Wood Wise

CREATING TOMORROW'S WOODS

Tree and woodland conservation • Autumn 2021

WOODLAND TRUST

WHERE SHOULD WE ESTABLISH NEW WOODS?

CREATING WOODS FOR WILDLIFE

FACILITATING ESSENTIAL SOIL FUNGI

ENVIRONMENTAL IMPACTS OF TREE SHELTERS

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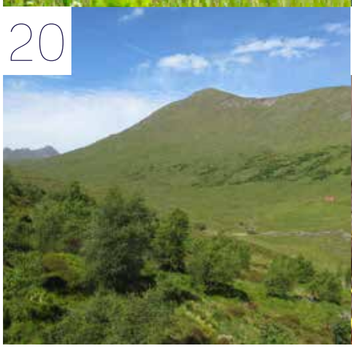
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The complexities and value of woodland creation

Richard Faulks/WTML

Abi Bunker

Creating woodland is a critical component of the response to both the nature and climate emergencies. But where new woods and trees are located in a landscape, and how they are planned, designed and established, will shape their impact and the benefits they deliver for people and wildlife.

Global ambitions for reforestation will be a key issue for the UN Climate Change Conference (COP26) being held in Glasgow this November. In the UK we face the challenge of meeting unprecedented ambitions to increase woodland cover to 17% over the next 30 years. These ambitions must be pursued using the very best evidence and tools, along with an understanding of the value of existing and alternative uses of the land, and the aspirations and motivations of landowners.

As well as driving nature recovery and ecological restoration, new woods and trees can be important for carbon storage, water resource and flood management, the supply of sustainable building material, and providing places for people to connect with nature. While this means they provide a multitude of benefits and opportunities, it can mean that they are complex to create.

There is, however, a wealth of knowledge in the conservation and forestry sectors. Our understanding of the complexities is ever improving so that we can make the best decisions with the best intentions. The Woodland Trust has recently released a guide to our approach to woodland creation, which details the whole process from idea conception to the establishment of well-functioning woody habitats.

This issue of *Wood Wise* begins with interesting insights from Emma Gardner on why we must understand and prioritise the reasons for woodland creation before deciding where best to locate new woods, in combination with an in-depth knowledge of the landscape and the needs of different species. A well-established approach, known as 'integrated design', supports such decision-making; Richard Hellier describes the application of landscape design principles through this integrated approach to deliver quality woodland.

There has been a lot of attention recently on planting trees for carbon capture and storage, but with the catastrophic declines occurring in woodland wildlife, all new woodland needs to contribute to species' recovery. Clare Pinches from Natural England explains why both the location and detail of the design are important if woodland creation is to drive nature recovery. Even young woodlands can support a variety of specialist woodland wildlife species; Emily Warner demonstrates this through her PhD research in the Cairngorms.

An example of how we are constantly acquiring new knowledge comes from Andy Taylor's research on mycorrhizal fungi and tree associations. This new understanding of soil fungi can inform woodland creation design and support successful tree establishment. Another active research area concerns the use of plastic tree shelters. Charnett Chau and colleagues conducted a full life-cycle assessment of currently available tree shelters, and they explain the environmental impact of different scenarios to make optimal choices for tree survival and the environment.

For more information on woodland creation and tree establishment, and help with navigating the complexities, check out our guide to the Woodland Trust's approach to woodland creation, soon to be available at **woodlandtrust.org.uk/woodlandcreation**.

Abi Bunker is director of conservation and external affairs at the Woodland Trust, providing strategic leadership across the Trust's conservation, campaigning and policy-influencing work.

Woodland creation: taking a landscape-level perspective

Emma Gardner

The UK has pledged to increase tree cover on an unprecedented scale, but where should all these trees go? How do we identify the best places for new woods and whose priorities do we use to decide what the 'best' place is? To answer these questions, we need to see woodlands as part of dynamic landscapes. We must widen our perspective to consider not just what they mean to us, but also the many varied roles they play for other species.

Dr Emma Gardner is a quantitative ecologist and research fellow at the UK Centre for Ecology and Hydrology. She works with researchers, NGOs, practitioners and stakeholders to investigate how human and biodiversity benefits can be achieved in tandem through woodland creation.

