveys showed that the supporting functions of many soils are sub-optimal and must now be limiting yield through decreasing carbon content, pore space for roots and water-holding capacity.
- Nitrogen (N) in high quantity is essential for the growth and yield of crops but applied as mineral fertiliser also causes pervasive ecological damage. However, the potential contribution of legume crops to offset fertiliser N with biologically fixed N was unknown. Field studies in the project showed that faba bean fixes 150 to 200 kg/ha, equivalent to the N applied to a high input winter cereal.
- The content of carbon (C) and nitrogen (N) in soils and plants, and the C:N ratio, were found to be sensitive indicators of ecosystem status. Nitrogen in particular provided a common currency, linking the economic returns from production through the price of fertiliser to the abundance and activity of living things costed through their N content. Beneficial in-field plants and food webs comprise a small proportion of the N used by crops – for example, the parasitic wasps and other biological control agents that provide useful functions take up less than 0.001% of the annual N flux.
- Data from the site networks and field platform, coupled with national-scale statistics, allowed maps of agricultural output and management intensity to be constructed. Potential localities and regions were identified where intensification was concentrated and could therefore be a cause for concern (Fig 1). This procedure enables a regional or national assessment to be made from a field-scale change in management.

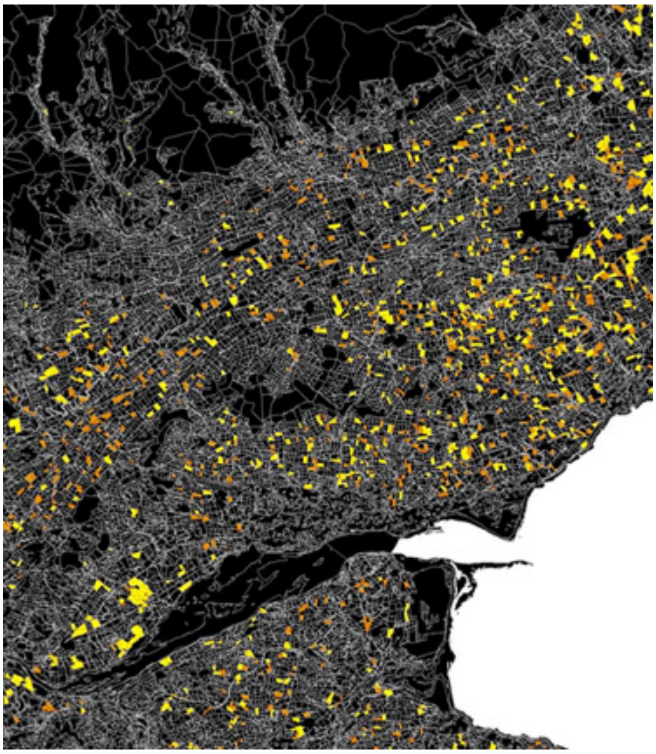

Fig 1: Map of high intensity potato (brown) and oilseed rape (yellow) in parts of Angus, Perthshire and Fife.

Conclusion

The croplands have remained diverse and high yielding compared to those in many other parts of the UK, but are suffering ecological degradation where high-input cropping is the norm. Solutions will require a long-term strategy: a return to carbon-building crops as part of the high-intensity rotations now seems inevitable, as is the reintroduction of legumes to reduce mineral nitrogen inputs. Many options are being examined in realistic cropping systems at the Centre for Sustainable Cropping, Dundee.

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12. Nature conservation and ecosystem delivery

