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Forest Research

WOODLAND TRUST

THE LANDSCAPE ECOLOGY OF FORESTS, WOODLANDS AND TREES

ialeUK Conference

7–8 SEPTEMBER 2021, THE UNIVERSITY OF EDINBURGH, UK

iale.uk/conference2021

Foreword

These proceedings contain the abstracts of the 25th ialeUK conference The Landscape Ecology of Forests, Woodlands and Trees, held online on 7 and 8 September 2021. The conference brings together people with relevant expertise from across science, policy, conservation and industry, to learn from each other, and identify ways in which landscape ecology can support ambitious policy targets, including those for woodland expansion, greenhouse gas reduction, biodiversity conservation, commercial viability, and sustainable development goals.

The programme for this year's conference includes 34 talks, with key notes by Jo Pike (CEO of the Scottish Wildlife Trust); Jenny Hodgeson (conservation biologist at the Liverpool University); Sallie Bailey (deputy chief scientific advisor at Scottish Government) and Jon Stokes (director of Trees, Science & Research at The Tree Council).

We are pleased that a third of the talks are by non-academic experts from conservations NGOs (Woodland Trust, RSPB), Government agencies (NatureScot, Natural England), and other organisations with an interest treescapes including Galbraith and the National Forest Company.

The conference is structured in five sessions:

- **Public benefits** will demonstrate emerging models, evidence and practical case-studies that illustrate how the ecosystem services framework can support landscape and forestry decisions.
- **Restoring, planting and connecting** will present exemplary initiatives putting these principles in practice, along with new research that can support restoring, planting and connecting forests, woodlands and trees.
- **Monitoring forests, woodland and trees** will report progress to understand and quantify change woodlands and trees and hedgerows.
- **Trees and hedgerows** will highlight the ecological and socio-cultural importance of trees and hedgerows, bringing together both urban landscape ecology and the more traditional focus on rural landscapes.
- **Ecological resilience** will present new understanding of these impacts and strategies to increase resilience in a range of settings, including native and productive forests.

Marc Metzger, Vanessa Burton, Adrian Southern, Jess Neumann

Tues 7 Sept — **Public benefits**

Forests, woodlands and trees provide a wide range of cultural, provisioning, regulating and biodiversity benefits, but evidence and understanding is complex and incomplete, and practical planning and ecosystem services-based management approaches are new. This symposium demonstrates emerging models, evidence and practical case-studies that illustrate how the ecosystem services framework can support landscape and forestry decisions.

Quantifying the benefits of different woodland types in Wales to inform afforestation policy.

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The Welsh Government has an ambitious target for woodland expansion, which it views as a key action to help mitigate the impacts of climate change and reduce flood risk through land use. Afforestation policies do not necessarily distinguish between woodland types, despite evidence that native broadleaved woodlands better support native, priority fauna and provide a more secure carbon store than commercial, non-native conifer plantations. We set out to quantify the benefits of native broadleaved woodland creation so that we can provide advice which builds confidence that investing in its creation will secure multiple benefits for society and biodiversity and represent good value for money.

To assess the biodiversity benefits provided by different woodland habitats in Wales, we drew on data from the Breeding Bird Survey and Repeat Woodland Bird Survey, and compared population densities and species diversity among different habitat types and stages of succession. These statistical analyses confirmed that woodland birds in Wales prefer woodlands dominated by broadleaved species (or a mixture of broadleaved and coniferous), and habitats with complex structures and microclimate heterogeneity. We then performed a literature review of the evidence for public preferences for different woodland types in the UK, finding that the public have a stronger preference for broadleaved woodlands over commercial conifer plantations, citing greater benefits to biodiversity, landscape aesthetics and a preference for native over exotic species. Finally, we carried out modelling of key ecosystem in three sub-catchments in Wales, comparing the benefits provided by two woodland expansion scenarios: 1) primarily broadleaved woodlands and 2) primarily conifer plantations. Across the three catchments, the broadleaved scenario lead to greater carbon sequestration and better natural flood management than did the conifer scenario.

Combining the results of these three sections shows a consistent preference towards broadleaved woodlands over conifer plantations. Given the long time-frame over which such woodlands mature, and the preference woodland birds for established habitats, work to manage existing woodlands should be prioritised in addition to woodland expansion. Care should also be taken to ensure woodland expansion complements existing landscapes, such that habitats of biodiversity and social value are not replaced. Overall, the analysis shows that in order to deliver the most beneficial woodland expansion for Wales, policies must be designed to drive targeted woodland expansion that aims to deliver multipurpose woodlands. The analysis also shows that multiple ecosystem services can be delivered when new woodlands are appropriately designed and located.

Beyond Carbon. Expanding and creating woodlands in Scotland for multiple public benefits.

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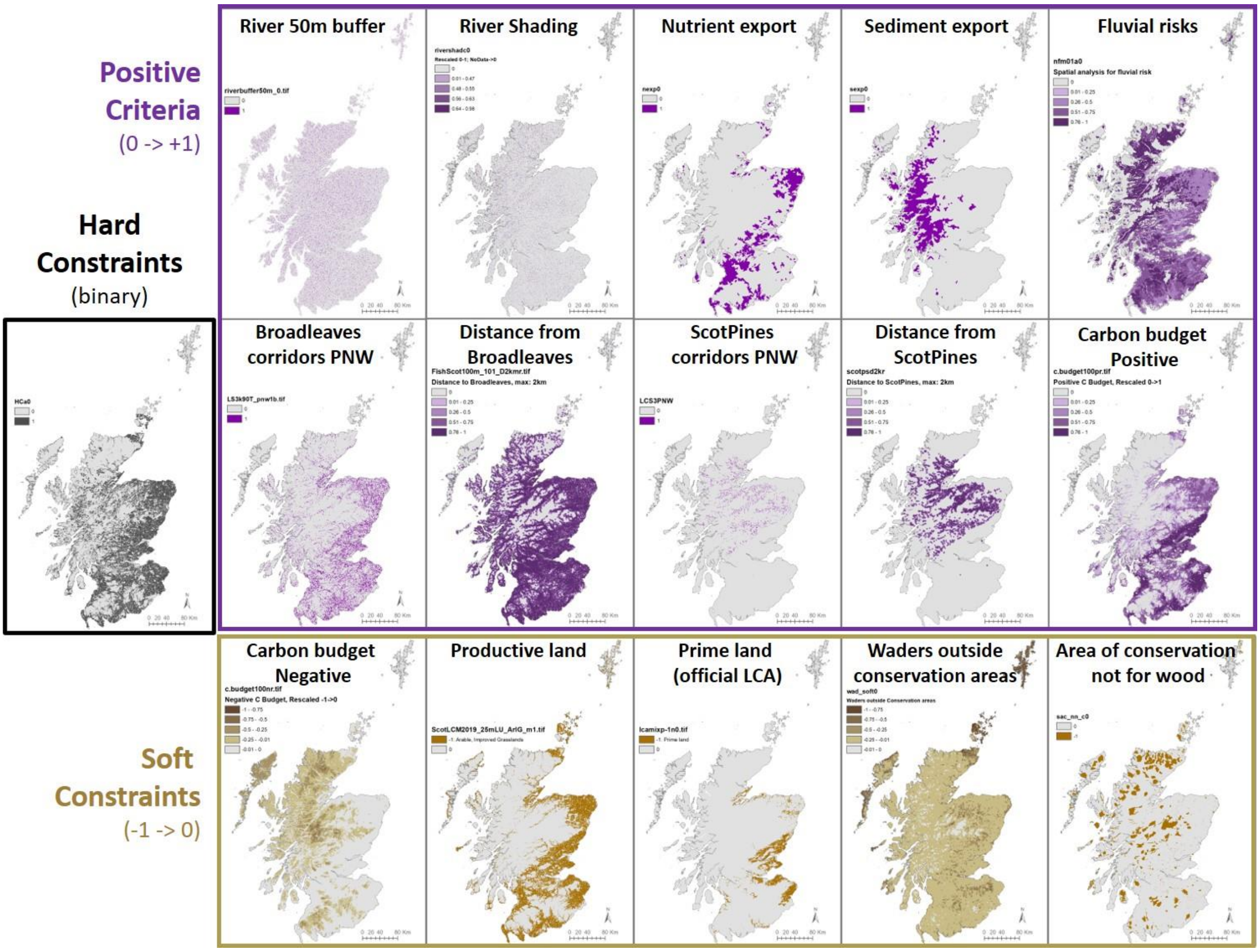
Creating new woodlands has the potential to restore habitat and is also widely perceived as necessary for the UK and Scotland to meet net-zero emissions policy goals. Besides their climate change mitigation potential through carbon storage, the protection and expansion of existing woodlands, and the creation of new ones, can also be associated with multiple other benefits, directly or indirectly contributing to climate change mitigation. For example, a decrease in soil erosion and diffuse pollution, mitigation of flooding, shading for cold water dependent aquatic species, and improved connectivity among existing woodlands.

However, spatial aspects of woodland creation are a crucial consideration because benefits and potential dis-benefits depend on local suitability, on the potential encroachment on other habitat types, and on existing risk factors that woodlands could mitigate or exacerbate. For example, the potential for carbon gain is not ubiquitous but depends on local soil and climatic attributes. We present a comprehensive interdisciplinary analysis of the spatial pattern of multiple benefits (ecosystem services) and constraints associated with woodland expansion in Scotland. It is based on several models whose outputs are used in a multi-criteria analysis to show how they combine spatially to suggest priority areas for expansion and areas that are low priority or best avoided.

The results can help realise the goals of the Scottish Land Use Strategy, by guiding the targeting of incentives such as carbon payments and forestry grants in such a way that would increase benefits and minimise trade-offs.


Positive Criteria
(0 -> +1)
Hard Constraints
(binary)
Soft Constraints
(-1 -> 0)
River 50m buffer
River Shading
Nutrient export
Sediment export
Fluvial risks
Broadleaves corridors PNW
Distance from Broadleaves
ScotPines corridors PNW
Distance from ScotPines
Carbon budget Positive
Carbon budget Negative
Productive land
Prime land (official LCA)
Waders outside conservation areas
Area of conservation not for wood

A biodiversity index for Britain's national forests.

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For managers of large land holdings, delivering policy through practice is a landscape scale challenge. The managers of Britain's national forests deliver countrywide policies (e.g. concerning Sustainable Forest Management) and, as public bodies, have a statutory duty to further the conservation of biodiversity. Learning from the last 20 years show that for biodiversity, not only is within forest condition important but also the local and landscape scale state of diversity, extent, and connectivity of habitat in and surrounding forests [1]. Delivering biodiversity 'duty' in an informed and justifiable way across entire national forest estates requires that choice and siting of local actions and responses to estate-wide initiatives consider the multi-scale context of forest and land resources. Further, reporting objectively on the 'duty' requires that the collective effect of management on biodiversity across the national forest estates is systematically assessed.

Our solution, co-developed with end-users, is a suite of metrics, which together describe the biodiversity potential of every management unit (sub-compartment) across the national forest estates. The metrics are calculated in a transparent way from spatial data collected annually as part of the public bodies' forest inventory. Like other indices of forest biodiversity [2,3], the metrics measure a mixture of features which have an expected relationship with biodiversity. Further, many of the features used can be modified through forest and land management decisions.

Primarily designed for strategic monitoring and reporting, the individual metrics are aggregated into a set of indicators which are combined to form an Index. The individual indicators and index can be reported at the regional or national scale, with between year comparisons calculated.

Of use at the tactical and operational level, this spatial and objective assessment of biodiversity potential provides information for local planning and management decisions. Accessed through a web-based tool implemented in R Shiny, each metric and indicator can be viewed at the appropriate scale and the component habitat features underpinning the metrics can be interrogated to help visualize woodlands across the estate.

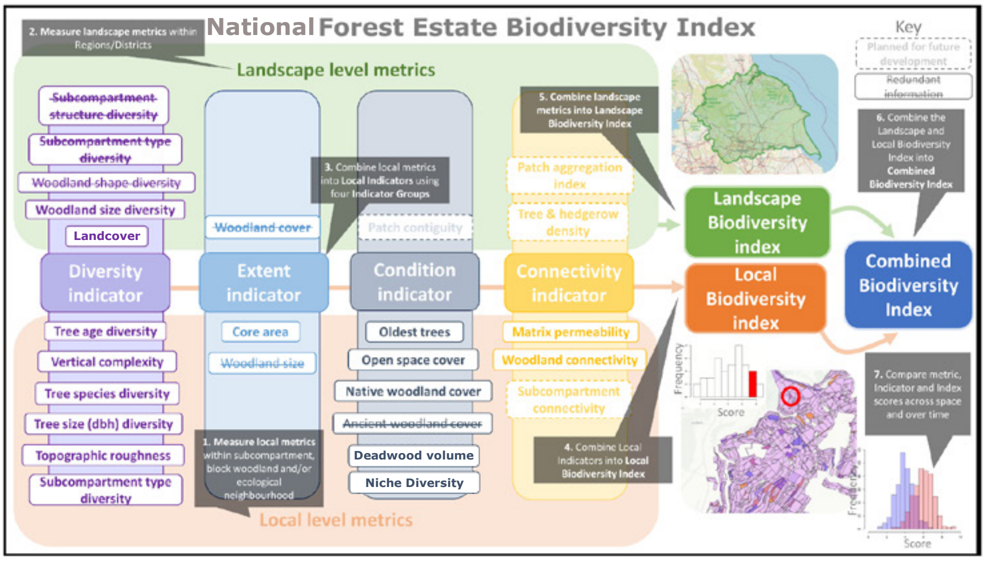
We are now strengthening utility of the Index through case study application to land management planning. We anticipate this will highlight new spatial data (e.g. for validation) and processing needs.

1 Bellamy C et al., 2018. Encouraging biodiversity at multiple scales in support of resilient woodlands. For. Comm. Res. Note 033: 1–14

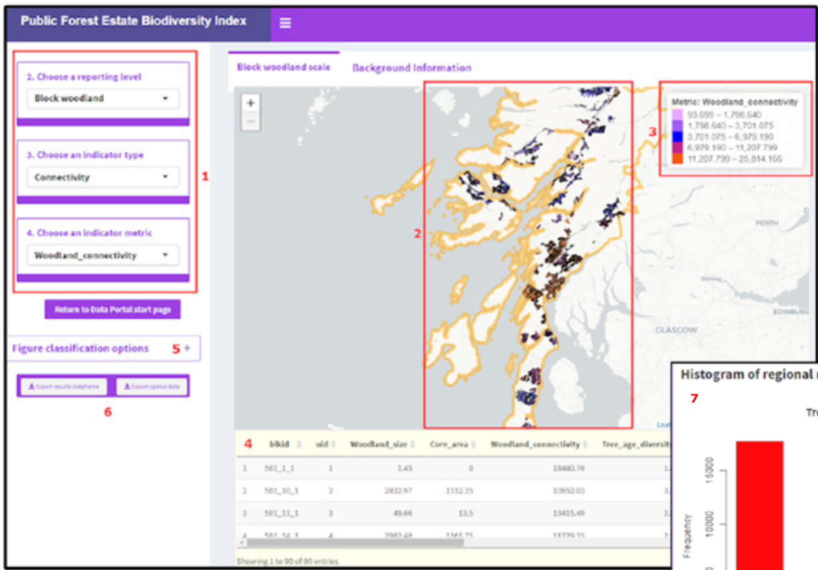
2 Geburek T et al., 2010. The Austrian Forest Biodiversity Index: All in one. Ecol. Indic. 10: 753–761

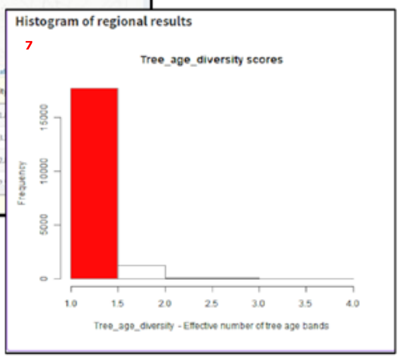
3 Ditchburn B et al., 2020.NFI woodland ecological condition in Great Britain. National Forest Inventory, Forest Research, Edinburgh.