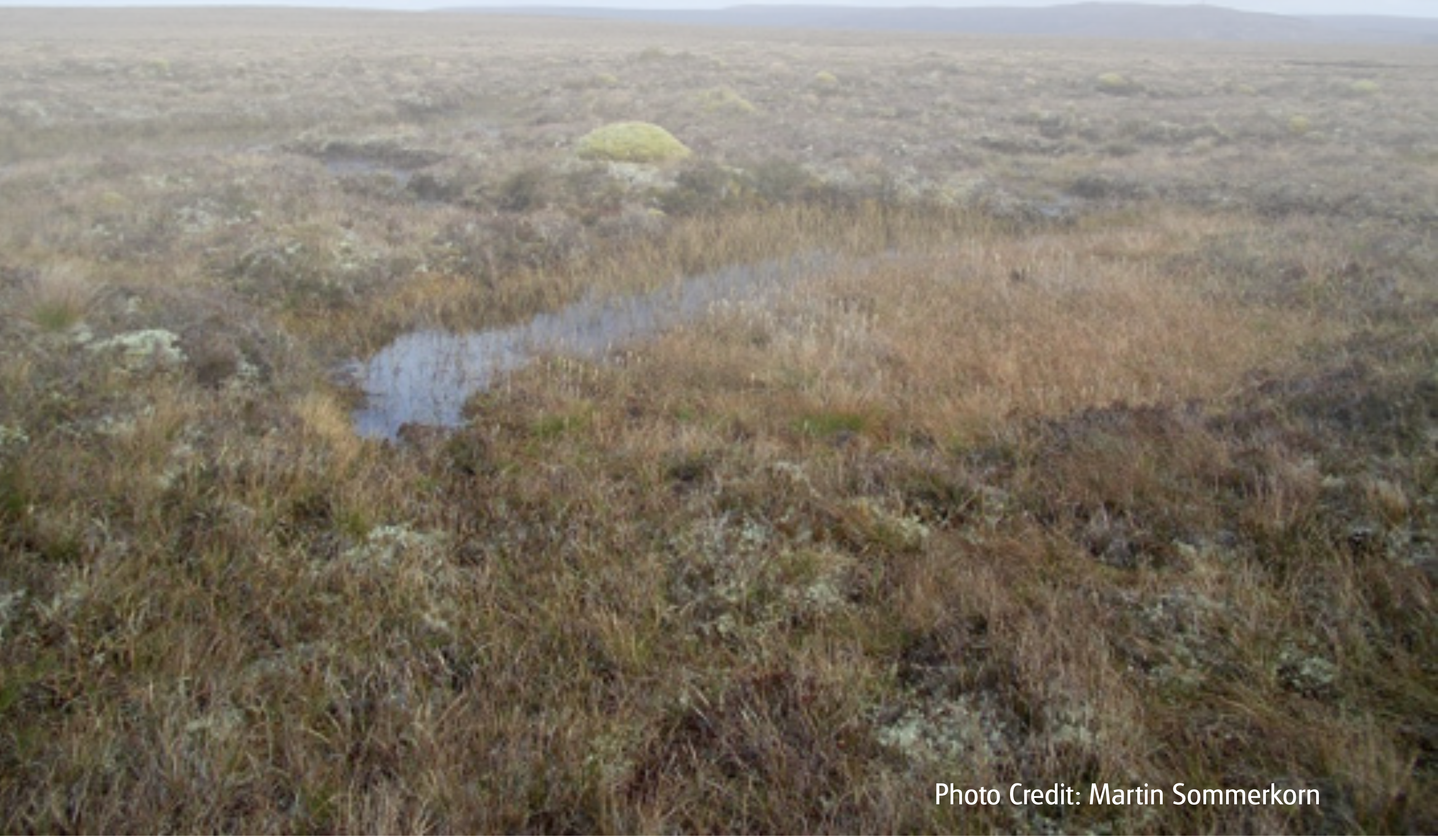

Photo Credit: Martin Sommerkorn

Background

In recent years there has been a major shift in nature conservation policy at both international and national levels (i.e. see Aichi Targets and the 2020 Challenge for Scotland's Biodiversity). The focus now is not only to conserve biodiversity but also to enhance the benefits it provides for all people (ecosystem services). Understandably, there is great interest by practitioners and policy makers alike to increase our understanding of how nature conservation affects ecosystem services. Whilst a number of studies have examined the effects of biodiversity conservation on the delivery of ecosystem services, they are often limited in the scope of the ecosystem services (ES) assessed (i.e. carbon stocks) and can suffer from confounding spatial issues. This has led to contrasting and conflicting evidence about the impacts of nature conservation on ecosystem services.

Therefore, we examined the impacts of nature conservation across multiple habitats in the UK, for the full range of ES.

Approach

We examined the delivery of ES across nine case-studies, using expert opinion. The case studies covered a range of habitats and explored the delivery of ES from a 'protected site' and a comparable 'non-protected' site. By conducting pair-wise comparisons of ES delivery between comparable sites our study attempted to mitigate confounding cause and effect factors in relation to spatial context.

Results

- The analysis showed that protected sites deliver overall higher levels of ES than non-protected sites, with the main differences being in the cultural and regulating ecosystem services (Table 1).
- Against expectations, there was no consistent negative impact of protection on provisioning services across the case studies.
- Whilst the analysis demonstrated general patterns in ES delivery between protected and non-protected sites, the individual responses in each case study highlight the importance of the local social, biophysical, economic and temporal context of individual protected areas and the associated management.

Conclusion

Our study attempted to assess delivery of a full suite of ES, which we believe is crucial if we wish to gain an integrated and holistic understanding of the impacts of nature conservation on ES delivery. The lack of bundling of ES in our study indicates that research which focuses on just a few ES may give an incomplete or distorted picture of ecosystem delivery. More comprehensive research on how best to implement assessments which incorporate all of the cultural and regulatory benefits of nature conservation is essential. We also need to focus on new approaches to assessing services where conventional scientific data is costly and slow to collect, using more appropriate methods based on eliciting knowledge from local stakeholders and experts.

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Category	Ecosystem Services	Significance
Cultural	Aesthetics†	**
	Artistic	*
	Cultural heritage	
	Education	**
	Religious	
	Environmental Stewardship	**
	Tourism/Recreation	
Provisioning	Energy	
	Fibre	
	Food	
	Freshwater	
	Genetic Resources	*
	Raw Materials	
Regulating	Air Quality	
	Climate	
	Diseases/Pests	
	Hazard	
	Pollination	*
	Soil Quality	*
	Water Quality	*
Supporting	Nutrient Cycling	
	Primary Production	
	Soil Formation	
	Water Cycling	
Total	All Services	**

Table 1: A test of the differences between ecosystem service delivery between protected and non-protected sites. Significance levels indicated by * $0.05 \le p < 0.01$, ** $0.01 \le p < 0.001$.†This category included the wide range of benefits people get from experiencing nature as well as species and habitats of conservation importance.

This booklet summarises some of the key findings concerning ecosystem services that have arisen from the Scottish Government Rural and Environment Research and Analysis Directorate's funded research programme "Environment – Land Use and Rural Stewardship".

The research programme ran from 2011 to 2016 and involved researchers from:

Biomathematics and Statistics Scotland

Royal Botanic Garden Edinburgh

Scotland's Rural College

The James Hutton Institute

This programme receives financial support from RESAS