Workflow for generating the index



Visual front-end to the index in the form of an interactive online R shiny app

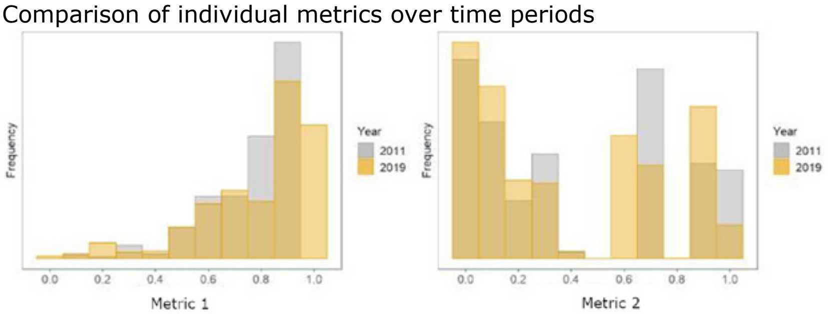




App image key:

1. Options allow user to select for specific reporting level, indicator type, and individual metric type
2) Main interactive map showing index results
3) Legend for results
4) Results table
5) Figure classification options
6) Option to export current dataset
7) Histogram of regional results - if user clicks on individual sub-compartment/block, this woodland's score in the regional context is highlighted on the histogram in red.

Comparison of individual metrics over time periods



Forests without fences – bridges to the future.

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The aim of this paper is to present evidence that despite considerable public investment in forest creation, restoration and expansion over the past 40 years, there has been a steady erosion of the total amount, and ecological quality of Scotland's natural woodland. With average densities of wild herbivores across Scotland well above the level required for woodland regeneration, the principal defense against their impacts is fencing. Fences at best protect woodland for 20 years, after which time without maintenance, they become porous and herbivores can get back in. The two pictures show how the ecological richness in the understorey has been impacted when fences are removed.

Overgrazing of our natural woodlands has been happening for hundreds of years, so they now are smaller, more open and less diverse, lack structural diversity or "filling", have few flowers and no replacement trees. A survey of the native woodlands of Scotland published in 2014 showed that about 18,000ha (an area the size of Glasgow) of ancient and natural woodland has been lost to unenclosed open land in the uplands since the 1960s, with pressure from herbivores a major contributing factor [1]. Herbivore pressure has also reduced the species and structural diversity of our woods. Only 64% of protected woodlands were reported to be in favourable condition in 2021 [2], although the actual situation may be much worse as this figure is based on old monitoring data and herbivore pressure has continued to increase during this period.

Woodland expansion, restoration and creation is very topical, with governments setting challenging targets to address the dual biodiversity and climate crises. But while the drivers might be new, this work has been going on for decades, and since the early 1980s government policies and incentives have been targeted at creating, expanding and restoring natural woodland. The high densities of deer across Scotland have posed a persistent threat to delivery of this ambition. It has been standard practice for this work to take place behind the protection of 6 foot high deer fences, and more than £100 million of public money has been spent since the 1990s on deer fencing for woodland regeneration and expansion in Scotland. Deer fences were meant to protect these precious woods and help the process of ecological restoration — so what has gone wrong?

In this paper we will look at some ways in which we can restore health and vitality to our woodlands and "pay forward" our debt to nature, and how we can get more and better woods connected through healthy ecosystems at a landscape scale without the need for costly deer fencing.

1 Native Woodland Survey of Scotland (2014)

2 https://www.nature.scot/doc/proportion-scotlands-protected-sites-favourable-condition-2021

These two pictures show a woodland exclosure on the Isle of Mull fenced against herbivore impacts for 30 years. The picture on the top shows how understorey had developed during this time. The fence was dismantled and two years later the picture on the bottom shows how the ecological richness in the understorey has been impacted.

Regenerative forestry in practice in the UK.

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‘Regenerative agriculture’ has become a powerful concept driving change not just for farmers, but for the food industry. Yet in forestry, ‘Sustainable Forest Management’ is the core concept, and forestry practices are rarely considered in the context of whole supply chains such as construction or energy. This paper provides a practitioner perspective on how forestry and wood production in the UK should be conceptualised and contextualised in the Circular Economy. First, it explores the roots of the sustainable/regenerative terminology to argue that ‘regenerative’ is the appropriate aspiration for UK forestry, given that it is based on planting and nurturing young forests in long-deforested landscapes to produce a low-carbon and low-waste material. Second, it explores what aspects of UK forestry practice could already be considered regenerative. Third, it proposes that the regenerative framework could set us on the path to two developments key to meeting climate and biodiversity targets: integrated farm-forestry land use, and integrated non-food supply chains.


Regenerative forestry in practice in the UK
Dr Eleanor Harris, Galbraith
Where should we be?
Sustainable hunter-gatherer
Maintains wild ecosystems
Regenerative farmer
Nurtures new ecosystems
Where are we?
Carefully expanding
Progressively restructuring
Developing governance
Where could we be?
Integrated land use
Integrated supply chains
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Seeing the wood and the trees? Lessons from applying ecosystem services in forest planning.

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In the UK and globally, forestry is experiencing an upsurge in interest as forests are anticipated to play a major role in addressing the twin crises of biodiversity loss and climate change that our society currently face. In the UK, forest management has traditionally focused on timber production; yet they provide many more ecosystem services (ES), including climate mitigation, slope stabilisation, and numerous wider ecological and social benefits. In the case of forestry, which requires long-term planning, understanding the impacts of forest management is a critical part of predicting the future supply of these benefits, which can then inform decision-making. This talk will present a transdisciplinary approach to using evidence of management impacts on ES to support planning and management decision-making. Collaboration was identified at the outset as critical. The project was co-developed with a forest planning manager (FM), and the activities undertaken formed five phases.

The main findings showed that forest management decisions have more impact than climate on future ES supply in this region (NW Scotland). Furthermore, forest structure is more important than species for ES supply in multi-objective conifer plantations. We found more trade-offs among ES under higher intensity management, and more synergies under lower intensity management. The simulation showed that time lags must be anticipated and accepted for delivering a wider suite of ES than timber. The ES framework provides a suitable method for delivering evidence that demonstrates how management influences the supply of benefits beyond timber that can inform forest planning. Co-developing the approach ensured the results were salient, and resulted in direct changes to the forest's management plan that should deliver wider environmental and social benefits in the future. The FM can apply the lessons learned in future planning decision-making.

The impact of lived experience and situated expertise on changing landscapes and solving 'wicked' challenges; (Trees for NFM).

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"Wicked" environmental challenges mean facing complex socio-ecological changes to our landscapes. Solutions to these are wide ranging and include our case study focus, tree planting for Natural Flood Management (NFM) [1]. Yet methods of determining solutions remain traditionally technocratic [2].

We explore the lived experience and expertise of landowners and managers, those in a position to implement landscape change, in a case study river catchment. By integrating this social data into a hydrological modelling process, we demonstrate direct scientific impact of this local, cultural knowledge and expertise. The process of engagement with landowners and managers at the outset ensured model output was both physically and culturally relevant to the catchment, whilst also challenging how models should be used as evidence in designing for change. We show that knowledge co-created by the hydrological models sits amongst a web of other 'knowledges', both scientific and cultural, with direct implications for governance.

We present this work as an interdisciplinary exploration of the social and physical influences on transitioning landscapes, problematizing the process of combining these two geographies and presenting practical methods for tackling this.

A mixed methods approach enabled the capture of a rich case study data set including both physical and cultural data e.g. semi-structured emplaced interviews, participant mapping, remote sensed data analysis etc. A process of 'analytical mapping' and triangulation of these data sets enabled feedback between disciplinary areas. An analysis and application of this data informed the development of scenarios that were used in a SHETRAN [5] hydrological model of the catchment. By examining the impacts of 'alternative land use' focusing on different treescapes, we are able to identify behaviours relevant to this catchment. Results from the hydrological model provide insights into unexpected responses and the importance of catchment and cultural heterogeneity.

Our findings are co-produced, including participant evaluation workshops as well as the detailed analytical analysis of the case study. This process sheds light on the decision-making of farmer/land-managers, supporting literatures recognising the importance of lived experience, strong situated scientific and environmental knowledges [4, 5].

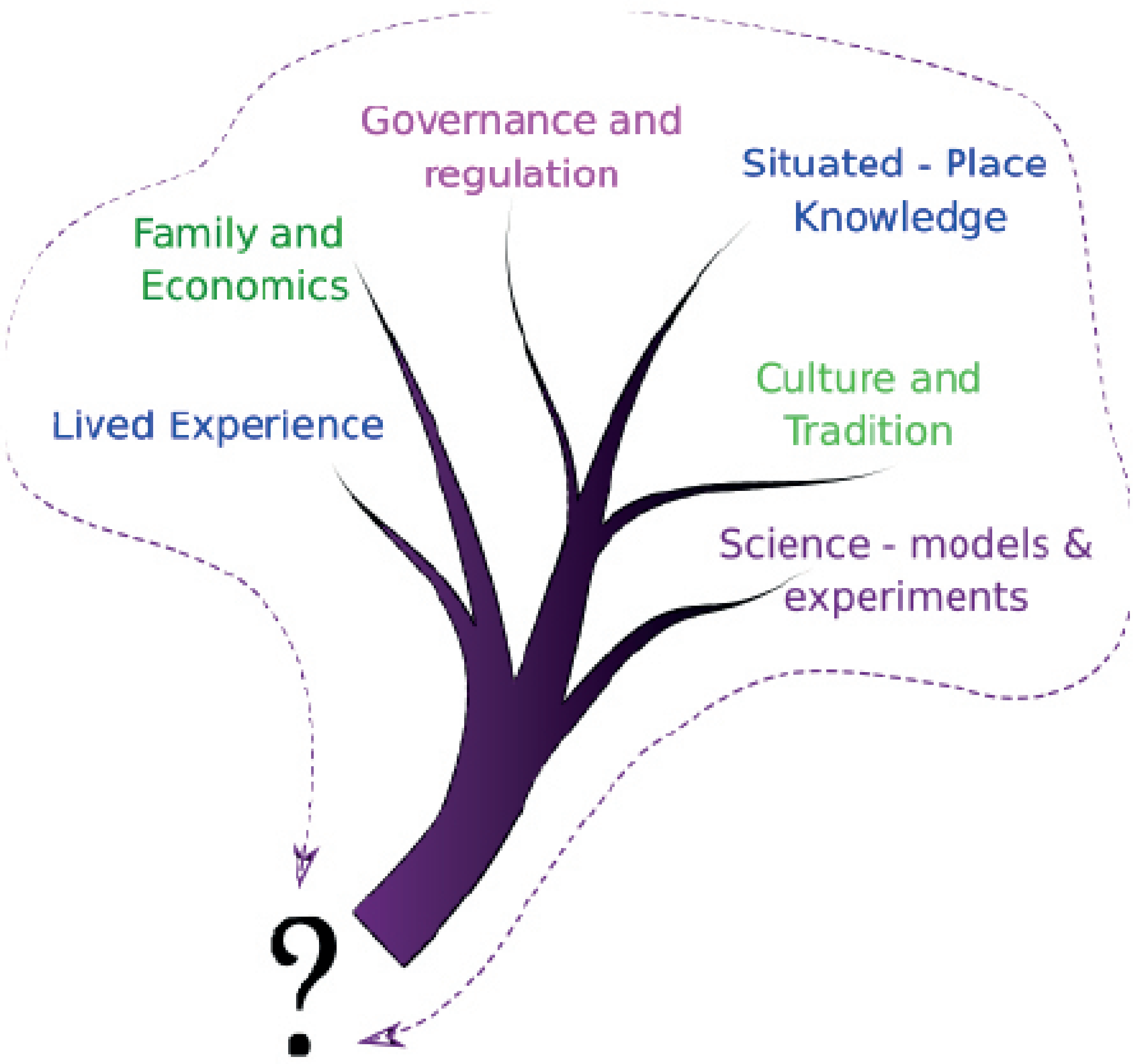
1 Lane, S.N. (2017), Natural flood management. WIREs Water, 4:1211. https://doi.org/10.1002/wat2.1211

2 Krieger, K. (2013), Institutions and risk-based governance. Regulation & Governance, 7: 236–257. https://doi.org/10.1111/rego.12009

3 https://research.ncl.ac.uk/shetran/ accessed 23rd July 2021

4 Emery, S.B. and Carrithers, M.B. (2016) From lived experience to political representation: Rhetoric and landscape in the North York Moors. Ethnography, 17(3): 388–410. doi:10.1177/1466138115609380.

5 Wynne, B. (1996) May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide. Wynne, B. (ed.)


Governance and regulation
Situated - Place Knowledge
Family and Economics
Culture and Tradition
Lived Experience
Science - models & experiments
?

Developing a shared vision for sustainable regional land use in the Southern Ayrshire and Galloway Biosphere in Scotland.

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Climate change and evolving societal demands emphasise the need to manage our landscapes to be more resilient and adaptable, and the importance of restoring and improving our ecosystems. However, getting agreement on which elements of the landscapes should or shouldn't change can be difficult as conflicting views and tensions may arise if people feel that their voices have not been heard. We tested a visioning approach in the Galloway and Southern Ayrshire Biosphere. Located in in South West Scotland, the Biosphere aims to promote a more sustainable, balanced and sustainable use of the natural, cultural and social assets of the region. The Biosphere comprises of a mix of landscapes highly valued for their cultural and ecological importance, alongside large areas of productive conifer plantations and intensive dairy farming. Through a collaborative process with a diverse group of stakeholders we identified a shared vision that combined social, economic and environmental aspirations. The future vision is for a varied, mixed and integrated living and working landscape that provides an excellent place to live and work with a strong identity and a respected and celebrated natural and cultural heritage. The vision narrative was used to develop spatial criteria to identify where changes in land use of land management could potentially take place, e.g., improving habitat quality by planting trees alongside riparian areas and close to communities or restoring peatlands. Maps identifying the areas of potential land use change were shared and discussed with stakeholders at the Biosphere and landscape scale to support discussions on how and where land use and land management should change in the Biosphere to achieve the vision. Despite challenges due to COVID-19, the approach worked well and could be replicated to develop regional land use visions elsewhere to support land use planning and reconcile tentions over competing land use.

Vision for land use and land management in the Galloway and Southern Ayrshire Biosphere in 2050

The Biosphere is a diverse, mixed and integrated living and working landscape. It supports a wide range of innovative low carbon and biodiversity friendly land-based activities including farming, forestry, tourism, and nature conservation. The Biosphere is recognised internationally as a region that demonstrates how sustainable development is good for people, the environment and the local economy.

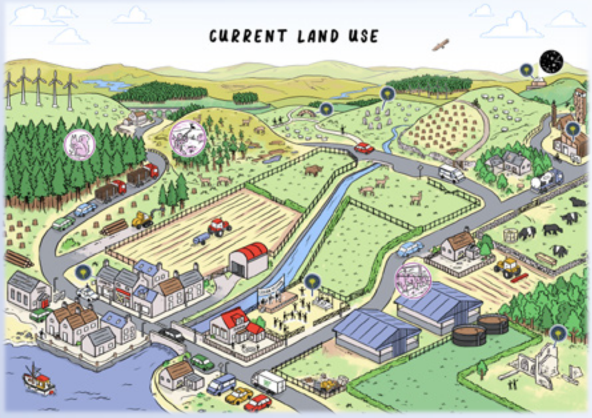
The Biosphere is an excellent place to live and work. Better digital and physical infrastructure, public transport and affordable low-carbon timber housing will support the local economy, making the Biosphere an attractive and pleasant home for all age groups. Employment opportunities and accessibility retain those who have grown up locally and stimulate inward migration from folk who left the region and outsiders charmed by the Biosphere's reputation as an attractive and innovative rural community.

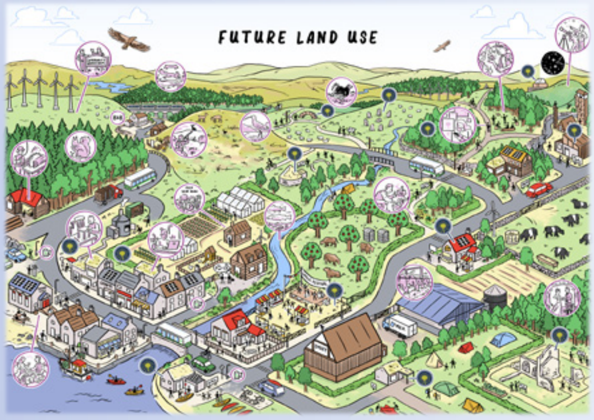
The Biosphere has a strong identity. Natural and cultural heritage sites and local traditions and culture are respected and celebrated, strengthening sense of place and inspiring local arts and culture. Pride and knowledge of natural and cultural heritage drives the Biosphere's reputation for nature-based tourism, traditional crafts and local art, and regional food which provide an important contribution to the Biosphere's economy.

Land uses are integrated to provide multiple benefits and support biodiversity and carbon storage. Environmental protection upheld and conservation targets are achieved. Degraded peatland is restored, and existing forest plantations restructured to increase biodiversity and amenity value. Any additional woodland is carefully considered to maximise benefits (climate mitigation, biodiversity, jobs, timber, and recreation opportunities) and avoid negative impacts on the open landscape character and local infrastructure.

Local food, timber and energy provides many local needs. Less imported food and timber reduces carbon emissions from transport and support local employment. A local circular economy maximises value and environmental standards and minimises waste. Energy needs are met with local community and household renewable energy generation. Mixed 'productive' woodlands provide quality timber, including native hard woods that support local industries.

Cooperation, collaboration and consensus help achieve integrated land use. Regional partnerships identify priorities and help translate national priorities into what is needed and suitable for the Biosphere. Where there are competing land use demands, changes are properly guided, scrutinised, assessed and justified to ensure that the future outcome is greater than before. Regulations, incentives and support are aligned to favour mixed and integrated land use that provides multiple social, environmental and economic benefits.





Illustrations by

This vision was developed in a participatory process of two workshops and a web-based survey with a diverse group of stakeholders in the Biosphere as part of the EIT Climate KIC funded FORLAND R project.. For further information contact marc.metzger@ed.ac.uk

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Tues 7 Sept — **Restoring, planting and connecting**

It is now a decade since the publication of the Lawton review put the landscape ecology principles of 'bigger, better, and more joined up' into the limelight. This symposium presents exemplary initiatives putting these principles in practice, along with new research that can support restoring, planting and connecting forests, woodlands and trees.

Decision support tools for woodland creation on UK farmland.

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Current polices supporting the planting of new woodlands on farmland aim to increase carbon capture and reduce biodiversity loss in agricultural systems, as well as supporting other ecosystem services [1]. However, creating farm woodland typically removes land from agricultural production, presenting a major perceptual and economic barrier [2]. Woodland planting also needs to be targeted so as not to exclude alternative beneficial environmental management actions that may be better suited to a given location. Farmers thus need access to reliable information on where best to create farm woodland, giving, in effect, the environmental equivalent of the high-resolution precision agricultural data which now support many agronomic decisions.

We created decision support tools to help farmers balance agricultural production, environmental considerations and aesthetics when planning farm environmental management, including woodland creation. E-Planner is a free, web-based, tool which presents high-resolution (5 m) maps indicating the suitability of land for different environmental management opportunities (Table 1). The maps are based on high resolution spatial data on factors known to affect the relative likelihood of environmental management actions delivering their goals (e.g. topography, soil properties, habitats, landscape features) and validated against expert assessment. E-Planner allows selection of an area of interest from anywhere in GB, then loads the suitability maps, allowing easy exploration of the relative suitability of different options for a given area or different areas for a particular option (Figure 1). The maps are visualised in a similar, easy-to-interpret way to that used by existing software platforms for agronomic data, and we are currently trialling integration of the E-Planner maps into such platforms to facilitate balancing agricultural production with environmental delivery.

Novel tools to facilitate communication and knowledge exchange between agricultural stakeholders are also important in the successful planning of land management such as woodland creation [3]. Our E-Viewer tool uses the Unity gaming engine to create realistic, immersive visualisations of potential landscapes as influenced by recommendations from E-Planner, allowing farmers and other stakeholders to explore how adding new habitats, might change the look and feel of familiar landscapes (Figure 2). Together, these tools provide users with the data to support, communicate and refine their environmental management decisions.

1 www.gov.uk/guidance/england-woodland-creation-offer, accessed 9 July 2021

2 Howley P. et al., 2015. Explaining the economic 'irrationality'of farmers' land use behaviour: the role of productivist attitudes and non-pecuniary benefits. Ecological Economics 109: 186–193

3 Lawrence, A. & Dandy, N. (2014). Private landowners' approaches to planting and managing forests in the UK: What's the evidence? Land use policy 36: 351–360

Table 1 Summary of the environmental management opportunities for which suitability is mapped in E-Planner, along with the biophysical variables contributing to each opportunity and examples of possible implementation actions for each opportunity.

Environmental opportunity	Variables affecting suitability	Example management actions
Woodland creation 	Enhances connectivity of existing woodland Moderate slopes Highly erodible soils Forms riparian corridors	Planting of native trees on-farm Protection of existing trees
Wet grassland restoration 	High risk of flooding High topographic wetness Well connected to existing habitat Suitable soil hydrology	Establishing cutting and grazing regimes Managing drainage Reseeding of suitable wildflowers
Water resource protection 	Close to watercourses Steep slopes Highly erodible soils	Grass buffer strips Cover crops Water storage features
Sown winter bird food 	South-facing aspect Out of shade Low topographic wetness Far from watercourses Close to woodland	Sow seed-bearing plants Supplementary feeding
Flower-rich pollinator habitat 	South-facing aspect Light soil Out of shade Low topographic wetness Well connected to existing habitat	Sowing annual pollen/nectar plants Establishing perennial wildflower areas Restoration of species-rich grassland

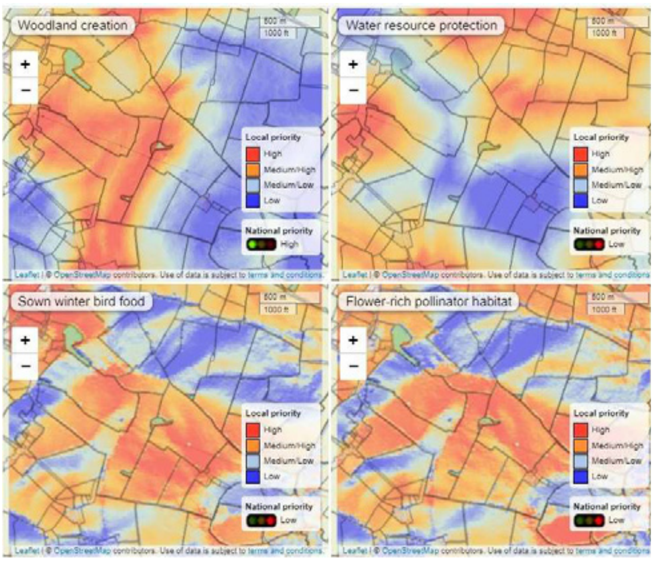

Figure 1 Example E-Planner opportunity maps for a single farm. Up to four maps can be shown at once, as chosen by the user. E-Planner allows panning and zooming of any map, with all other maps tracking to the same extent for ease of comparison.

Figure 2 Example E-Viewer landscape screen capture, contrasting a monoculture of wheat (left hand side) with the same landscape enhanced with field margins providing flower-rich pollinator habitat (right hand side).

Encouraging management diversity to restore diverse forest habitats in production forest landscapes.

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Context. Forest biodiversity is closely linked to habitats heterogeneity, while business-as-usual forest management causes habitat homogenization. Stand-level forest management approaches have been developed to restore within-stand habitat heterogeneity, but we do not know how their application at the landscape scale would promote biodiversity.

Objective. We introduce the concept of management diversity and investigate the potential benefit of diversifying management regimes to increase landscape-level heterogeneity (between-stand), including its temporal dimension.

Methods. We tested if management diversity can benefit biodiversity in a representative forest landscape of central Finland. Forest stands were simulated 100 years into the future (over 20 time-periods) under business-as-usual management (BAU), set-aside (no management) and 12 alternative management regimes. We created virtual landscapes to (i) compare the individual performance of management regimes, and (ii) test for the effect of management diversification. For each virtual landscape, we evaluated habitat availability of six biodiversity indicator species, multispecies habitat availability (average), and their temporal variability.

Results. Each indicator species responded differently to management regimes, with no single regime being optimal for all species at the same time (Fig. 1). On average across time-periods, management diversification led to a 30% gain in multispecies habitat availability, relative to BAU (Fig. 2a). By selecting a subset of five alternative management regimes with high potential for biodiversity, gains can reach 50% (Fig. 2b). Increased management diversity also reduced the variation of multispecies habitat availability over time, but could not prevent long-term decline due to rotation cycle (Fig. 3).

Conclusions. Management diversification can yield large gains in multispecies habitat availability with no or low economic cost, and thus can be considered a cost-effective biodiversity tool to restore diverse forest habitats. Management planning also need to account for temporal variability to avoid bottlenecks.

Encouraging management diversity to restore diverse forest habitats in production forest landscapes

Rémi Duflot, Kyle Eyvindson, Lenore Fahrig, Mikko Mönkkönen

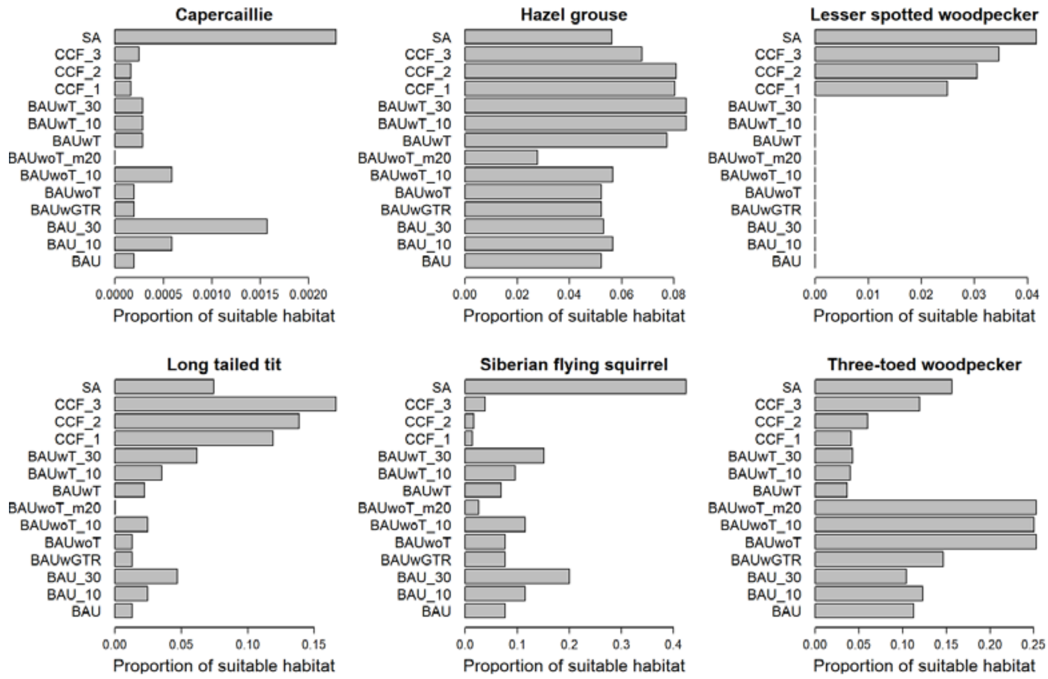

Figure 1. Habitat availability of the six biodiversity indicator species in landscape entirely (i.e. all stands) managed using a single management regime.

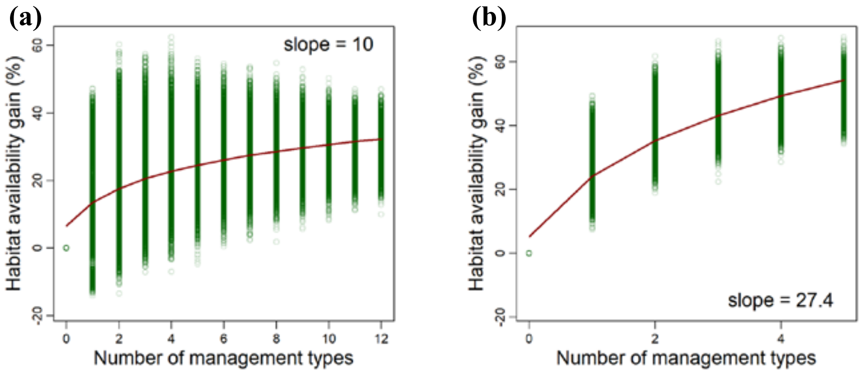

Figure 2. Multispecies habitat availability gain (%) as a function of the number of management regimes included. The 12 alternative management regimes (a) or the five alternative management regimes with high potential for biodiversity (b), are included in addition to BAU (Business As Usual). The reference scenario (n = 0) is entirely manage with BAU. The proportion of set aside is 0%.

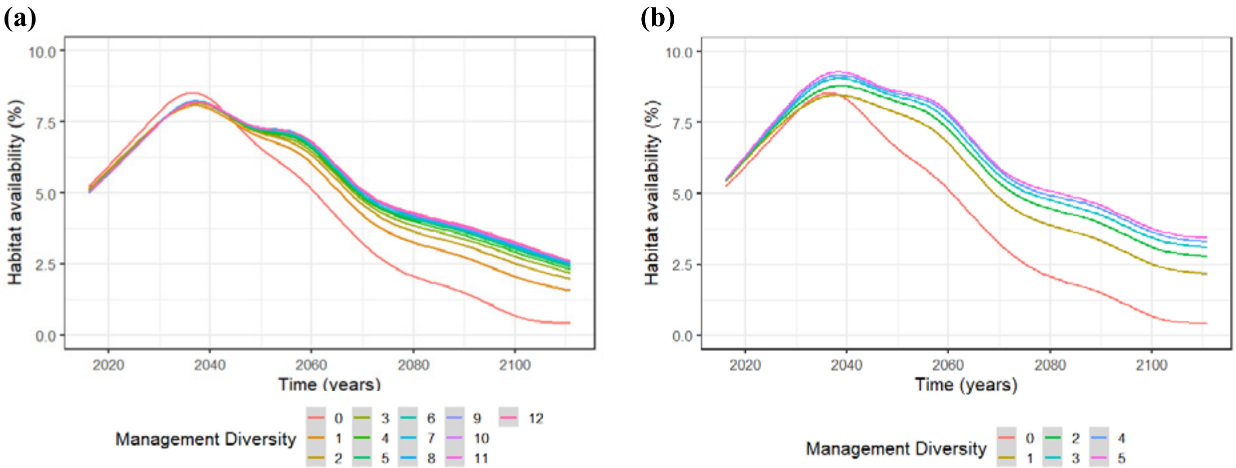

Figure 3. Multispecies habitat availability (proportion of forests area) across the 20 time-periods. The 12 alternative management regimes (a) or the five alternative management regimes with high potential for biodiversity (b), are included in addition to BAU (Business As Usual). The reference scenario (n = 0) is entirely manage with BAU. The proportion of set aside is 0%.

Opportunity mapping for landscape-scale restoration in the National Forest.

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The National Forest was established nearly 30 years ago with the aim of creating the first new forest in England in over 1000 years. The selected area covered around 200 square miles of the Midlands, much of which had been heavily scarred by extractive use. Through engaging local communities and landowners, the National Forest Company (NFC) has increased the overall forest cover (including woodlands, wood pastures and other priority habitats) from around 6% in 1991 to over 21% in 2020 [1].

Over recent years growing emphasis has been placed on the concept of the 'the right tree in the right place' for habitat restoration projects [2]. While an important concept, this idea requires extensive local knowledge and so can present a challenge when planning restoration on a landscape scale. Our aim was to create a model that could highlight opportunities for restoration that offer the most significant benefits across a range of environmental and societal factors. Our three main questions were (a) where can we plant? (b) where should we plant? (c) what public benefits can these sites provide?

We first removed developed land from within the Forest bounds or land that was part of transport infrastructure. Areas of high-grade agricultural land or those with existing priority habitats (including local and natural ecological designations) were also discounted as potential restoration sites. The remaining land was then assessed against potential areas of public benefit: accessibility for local communities, deprivation levels of those communities, potential to increase habitat connectivity, and potential benefits to water quality, flood risk and air quality.

The scores from these assessments can be combined to give an overall public benefit index for each site (Figure 1) but the real value from this model comes from being able to assess the sites based on individual factors. For instance, a land parcel close to an urban area but surrounded by agricultural land might score highly for public access benefit but lower for biodiversity benefits. Its suitability for restoration would therefore depend on the overall aim of the program, and planting regimes can be adjusted accordingly.

This opportunity mapping has already allowed the NFC to adopt a more critical approach to its restoration, opening up important discussions on planting priorities as we develop our new 25-year vision. However, further model development is needed to include additional relevant factors and only by following this assessment by gaining site specific knowledge can decision makers have the best opportunity possible to maximise the impact of their work.

1 National Forest Company, 2020. NFC Annual Report and Accounts 2019–20. Available from www.gov.uk/official-documents, accessed 29 July 2021

2 Di Sacco et al, 2021. Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. Global Change Biology 21 – 00:1

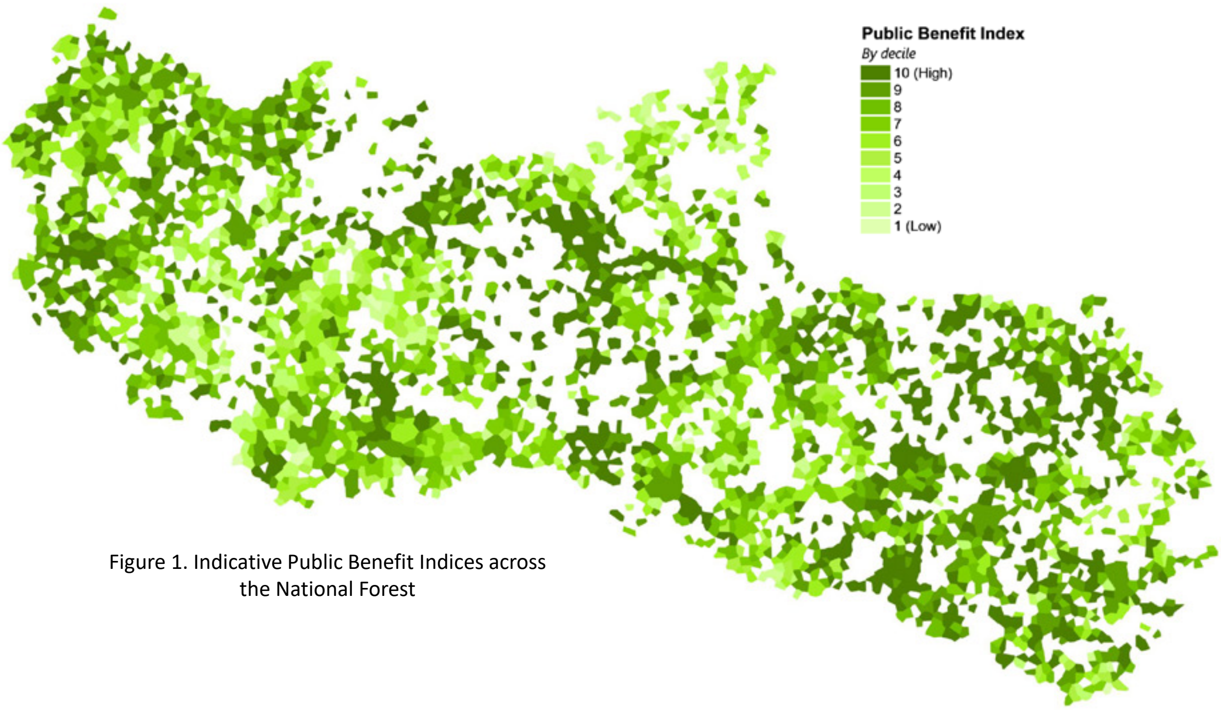

Figure 1. Indicative Public Benefit Indices across the National Forest

Cairngorms Connect – the UK's biggest habitat restoration project.

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Cairngorms Connect (CC) is the UK's biggest habitat restoration partnership, covering 600sqkm of contiguous land within the Cairngorms National Park. The area is managed by four partners: Wildland Limited, NatureScot, RSPB Scotland and Forestry & Land Scotland — collaboration between a private landowner, government agencies and a conservation NGO. Together they share a 200-year vision to restore and expand woodlands, peatlands and floodplains, at a vast scale.

This spectacular landscape ranges from 200m asl to 1309m asl — the second-highest summit in Britain. It includes the biggest remnants of Ancient Caledonian pinewoods, dynamic highland rivers, tranquil lochs, and high mountain plateau. Over 5,000 species have been recorded, and 20% are Nationally Rare or Scarce. In 2021, the CC forests held 55% of Scotland's known lekking male capercaillie. Yet, over centuries, habitats have been substantially modified and fragmented, many species have declined, and the effects of climate change are now taking their toll.

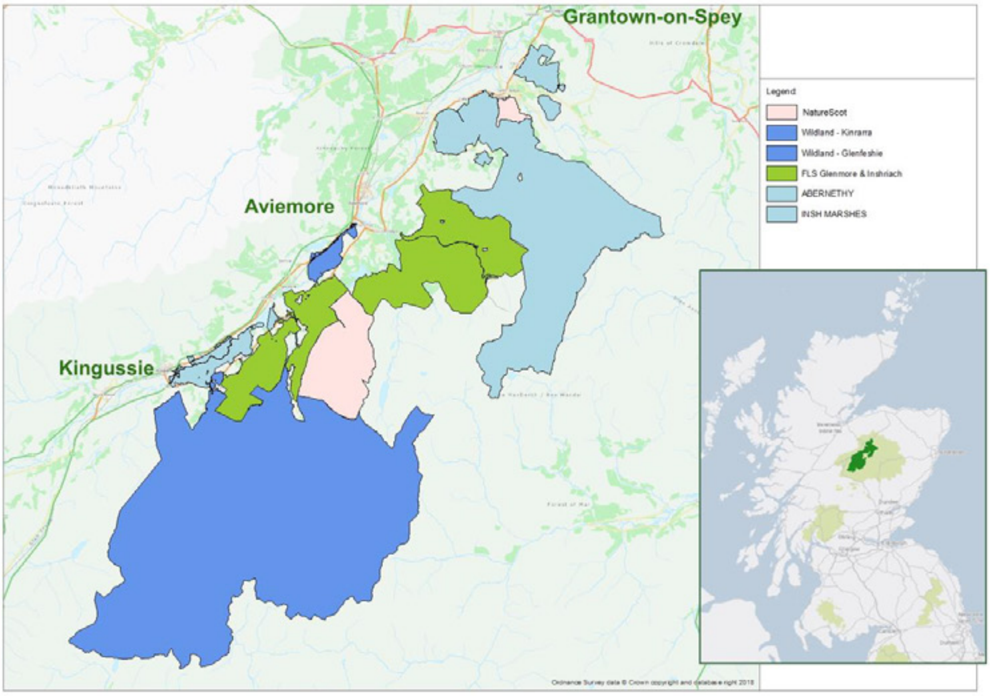
We outline what makes CC a significant restoration project, and the importance of working collaboratively at a landscape-scale. The project's vision is highly ambitious — not least, our forest restoration plans.

The project encompasses 130sqkm of near-contiguous forest, much of it designated SAC/SPA. It is an intimate mix of Caledonian pinewood remnants, plantations of Scots pine and non-native conifers, all regenerating prolifically. Remnant forest bogs pepper the forest — some are intact, whilst others have been drained and planted. We describe our work to reverse damage: removal of non-native invasive conifers, Scots pine plantation restructuring, field layer management and restoring forest bogs.

Most ambitious, is our vision to expand the forest to its natural altitudinal limit, doubling the forest area to 260 sqkm, plus 50sqkm of montane woodland rising to 950m asl. Much has already been achieved, primarily by natural regeneration. Where seed sources are poor or absent, we are planting seed sources, amounting to 1,082 ha in 2019–2021 alone. Forest expansion is achieved by collaborative deer control (i.e. without deer fencing) across 60,000ha – an approach at a scale unparalleled in the UK. In 2018, CC was awarded $5mUSD by the Endangered Landscapes Programme — one of eight such projects across Europe.

Restoration reduces biodiversity loss and contributes to Net Zero carbon targets — increasing sequestration and reducing emissions. It also mitigates for the effects of climate change. Our nine monitoring indicators track outcomes for species, habitats, and people. Alongside restoration, we promote the role of restoration in wellbeing, recreation and the economy for communities of place and interest.

Cairngorms Connect – the UK's biggest habitat restoration project



Cairngorms Connect

Forestry and Land Scotland
Coilltearachd agus Fearann Alba

rspb giving nature a home

NatureScot
Scotland's Nature Agency
Buidheann Nàdair na h-Alba

CAIRNGORMS NATIONAL PARK AUTHORITY
ÙGHDARRAS PÀIRC NÀISEANTA A' MHONAIDH RUAIDH

Modelling the biodiversity consequences of woodland creation to help inform landscape decisions.

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Woodland creation can bring many benefits, such as carbon sequestration, flood alleviation and recreation. However it also has big consequences for biodiversity. While woodland-dependent species may benefit from the increase in habitat and connectivity that tree planting brings, species that rely on open habitats can be negatively affected. Furthermore, many species that make use of woodland also require other habitat resources in close proximity, such that the degree to which they may benefit from woodland creation depends strongly on surrounding landscape context.

Our government has pledged to increase tree planting and there is an urgent need for tools to inform where these trees should be planted. Crucially, such tools must balance the needs of other species alongside human-centric benefits. Existing score-based biodiversity metrics are based on habitat accounting and cannot capture how habitat provision translates into abundance of mobile species whose populations are sensitive to habitat configuration. Doing so requires process-based biodiversity models that realistically represent the way species with multiple habitat requirements move around the landscape.

Our project (https://landscapedecisions.org/how-many-trees-should-we-plant-and-where/) is developing a state-of-the-art biodiversity model, designed to simulate the daily foraging movements and population processes of eight representative species groups of conservation concern (including birds, bats, amphibians, reptiles and bumblebees). Together, these chosen groups span a range of habitat/mobility requirements and responses to woodland creation. Each sub-model has been co-developed alongside NGOs with taxa-specific expertise, in order to ensure that it realistically represents the needs and limitations of the species group, and the aim is to produce a combined model capable of reliably predicting species' population size and distributions for a given input landscape.

We outline the model development process, showing how the core functions have been adapted to simulate species as diverse as bats and lizards. We then present our first results from validating the model outputs against observational datasets and highlight some of the challenges faced when trying to reliably predict landscape use by mobile and not-so-mobile species. These range from uncertainty in movement processes and habitat use, to unrecorded past events causing species absences from otherwise suitable patches and lack of sufficiently detailed habitat mapping.

We conclude by demonstrating how the models might be used to estimate the impact of land-use change on species, specifically the addition of new woodlands to a landscape. We outline how future work with project stakeholders will link this biodiversity model to human benefit models in order to form a combined tool that enables them to evaluate proposed woodland creation scenarios and identify those that best balance benefits, within areas where they are actively working to support woodland creation.

Restoring woodland structure for birds through agri-environment funding.

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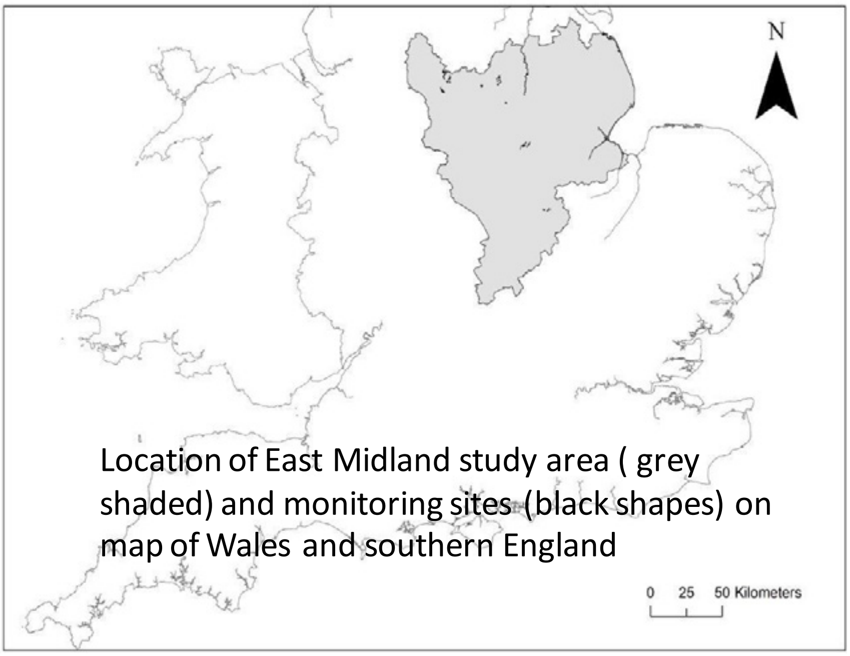
During the twentieth century large scale changes in woodland management practices led to a change in woodland structure with woodland becoming high forest with less structural heterogeneity at both the wood scale and landscape scale. This has been one of the drivers of declines in a number of woodland bird species. Guidance on how to manage woods for birds was developed by RSPB and FC and these principles were incorporated into Woodland Improvement Grants (WIG). A project was initiated in the East Midlands, England during 2009 to promote uptake of these grants and test its effectiveness in improving populations of 13 target bird species.

As landowners signed up to five year WIG contracts sites were selected for monitoring, both sites with management plans and control sites with no planned management. Data on woodland structure and bird populations were collected at the beginning of WIG contracts (2010–12) and again in 2019. The main management options employed were conservation thinning (74% sites), ride widening (46%), ride management (38%), restructure canopy species composition (28%), and dead tree creation (26%). The result is an irregular reduction of closed canopy trees to allow the development of field and shrub layers. The management had a positive effect on the group of target bird species, with abundance of the group as a whole increasing or stable between the two survey periods on the WIG managed sites while decreasing on the control sites. This pattern was similar across individual species although most were too infrequently recorded to individually analyse statistically, and the result was not due to a changes in a single dominant species. From the size of the difference in abundance change between WIG managed sites and control sites it was estimated that 36–50% of the population in a landscape would need to be subject to woodland management similar to that under WIG to halt the decline of these species.

The woodland management options available within the WIG in this project were incorporated into the successor Countryside Stewardship and the new Environmental Land Management Scheme being developed in England. The results of this project show that policy instruments developed to address biodiversity declines in woodland can have a positive effect at the wood scale. However it needs sufficient promotion and funding to get suitable woodland management implemented at a wide enough scale to impact on the trends of national indices of biodiversity health. Woodland management addresses the problem of homogenisation of woodland structure at the wood scale and shows that improving quality of woodland habitats can restore biodiversity. The current policies of increasing woodland cover across the UK could also temporarily address the problem of homogeneity of woodland structure between woods across large scales, producing an increasing area of early succession woodland.



Location of East Midland study area (grey shaded) and monitoring sites (black shapes) on map of Wales and southern England


Restructured stand to reduce dominance of conifers

Conservation thinning

Hidden dangers of converting UK woodlands to native species.

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In response to the timber shortage in the early part of the 20th century, alongside the afforestation of non-forested land, many ancient woodlands were cleared to grow non-native coniferous species. Today, National Forest Inventory data shows there is currently 1,461,000 ha of coniferous forest present in the UK. Whilst providing economic value, coniferous plantations have frequently been associated with negative impacts on surrounding surface water and groundwater quality. This is due to high levels of nitrogen accumulation in their soils resulting from prolonged periods of elevated nitrogen deposition from agricultural, industrial and traffic emissions. Data from the Level II Intensive Forest Monitoring Network has confirmed that reductions in air pollution following the implementation of emission control policies have reduced nitrate leaching in some locations [1], but local sources of emissions continue to drive elevated levels of nitrate leaching in others [2].

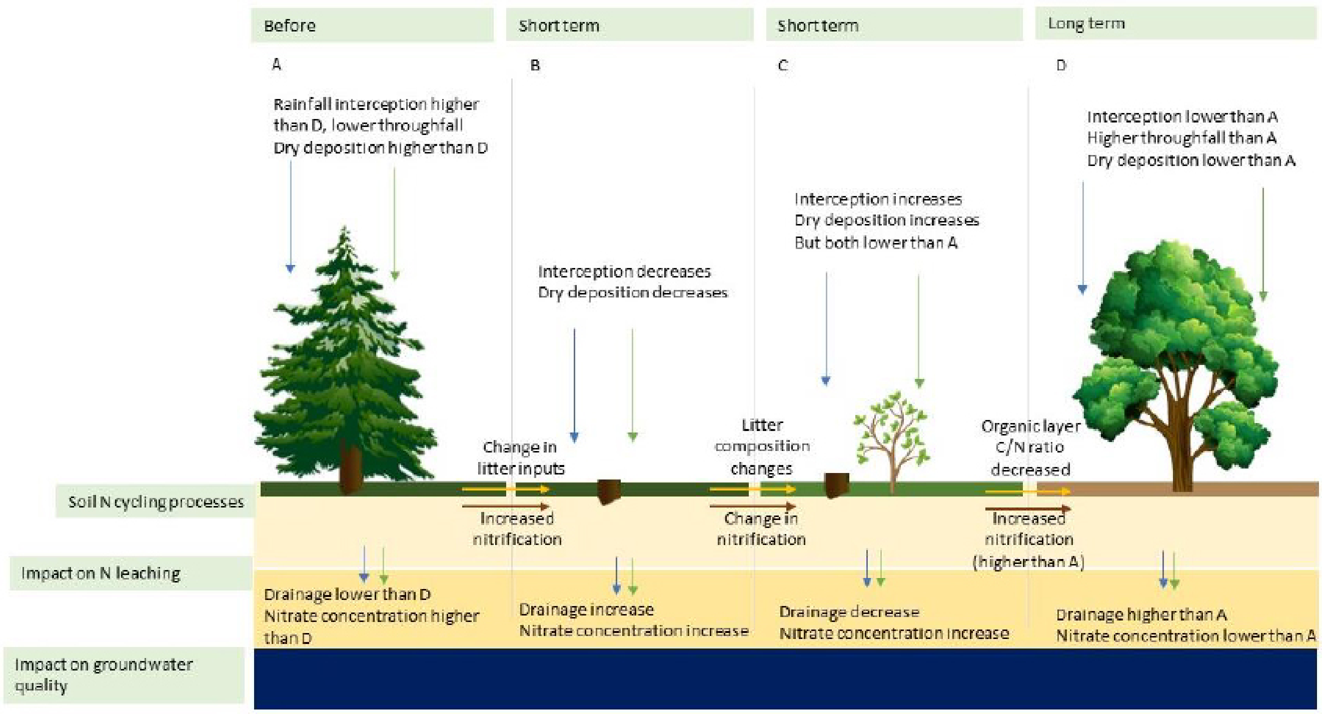
The conversion of coniferous plantations to broadleaved woodland enhances landscape quality. The restoration of native woodland to enhance biodiversity has been supported through biodiversity strategies (e.g. Biodiversity 2020), government policy (e.g. The Keepers of Time Statement), and local policies. Mature broadleaf woodland protects water quality and can mitigate pollution from agricultural land [3]. However, the conversion of a coniferous plantation typically stimulates the breakdown of organic matter, which may initially dramatically increase nitrate leaching from the soil zone, the impacts of which may not be reflected in groundwater quality for decades.

The objective of our work is to investigate changes in nitrate leaching in a chronosequence of the conversion process at Thetford forest. Here we present the initial findings from summer 2021, with a focus on the changes in soil C:N ratios which act as indicators of nitrate leaching. We discuss how we will use these results to compare the significance of leaching outputs from forested land to those from agricultural land. We conclude that there is a need to consider the hidden dangers of converting forests and the significance of these impacts compared to other sources of nitrate pollution in the landscape when seeking solutions to enhance water quality. This improved understanding of changes in forest management on water quality will allow the UK to meet commitments set out by Forest Europe.

1 Vanguelova EI et al., 2019. Nutrient and carbon cycling along nitrogen deposition gradients in broadleaf and conifer forest stands in the east of England. Forest Ecology and Management 447: 180–194.

2 Vanguelova EI et al., 2007. Ten years of intensive environmental monitoring in British forests. Information note FCIN088: UK,Forestry commission.

3 Nisbet T. et al., 2011. Woodland for water: woodland measures for meeting water framework directive objectives. Surrey, Forest Research.


Before
Short term
Short term
Long term
A
B
C
D
Rainfall interception higher than D, lower throughfall
Dry deposition higher than D
Interception decreases
Dry deposition decreases
Interception increases
Dry deposition increases
But both lower than A
Interception lower than A
Higher throughfall than A
Dry deposition lower than A
Change in litter inputs
Litter composition changes
Organic layer C/N ratio decreased
Soil N cycling processes
Increased nitrification
Change in nitrification
Increased nitrification (higher than A)
Impact on N leaching
Drainage lower than D
Nitrate concentration higher than D
Drainage increase
Nitrate concentration increase
Drainage decrease
Nitrate concentration increase
Drainage higher than A
Nitrate concentration lower than A
Impact on groundwater quality

Colonisation Patterns of Woodland Ground Flora.

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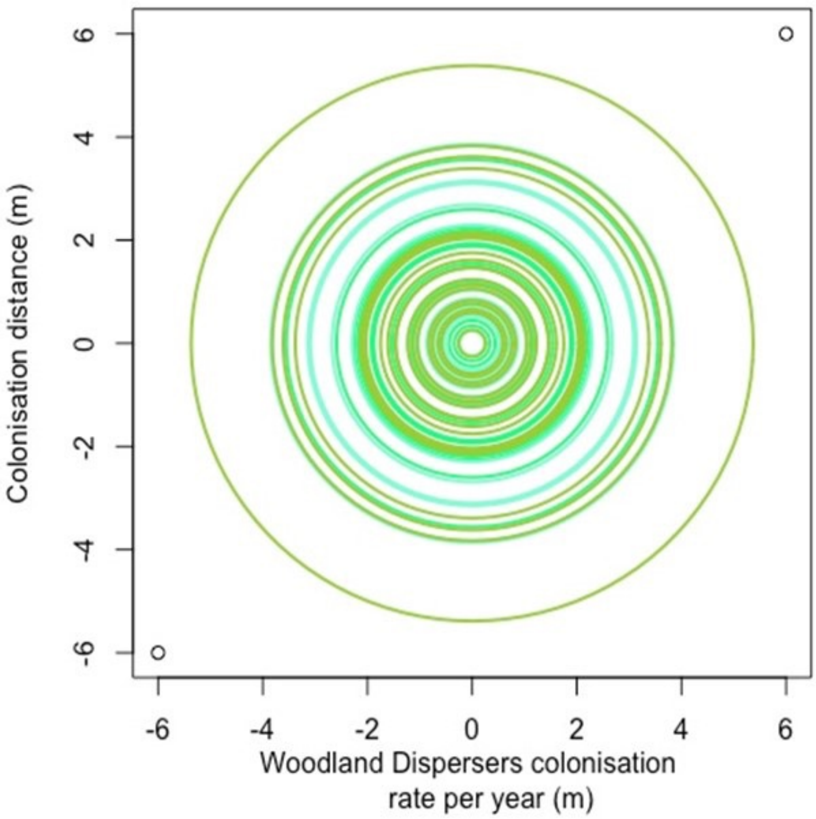
A study was carried out into the colonisation patterns of ground flora in newly planted woodlands. Nine ancient woodland indicator species, four woodland indicator species together with lesser celandine (Ficaria verna) were analysed. The research was carried out over a two-month period within thirty newly planted broadleaved woodlands in Northern Ireland. The distance each species dispersed into the woods was measured and a colonisation rate was calculated per species based upon their distance of dispersal and the age of the wood. Linear regression of the effects of twelve habitat variables on colonisation rates revealed that the greater dispersal distances were associated with the source habitat, in particular the conditions of hedges, existing mature woods, and riparian zones. The dispersal distance was improved if these sources were managed and were connected to the newly planted woodland. Active management can improve connectivity features and allows for the establishment of a richer woodland floral biome. In the study tree species and density of planting did not affect the pattern of dispersal. The colonisation rates were also investigated using hierarchical cluster analysis, and the fourteen species were assigned to four groups that explained their colonisation patterns, the Ancient edge huggers (ransom, wood sorrell, harts tongue fern, dog violet, wood anemone), Expansionists (primrose, greater stitchwort, golden saxifrage, bluebell, enchanters nightshade), Woodland dispersers (jack in the pulpit, male fern, herb bennet), and Exploiters (Lesser celandine). The colonisation patterns are also presented in novel fingerprint graphs. The new descriptors along with the fingerprint analysis provide evidence of how these ground flora colonise new woodlands. In addition, they provide a framework to predict future establishment distributions within newly planted broadleaved woodlands as illustrated in the figure.



Key to species included in study

Weds 8 Sept — **Monitoring forests, woodland and trees**

This short mini-session reports progress to understand and quantify change woodlands and trees and hedgerows.

The 'Bunce' Woodland Survey of Great Britain: latest news from the 2019–2022 re-survey.

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Britain's woods are suffering the impacts of increasing numbers of new pests and diseases, inappropriate levels of grazing and browsing, climate change, nitrogen deposition, and improper use or management. As the natural world faces these growing threats and challenges, the value of long-term datasets to help understand these issues increases rapidly.

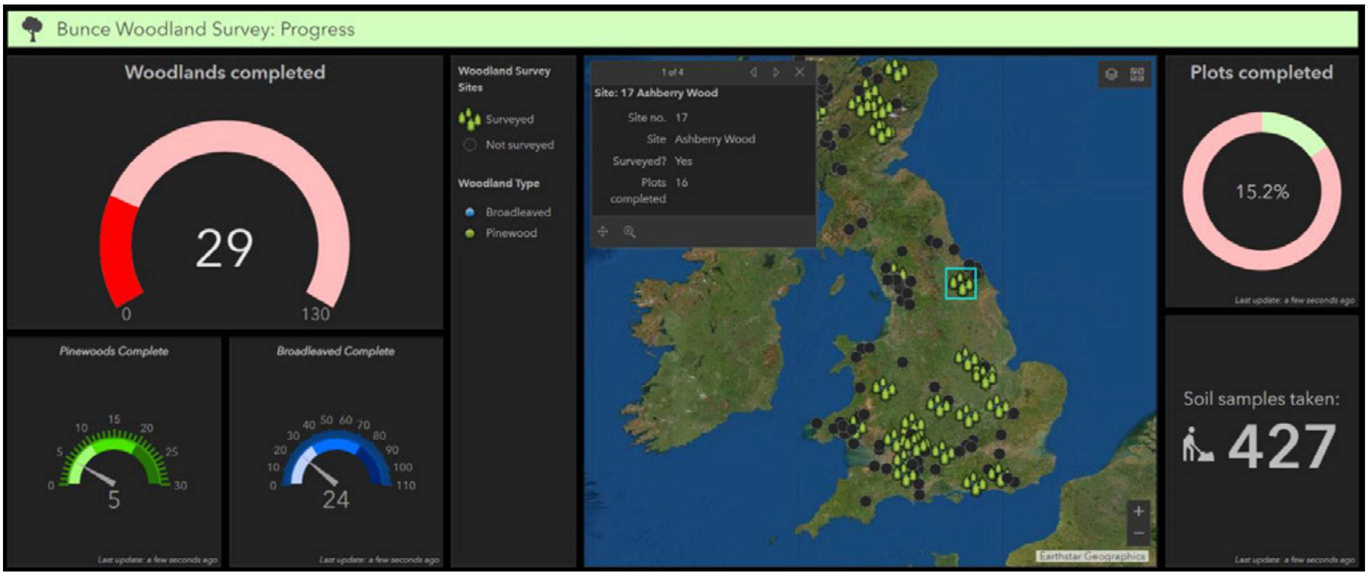
One such long-term survey is the 'Bunce survey' of woodlands, a ground-breaking survey, first undertaken in 1971 by Professor Bunce and colleagues at the former Nature Conservancy, using a robust methodology for surveying soils and vegetation (understorey and canopy). This provided a baseline for tracking change in British woodland, and the methods went on to form the basis of the wider UK Countryside Survey. The original survey focused on 103 broadleaved woods across Britain and 27 native pinewoods in Scotland.

Starting in 2019, the UK Centre for Ecology and Hydrology are managing a repeat of the survey with the support of the Woodland Trust and a number of other organisations. The broadleaved woods have been re-surveyed once before, in 2000–2003, whilst the pinewoods have never been re-surveyed until now. The new data set will give us vital information about changes in light levels, soil pH and the activities of other species, which are in turn affected by wider environmental drivers, both natural and manmade, and by the management regime adopted for the wood itself.

An update regarding the progress of the latest re-survey will be provided, along with information concerning the methodologies and practicalities of undertaking such a survey.

1. Pinewoods, G. Routledge

2. Woodland Surveyors, 1971, UKCEH



3. Survey Progress Dashboard

Ancient Woodland Inventory update – making a new map of ancient woodland.

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The Ancient Woodland Inventory (AWI) identifies woods that share centuries of continuity on relatively undisturbed soils. They cover only 2.6% of England, and make up less than a third of our total woodland resource. As a group, they are our most important woodlands for their rich wildlife and cultural heritage. They create a link with the past: ecological touchstones in a changing landscape. Once lost they cannot be recreated.

Originally produced in the 1980's, without the benefits of computerised mapping techniques, the AWI inevitabley contains many ommissions and inaccuracies, and perhaps more crucially, it does not include any woods smaller than 2 hectares. The Inventory has been revised in South East England and Herefordshire using modern mapping techniques. This partnership project will expand this work across England. Project partners include the Woodland Trust (WT), Natural England (NE), Department for Environment, Food and Rural Affairs (Defra), Forestry Commission (FC), Ministry of Housing Communities and Local Government (MHCLG), and the Association of Local Environmental Record Centres (ALERC).

As well as being an essential tool for planning policy protection, the AWI provides a key evidence base to underpin landscape-scale plans such as Nature Recovery Networks and initiatives such as the Northern Forest. Understanding where our ancient woodland resource is will help us design Nature Recovery Networks where wooded habitats enable the landscape to function ecologically. It is the small, often linear woods, many of which are not on the exisiting AWI, that are key to enabling natural processes to operate at a landscape scale. The AWI can help us to understand where strategic woodland creation could reconnect this landscape, leading to the "better, bigger, more joined up" we are all striving towards. This will also be a crucial evidence base to inform climate change led woodland creation, ensuring we achieve "the right trees in the right place".

Ancient Woodland stores more carbon than any other woodland, as well as being a key biodiversity reservoir within the landscape. Carefully thought out integration of ancient woodland into our landscape-scale plans will help maximise these benefits and the resulting wooded landscapes will in turn improve the ecological functioning of this precious resource. This will enable us to make landscape scale plans that tackle both the biodiversity emergency and the climate change emergency in tandem. This will be crucial if we are to succeed in either!

Monitoring hedges and trees outside of woodlands.

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Hedges and trees outside of woodlands (TOWs) are a hugely important ecological and cultural landscape resource, comprising approximately 20% of all woodland cover, often in the places where structural diversity is most needed, including areas of intensive arable and grassland agriculture.

Recognition of this importance and the potential for these features to be part of the regeneration of trees in our countryside, emphasise the need for monitoring how they are changing over time. In recent decades, from 1984–2007, Countryside Survey (CS) was a key source of data on the extent and composition of hedges and on trees in the rural landscape of Great Britain (Figure 1) revealing significant patterns of change not recorded elsewhere.

This talk will highlight the findings from CS in terms of how hedges differed across GB and how they changed over the period of the survey in both extent and key management criteria (namely height and specific management categories). The context of these changes will be discussed, in particular legislation around hedges and policy support, largely through agri-environment schemes for their management and/or creation. Analysis on hedgerow condition as measured for the first and only time in 2007 will also be presented.

Findings relating to the numbers, types and ages of trees and differences across GB countries will be presented alongside analysis from work carried out jointly with Forest Research to understand issues around tree recruitment focused on hedgerow trees.

The final part of the talk will consider our current state of knowledge on the extents and condition of hedges and trees outside of woodland and consider its importance given current policy drives for increased tree planting and guidance for increased hedge planting for biodiversity. It will highlight work under Welsh monitoring programmes including the Glastir Monitoring and Evaluation Programme 2013–2016 and ERAMMP (currently in train). It will also describe work being carried out using earth observation data such as LIDAR and aerial photography, as well as data being collected by volunteers.

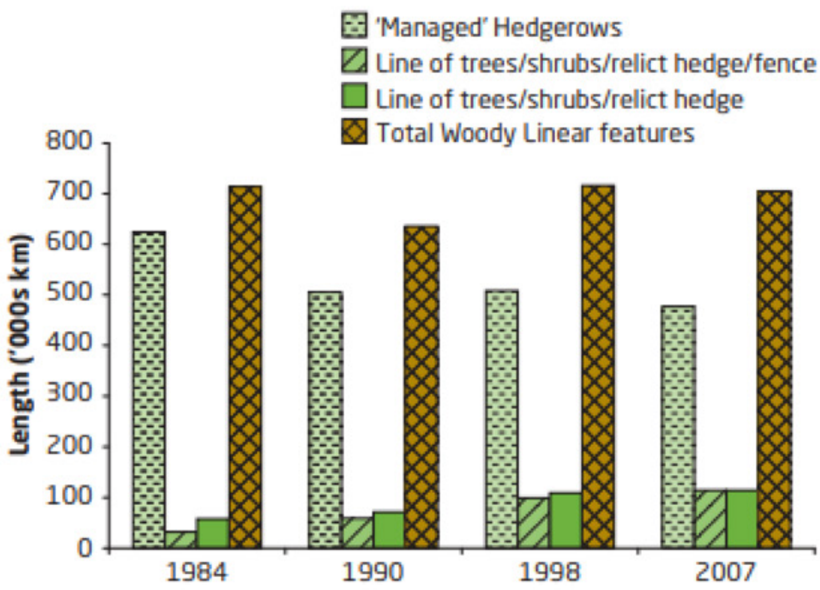

Figure 1. Changes in woody linear feature types across Great Britain ('000s km) 1984-2007

Weds 8 Sept —
Trees and hedgerows

Outside forests and woodlands — in both rural and urban landscapes — trees and hedgerows provide important ecological habitats and play a crucial role within ecological networks. This symposium highlights the ecological and socio-cultural importance of trees and hedgerows, bringing together both urban landscape ecology and the more traditional focus on rural landscapes.

Saproxylic stepping stones – investigating novel methods for protecting dead wood invertebrates.

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Ancient trees are some of the most valuable features for invertebrate diversity in woodlands, supporting thousands of saproxylic species [1]. Unfortunately, due to historical tree felling, ancient trees are a dwindling resource. There is a paucity of trees of lower age categories developing new dead wood habitats to replace those being lost to old age. This is particularly damaging as a large proportion of saproxylic invertebrates in Europe are already thought to be in decline due to loss of ancient woodlands and changing management practices [1].

Pasture woodlands offer optimal conditions for ancient trees, but they suffer from lack of recognition [2]. Being an intermediary habitat between woodland and grassland, they may not receive adequate protections under current habitat-based European schemes [2]. This research aims to identify future pasture woodland management practices to support saproxylic invertebrates through the tree age-gap problem.

A key aim of the research was to investigate population dynamics of saproxylic species in pasture woodlands. A flight interception trapping regime was carried out in UK National Trust landscapes where veteran trees exist in a range of tree density situations (Fig. 1). The differences in saproxylic beetle diversity under varied degrees of habitat isolation were observed to clarify the scales at which creation of new habitat should be prioritised.

Strategic tree planting will be a core approach to creating these new habitat patches; however, there will be long delays before new trees develop saproxylic microhabitats. For this reason, the present study also investigated the potential of temporary, manmade saproxylic habitats to be used in woodlands for mitigation. Structures containing wood mould ('beetle boxes') were designed to mimic basal tree hollows, the habitat of many scarce invertebrate species including the endangered violet click beetle (Limoniscus violaceus) [3]. These beetle boxes were installed in two woodlands and subsequently sampled to evaluate the abundance and diversity of occupying saproxylic beetles (Fig. 2). This work differs from previous beetle box trials which used tree-mounted boxes to replicate aerial hollows[4].

Overall, this research aimed to explore the potential impact of combined strategic tree planting and novel, manmade interventions. It is hoped that the findings will inform the future provision of saproxylic habitat stepping-stones through both spatial and temporal resource gaps.

1 Stokland JN et al., 2012. Biodiversity in dead wood. Cambridge University Press, Cambridge

2 Alexander KNA, 2016. Europe's wood pastures-rich in saproxylics but threatened by ill-conceived EU instruments. Bulletin de la Société belge d'Entomologie 152: 168–173.

3 www.iucnredlist.org/species/157572/5098447, accessed 23 July 2021

4 Carlsson S. et al., 2016. Boxing for biodiversity: evaluation of an artificially created decaying wood habitat. Biodiversity and conservation 25: 393–405.

Figure 1. Flight interception trapping in oak pasture woodlands was carried out to better understand beetle population dynamics in these landscapes.

Figure 2. Initial trials of 'beetle box' artificial basal tree hollow habitats investigated their potential for supporting vulnerable invertebrate species through spatial and temporal resource gaps.

Conserving ecological networks in the context of urban expansion: Siberian flying squirrel in Jyväskylä.

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Increasing urbanization call for the development of new methods for land use management to maintain biodiversity in urban areas [1]. Land use changes caused by urbanization not only decrease the amount and quality of habitats but also decrease habitat connectivity, which is a crucial component for species' long-term persistence [2]. The use of mitigation hierarchy to avoid, reduce and finally offset the negative impacts of development projects is a powerful tool to prevent biodiversity loss. However, the method is typically used on a local scale project-by-project basis, ignoring the cumulated effects of several projects on habitat connectivity. Our aim was to use spatial graphs [3, 4] and scenario analyses [5] to apply a landscape-level perspective to the mitigation hierarchy and to achieve a no net loss of connectivity during urban development. As a case-study we used an endangered species, the Siberian flying squirrel *(Pteromys volans)*, and 10 urban development projects in the city of Jyväskylä, Finland. We assessed the effect of uncertainty related to dispersal distance in each mitigation step. We found a negative impact of urban development on the network connectivity and identified important habitat patches and corridors which should be maintained to avoid and reduce the impacts. The no net loss of connectivity was achieved by offsetting new habitat patches that maximize connectivity. The effect of uncertainty was strong and not linear, indicating a risk of underestimating the impacts if dispersal distance is overestimated, highlighting the importance of accurate measurements. We showed with a real case-study that spatial graph analysis can be used to identify and prioritize the actions needed in the mitigation hierarchy to maintain habitat connectivity in the urban landscape. The results provide important knowledge for conservation and decision-makers, and the method can be applied in any kind of development project.

1 IPBES, 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

2 Hilty J. et al., 2020. Guidelines for conserving connectivity through ecological networks and corridors. IUCN, Gland, Switzerland.

3 Urban D. & Keitt T., 2001. Landscape connectivity: A graph-theoretic perspective. Ecology 82: 1205–1218.

4 Duflot R. et al., 2018. Combining habitat suitability models and spatial graphs for more effective landscape conservation planning: An applied methodological framework and a species case study. Journal for Nature Conservation 46: 38–47.

5 Bergès L. et al., 2020. Environmental mitigation hierarchy and biodiversity offsets revisited through habitat connectivity modelling. Journal of Environmental Management 256: 109950.

Attachment of abstract by M. Kosma & R. Duflot for ialeUK2021 conference

Conserving ecological networks in the context of urban expansion: Siberian flying squirrel in Jyväskylä

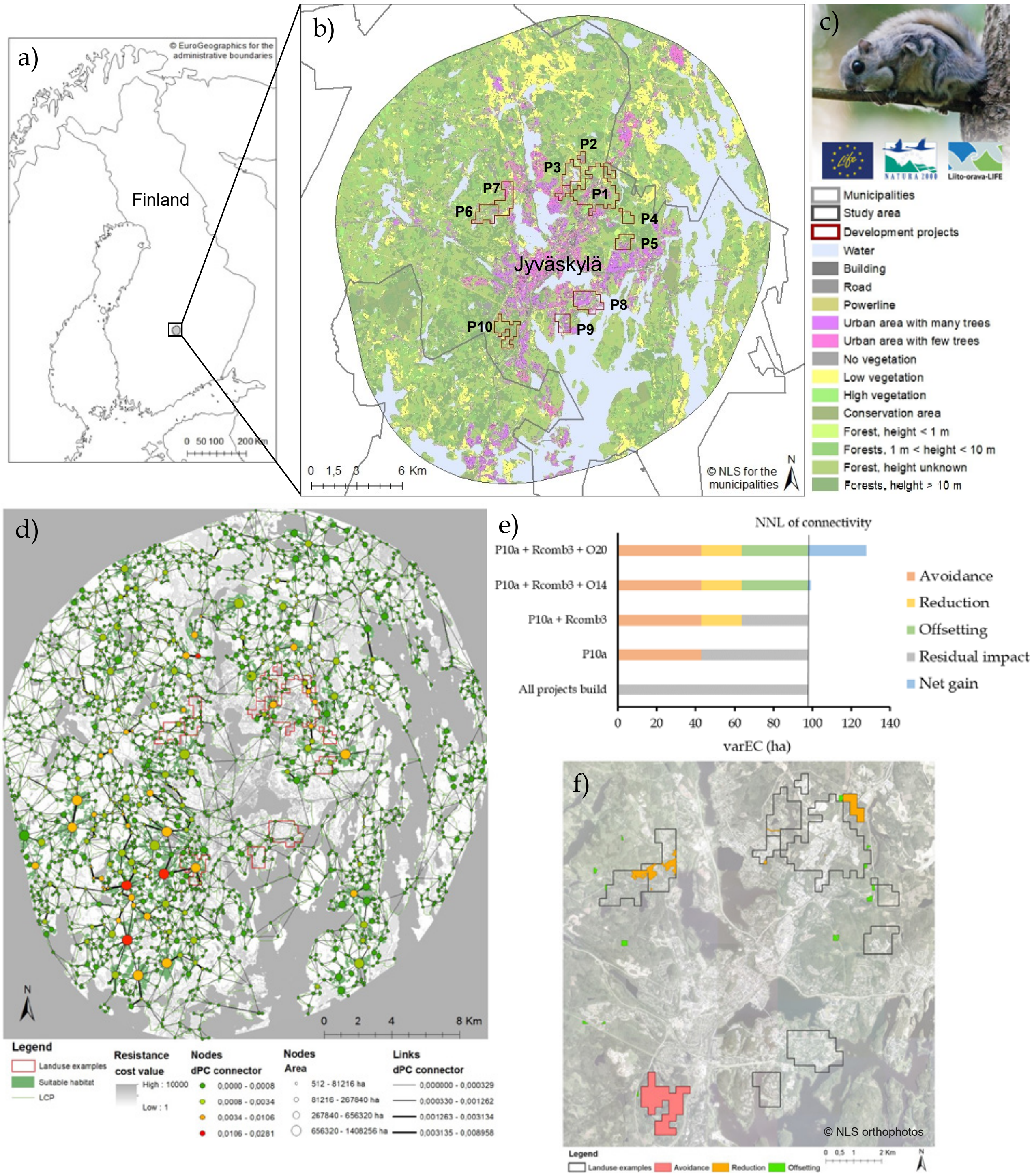

Figure 1. Some of the most important figures of the study. A) the geographical location of the case-study. B) the study area with landcover and urban development projects (P1 – P10). C) the study species, Siberian flying squirrel (*Pteromys volans*). D) the spatial graph representing the intact ecological network of flying squirrel. Habitat patches are presented at light green, and their nodes are classified by colour according to their importance to overall connectivity (*dPC connector*) and by size according to the area of the habitat patch. Least-cost paths (LCP) are represented as true paths (light green) and links (black) which are classified by width according to their importance to connectivity (*dPC connector*). In the background, resistance-to-movement layer is shown, where dark grey indicates high resistance values and white low resistance values for movement. Development project areas are delineated in red. E) summary figure showing the total impact of all development projects on the network connectivity and the effect of best actions in each step of the mitigation hierarchy expressed in the variation in Equivalent Connectivity in hectares (*varEC*) to reach the no net loss (NNL) of connectivity. F) a map showing the best mitigation actions spatially.

Mapping and characterising trees outside woodlands and hedgerows with remote sensing.

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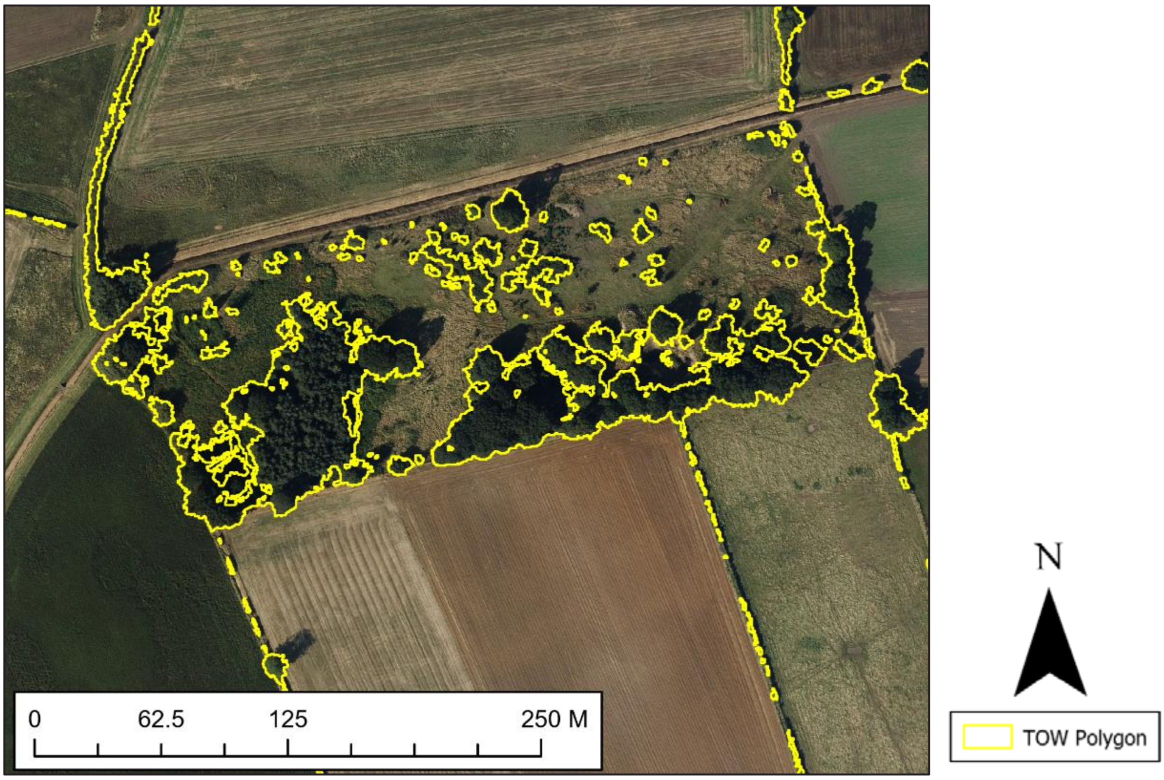
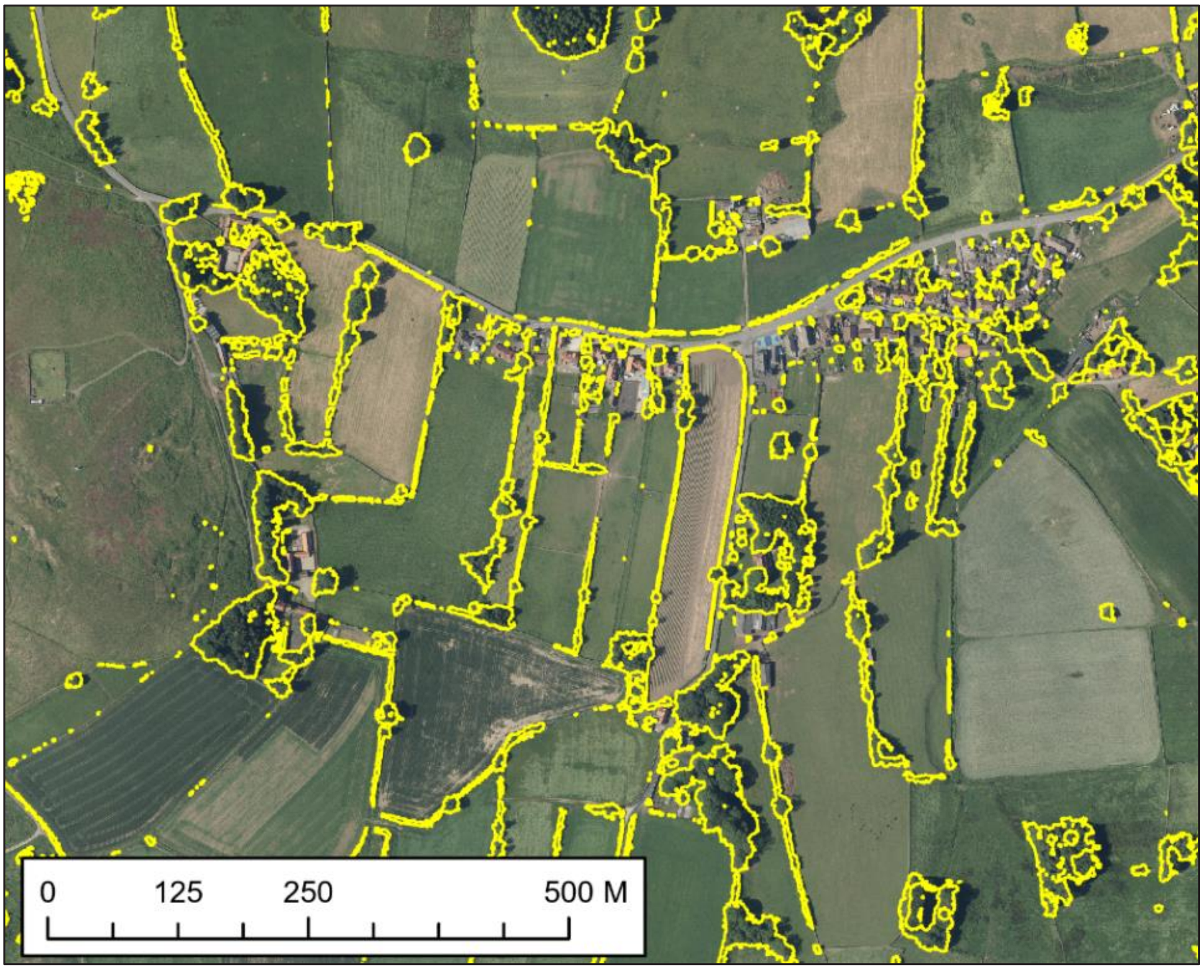
Trees outside woodlands (ToW) and hedgerows are estimated to represent around one fifth of tree cover in the UK. These features: hedgerows, trees in hedgerows, groups of ToW and isolated trees, provide valuable ecosystem services, such as habitat provision, reduction of soil erosion and carbon sequestration and biodiversity conservation. Current forest monitoring practices generally focus on documenting changes in continues wooded areas larger than half hectare. However, it is important to also monitor ToW and hedgerows, to gain a clearer and more detailed picture of the existing trees and hedgerows in the landscape. Thereby informing new tree planting initiatives, natural colonisation policy and various woodland creation drives.

Remote Sensing or Earth Observation data are a powerful tool for generating information at a national or landscape scale. However, mapping small-scale features, like ToW, remains a complex and difficult task. We employed remote sensing and machine learning techniques to develop a ToW and hedgerow mapping approach based on datasets with coverage across all Great Britain. The approach uses high spatial resolution reflectance and height data, combined with a hybrid rule based and machine learning approach to identify features with the characteristics of trees, tall, green, photosynthesising, and circular or long and thin features, in the landscape. Initially developed on rural WrEN sites [1], it has since been tested in variety of upland, lowland, and urban landscapes. Results indicate the overall commission errors of features greater than 10 m^2 is 12% across a variety sites.

The method and mapping work represents a scalable solution for large scale mapping of trees and hedgerows. Scalable meaning without the need for development of site-specific classification rule-bases or manual digitisation of training regions for classifiers. Thereby supporting landscape policy and management by providing much needed spatial and characteristic data on previously unmapped ToW.

1 www.wren-project.com, accessed 30 July 2021


0
62.5
125
250 M
N
TOW Polygon


0
125
250
500 M

Optimal hedgerow management and structure to support biodiversity.

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Hedgerows are a key semi-natural habitat in intensively farmed landscapes, providing food resources, habitat and shelter for wildlife [1], and facilitating ecosystem services such as pest control and pollination [2]. They are designated a priority habitat for conservation in Europe [1] and protected by legislation in several countries.

The support that hedgerows provide to animal and plant communities is strongly linked to their structural condition. The abundance, survival or fecundity of plants, birds, mammals and invertebrates were affected by the height, width, woody biomass, foliar quality and quantity, or gappiness of hedgerows [3]. In 2007, only 48% of managed hedgerows in Great Britain were in good structural condition [4].

Hedgerow condition needs to be substantially improved, and is largely determined by management, which has immediate and long-term effects on wildlife [5]. Management treatments were applied to 11 sites in a large-scale field experiment, and the effects assessed from 2010–2016. Hedgerows cut once every three years or less often (vs. every year), or allowed to retain recent growth at each cut (resulting in taller and wider hedges), were found to: provide more floral and berry resources for pollinating insects and overwintering wildlife respectively (Fig. 1); support more diverse Lepidoptera communities; and have more eggs of the conservation priority Brown Hairstreak butterfly (Fig. 2). Cutting in late winter (vs. autumn) increased resource provision and the abundance and diversity of Lepidoptera. Cutting in late winter resulted in fewer Brown hairstreak eggs, showing the importance of tailoring management to local species, and varying management to create heterogenous structures across a network of hedgerows.

There are current policy drivers to substantially expand the extent of hedgerows in the UK, both to conserve biodiversity and store carbon. Knowledge gaps remain about which landscapes new hedges may best be planted in, how landscape and hedgerow structural condition may interact to affect biodiversity, and how to optimise management across a network of hedgerows.

1 Staley JT et al., 2020. Hedgerow Favourable Conservation Status definition. http://publications.naturalengland.org.uk/publication/5565675205820416 UK Centre for Ecology and Hydrology

2 Morandin LA et al., 2014. Hedgerows enhance beneficial insects on adjacent tomato fields in an intensive agricultural landscape. Agriculture, Ecosystems and Environment 189: 164–70.

3 Graham L et al., 2018. The influence of hedgerow structural condition on wildlife habitat provision in farmed landscapes. Biological Conservation 220: 122–31.

4 Carey PD et al., 2008. Countryside Survey: UK Results from 2007. Lancaster, UK: NERC/Centre for Ecology & Hydrology

5 Staley JT et al., 2013. Changes in hedgerow floral diversity over 70 years in an English rural landscape, and the impacts of management. Biological Conservation 167: 97–105

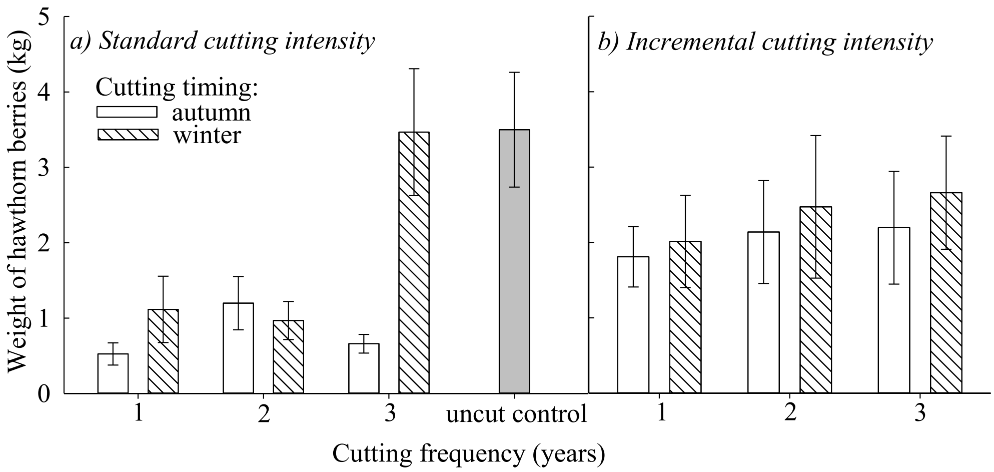

Figure 1. Fresh weight of hawthorn berries (mean ± SE) available over winter along 1m of hedge, under cutting frequency (every 1 vs. 2 vs. 3 years); timing (autumn (unfilled) vs. late winter (striped)); and intensity (standard (a) vs. incremental growth (b)) experimental treatments. Incremental cutting intensity = ~10cm of recent growth left each time the hedge is cut, resulting in a taller and wider hedge. A control treatment was not cut for the duration of the experiment. Cumulative berry weights over seven years (2010 – 2016). Reproduced from Staley et al. (2018a) Effects of hedgerow management and restoration on wildlife. Final report to Defra for project BD2114. NERC Centre for Ecology and Hydrology.

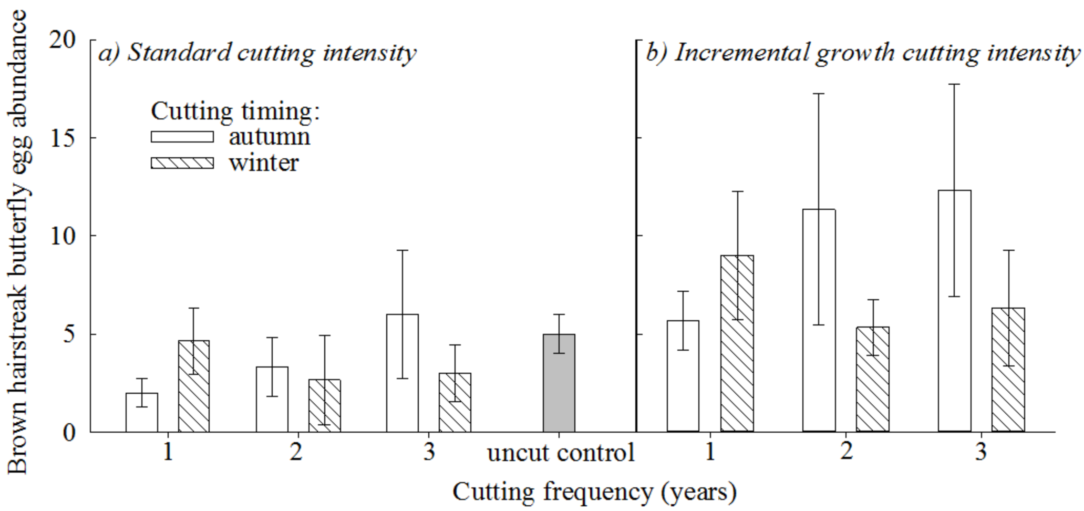

Figure 2. Cumulative abundance (mean ± SE) of Brown hairstreak eggs over four years (2012 – 2015) on blackthorn in 15m long hedgerow plots subject to cutting frequency (every 1 vs. 2 vs. 3 years); timing (autumn (unfilled) vs. late winter (striped)); and intensity (standard (a) vs. incremental growth (b)) experimental treatments since 2010. Incremental growth cutting intensity = ~10cm recent growth left each time the hedge is cut, resulting in a taller and wider hedge. A control treatment was not cut for the duration of the experiment. Reproduced from Staley et al. (2018b). Experimental evidence for optimal hedgerow cutting regimes for Brown hairstreak butterflies. *Insect Conservation & Diversity* 11:213-8, with permission of John Wiley and Sons.

1

Weds 8 Sept — **Ecological resilience**

Forests, woodlands and trees face a diverse and often inter-related set of pressures including climate change, invasive species, herbivore damage, pests and diseases. This symposium presents new understanding of these impacts and strategies to increase resilience in a range of settings, including native and productive forests.

Quantifying the functional connectivity of broadleaf woodland across the Northern Forest.

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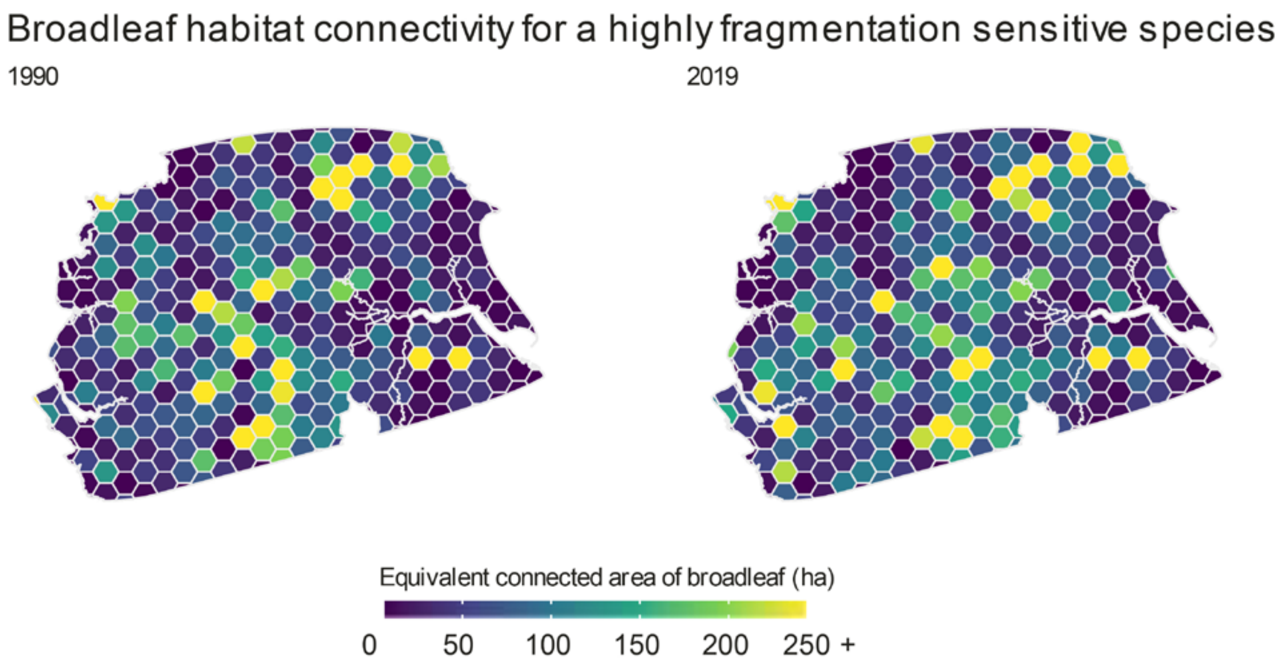
Despite site-based conservation measures and localised habitat creation, the fragmentation of native woodland across landscapes threatens many wildlife species. Historic fragmentation and habitat destruction have decreased the area and quality of habitat in many landscapes and increased the isolation of populations occupying different habitat patches.

The Northern Forest project aims to plant 50 million trees over the next 25 years. To benifit nature recovery most effectively, the new woodland created should be targeted to increase the size, quality, and linkage of existing native woodland. Building on previous work to develop indicators of functional connectivity that bring together information on woodland area and quality, as well as the cost of dispersal between patches, I estimated the functional connectivity of broadleaf woodland habitat across the landscape in 1990 and 2019 at various spatial scales for two generic focal species (moderately and highly susceptible to fragmentation). This work provides a baseline trajectory of recovery by which to assess landscape-scale habitat restoration efforts and inform its spatial targeting.

The index — Equivalent Connected Area (probability of connectivity) — aims to describe the size that ab hypothetical single high-quality habitat patch would need to be, to produce the same functional connectivity as an actual landscape. The contribution of individual patches increases with their area, quality, and linkage to other patches in the landscape. Patch quality was estimated using published, expert-elicited estimates of the negative edge effects of different land use types neighbouring habitat. Linkage between habitat patches was expressed as a negative exponential function of the least-cost distance between them. Least-cost distance estimates used published expert-elicited estimates for the cost of dispersal over different landscape types.

Comparison of functional connectivity across the landscape highlights hotspots of high ecological connectivity and areas where work might be targeted to increase connectivity between them. Comparison across time suggests that functional connectivity in the landscape has increased by 13% since 1990, prior to the Northern Forest project, which poses a useful baseline trajectory to assess the success of the project against.


Broadleaf habitat connectivity for a highly fragmentation sensitive species
1990
2019
Equivalent connected area of broadleaf (ha)
0
50
100
150
200
250 +

The importance of carbon sequestration rate considerations in area targets for afforestation: a strategic analysis of climate mitigation for Scotland.

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Area-based targets for afforestation are a frequent and prominent component of policy discourses on forestry, land use and climate change emissions abatement. Such targets imply an expected contribution of afforestation to the net reduction of greenhouse gas emissions, yet the nature of afforestation undertaken and its geographical distribution means that there is considerable uncertainty over the eventual emission reductions outcomes. This uncertainty is reduced if the net carbon balance is calculated for all potential afforestation sites, considering climate, soil characteristics and the possible types of afforestation (species and management regimes). To quantify the range of possible emissions outcomes for area-based afforestation targets a new spatial analysis method was implemented. This improved the integration of spatial data on antecedent land use with mapped outputs from forest models (ForestYield) defining the suitability and productivity of eleven forestry management alternatives. This above ground carbon data is then integrated with outputs from the ECOSSE (Estimation of Carbon in Organic Soils — Sequestration and Emissions) model which simulates the soil carbon dynamics. The maps and other output visualisations combining above and below ground carbon highlight where net carbon surpluses and deficits are likely to occur, how long they persist after afforestation and their relationships with antecedent land use, soils, weather conditions and afforestation management strategies. Using more productive land classes delivers more net sequestration per hectare and could mean greater carbon storage than anticipated by emissions reduction plans. Extensive establishment of lower yielding trees on low-quality ground, with organo-mineral soils could, though, result in net emissions that persist for decades. From the spatial analysis, the range of possible outcomes for any target area of planting is substantial, meaning that outcomes are highly sensitive to policy and implementation decisions on the mix of forestry systems preferred and to spatial targeting or exclusions (both at regional and local scales). The paper highlights the importance of retaining the existing presumption against planting of deep peat areas, but also that additional incentives or constraints may be needed to achieve the aggregate rates of emission mitigation implied by policy commitments. The findings of the paper are significant since they also suggest a need to reconsider how afforestation and related policies are framed, integrated, monitored and evaluated if afforestation is to deliver its expected contribution to climate change mitigation. Outcomes are represented with respect to climate change policy targets as modelled for Scottish Government, with the TIMES model.

Incorporating biotic risk into national-scale afforestation scenarios for Scotland.

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Photosynthetic carbon capture by trees is likely to be among our most effective strategies to mitigate against climate change. While tree planting has numerous potential benefits beyond carbon sequestration, increasing forest cover and connectivity can facilitate the spread of tree pests and pathogens, invasive species and forest fires. These consequences depend strongly on both how and where trees are planted, therefore it is critical tree-planting programmes consider the wider landscape context, and potential trade-offs with other environmental, social and economic benefits.

In this study, we assess the consequences of large-scale afforestation aimed solely at maximising carbon sequestration for three socially and ecologically important biotic risks to woodlands in Scotland: large-herbivore damage, invasion and disease, which compromise the capacity of forests to support biodiversity and deliver ecosystem services. Specifically, we: i) identify optimal locations for afforestation to maximise carbon sequestration, and ii) predict spatial variation in the effects of tree planting on the likelihood of rhododendron invasion, deer damage and tree health.

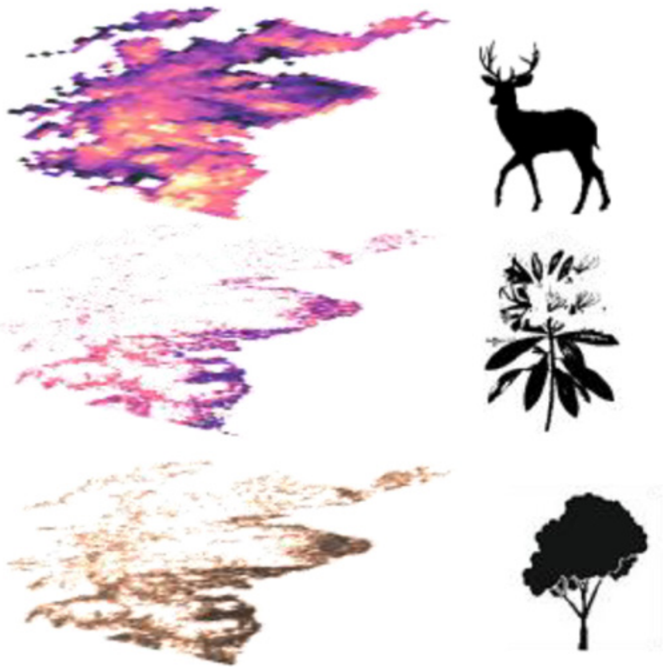
To identify spatially explicit planting programmes aimed at maximising net carbon uptake across Scotland by the year 2050, we use species-specific, site-level estimates of net carbon uptake following afforestation [1]. To estimate the effect of afforestation — and consequent changes in landscape forest cover — on biotic risks to woodland, we modelled site susceptibilities to biotic agents using the first cycle of National Forest Inventory (NFI). This rolling field survey incorporates over 15,000 1-ha forest 'squares' across England, Scotland and Wales (>6,000 in Scotland), from which data describing the site's biophysical attributes and human activities are collected using a standardised protocol [2].

Due to the contingency of the effects of afforestation (increased landscape-level forest cover) on regional environmental gradients, we find strong spatial heterogeneity in the direction and magnitude of the effect of afforestation on the three biotic risks across Scotland. Overlaying these 'effect maps' sensu [3] with the net carbon uptake maps reveals high spatial variation in strength of the trade-off among carbon sequestration and biotic risks. The trade-off maps enable the spatial targeting of management to reduce biotic risks to woodlands following afforestation.

1 Matthews, K.B. et al. (2020) Not seeing the carbon for the trees? Why area-based targets for establishing new woodlands can limit or underplay their climate change mitigation benefits, Land Use Policy, 97, 104690, https://doi.org/10.1016/j.landusepol.2020.104690.

2 Ditchburn, B. et al. (2020). NFI woodland ecological condition in Great Britain: Methodology. Edinburgh, UK: Forestry Commission National Forest Inventory.

3 Spake, R. et al. (2019). An analytical framework for spatially targeted management of natural capital. Nature Sustainability, 2, 90–97. https://doi.org/10.1038/s41893-019-0223-4



Large-scale study of UK woodlands reveals contrasting response of herbaceous plant species richness to mycorrhizal type of dominant tree species.

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Mature temperate woodlands are commonly dominated by ectomycorrhizal (EM) trees, whereas understory herbaceous plants predominantly form arbuscular mycorrhizal (AM) associations. Due to differences in plant-fungal compatibility between canopy and ground layer vegetation, the “mycorrhizal mediation hypothesis” predicts that herbaceous plant establishment may be limited by a lack of suitable mycorrhizal fungal inoculum.

Here we examined plant species data for 103 woodlands across Great Britain to test whether herbaceous plant species richness was related to the proportion of AM woody plants. To assign mycorrhizal type at the species level we carried out an in-depth review of published databases and re-examined original sources.

We found that in plots containing EM trees, the proportion of AM trees was positively related to herbaceous plant species richness. In plots dominated by AM trees, this relationship was negative or absent. The magnitude of the effect on herbaceous plant species richness was greater than that of shading, pH, and soil organic matter.

This work is the first to show that in temperate broadleaved woodlands the mycorrhizal mediation hypothesis is supported when EM type trees dominate and rejected when AM type trees dominate. Our findings suggest an important link between understory plant diversity and woody plant mycorrhizal types, with implications for woodland management.

The roles of Scottish woodlands and policy in the climate and ecological emergencies.

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Climate change and biodiversity loss are some of the greatest challenges facing society today. Yet all too often biodiversity and climate policies and actions are disconnected. Recently, and for the first time, the two international bodies the UN Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) joined forces to outline the interconnections between biodiversity and climate change. The IPCC and IPBES report that restoration offers one of the quickest and cheapest nature based solutions for addressing these challenges [1]. Yet achieving this in policy and practice is not simplistic. This paper provides insight into the balance of existing policies related to forests in Scotland, to address the climate and ecological emergencies via a policy review and key stakeholder interviews [2]. Scotland was one of first nations to declare a climate emergency and committed to becoming net zero by 2045. To achieve carbon neutrality, Scottish Government have recognised the crucial role of trees aiming to increase woodland cover to 21% of the total area of Scotland by 2032. This paper follows on from a review conducted for Scottish parliament (2), identifying some of the opportunities, limitations and uncertainties in existing policy in Scotland for forests to deliver for both climate and biodiversity. The paper outlines the history of UK/Scottish forest policies and the status of biodiversity and climate policy in Scotland in relation to forests. Certain themes become apparent with policies and proposals for woodland creation, such as dealing primarily with per-hectare targets. Area-based targets can lead to assumptions about net carbon reductions and biodiversity benefits [3]. In general, current climate policies that call for woodland expansion do not go far enough to secure benefits for biodiversity, nor mitigate risks to it. In reality, planting for carbon and biodiversity requires a more nuanced approach than is implied in most policies. As governments worldwide seek a 'green recovery' from COVID-19, aiming to cut carbon emissions and boost economies, forests have a crucial role. It is pertinent that to avoid further harm, biodiversity features in recovery measures. To achieve a coordinated approach, for climate and biodiversity, the policy mechanisms need to be there to drive it.

1 Pörtner, H.O. et al. (2021) Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change, http://doi.org/10.5281/zenodo.5101125

2 Yang A.L. (2020) The Multiple Roles of Scottish Woodlands, Scottish Parliament Information Centre, SPICe Research Briefing 20–58

3 Matthews, K.B., et al. (2020) Not seeing the carbon for the trees? Why area-based targets for establishing new woodlands can limit or underplay their climate change mitigation benefits. Land use Policy, 97, p.104690

Image 1. Scottish Native woodlands, Loch Sunart (2020)

State of the UK woods and trees – applying the key findings to landscape scale delivery in the UK.

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This first State of the UK's Woods and Trees report presents important facts and trends focusing predominantly on our native woods and trees. It reports on their extent, condition and wildlife value, the benefits people gain from them, the threats and pressures they face, what is being done to help them and what more we need to do (https://www.woodlandtrust.org.uk/state-of-uk-woods-and-trees). In summary, although woodland cover is gradually increasing, woodland wildlife is decreasing and the existing native woodlands are isolated and in poor ecological condition, and there has been widespread loss of the "trees outside of woods" that are vital components of the UK's landscapes. Not nearly enough is being done to diminish the threats that underly these broad trends, which are considerably reducing the benefits our native woods and trees provide for ecological processes, wildlife and people. There is a critical need to create and sustainably manage high quality and resilient ecological networks that strengthen the role that native woodlands and trees in the UK's landscapes. This presentation will report on how the Woodland Trust along side partners is rising to this landscape scale delivery challenge.