The presence of a woodland has consequences that extend far beyond the drip line of its trees. Likewise, the functions and community a woodland supports – both inside and outside it – are intrinsically linked to its place in the landscape. Choosing where to create woodlands means thinking about the landscape-level context of woodland creation and considering how this change may affect processes, functions and species both at the site where the woodland is created and in the wider landscape beyond.

Before asking where, we must ask why

If a medieval landholder wanted a woodland to provide fuel for their fire, the answer to where would be fairly simple: have it where it won't shade the vegetables and I don't have to cart the wood too far. If a committee of green woodpeckers were to vote where to put new woodlands, their answer might be next to the meadows where the ant hills are. No one likes a long commute. The answer to the question of where we put new woodlands begins with why we want to create them.

Current enthusiasm for woodland creation is driven by a range of desired benefits: woodlands can draw down and store atmospheric carbon, so helping efforts to reduce global warming; they can intercept and take up water, so reducing the risk of flooding; they can provide a source of renewable low-carbon building materials; and they can offer spaces for people to relax and reconnect with nature. Each of these reasons may suggest a different prime location for the new woodland. An accessible location for the local community might be favoured if the woodland is intended to improve recreational access. Meanwhile an out-of-town upstream location may be favoured if reducing urban flooding is the priority. However, a carbon storage perspective would avoid upstream peatlands, because the drying action of the trees would cause carbon emissions from the ground that outweigh any absorption by the trees themselves.

Usually, the aim is to achieve as many of these benefits as practicable. It is possible to run detailed hydrological simulations of how water flows through catchments and how outflow is altered by land-use change, to calculate the change in carbon storage when land is converted from one type to another, and to map where people do and don't have recreational access to woodland. By overlaying these measurements and predictions, locations can be identified where new woodlands would have the best chance of providing these multiple benefits desired by people.

Another motivation for woodland creation is to promote biodiversity. A biodiverse landscape contains myriad different species with different habitat requirements, life histories and levels of mobility. Determining the potential biodiversity consequences of woodland creation – and identifying locations that would promote this – requires a landscape-level perspective that is sensitive to the way different species use landscapes.

Differing species responses to woodland creation

Woodland is a specific habitat type. Some species, such as the barbastelle bat, are totally reliant on woodland and rarely exist outside it. Others may make use of woodland but require alternative habitats nearby for other purposes – a buzzard may nest in woodland but forage more widely, toads may forage in woodland but require a lake nearby to breed in. For some species, like the lapwing, woodland is totally useless; such species may be unable to survive in the shaded conditions it presents, it may not support their favoured food, or it may harbour their predators. Worse still, these predators may regularly foray out of the wood into neighbouring habitats that they do rely on.

Semi-natural ancient woodland is biodiverse – it supports hundreds of species – but a landscape is at its most biodiverse when it includes a mixture of habitats, in different sized patches. In this way, it can support specialist species that depend on large patches of specific habitats, generalist species, and those that need multiple different habitats in close proximity in order to thrive.

When identifying potential locations for woodland creation, we can mask out known locations of other priority habitats, such as species-rich grasslands or heathlands, where woodland creation might be detrimental to the specialist species that rely on them. Many of these habitats are geologically and/or hydrologically restricted in where they can occur and this is a clue: not only must we ensure that woodlands are not directly planted on these habitats, but we must also ensure tree planting nearby does not indirectly degrade these habitats, for example, by altering the local hydrological conditions. Reduced incidence of flooding downstream may be good for an urban settlement but not for a floodplain ecosystem.

Likewise, care must be taken that woodland creation does not interrupt connectivity between other priority habitats. While increasing tree cover may help woodland-dependent species move through the landscape, aiding dispersal of their young and facilitating gene flow, it should not be forgotten that populations of grassland specialists or heathland specialists require connectivity too.

Emma Gardner

Properties of a woodland such as size, shape and place in the landscape determine the functions and community that the woodland supports.

Woodland is a specific habitat type, good for some species and not good for others. We must take this into account when considering where new woodlands might be best placed to support biodiversity.

Seeing woodlands as part of habitat mosaics

Viewing the landscape in terms of distinct habitat types may begin to help us consider the needs of habitat specialists, but it is not sufficient for the multitude of species who make use of multiple habitats and may use different habitats for different things. For these, the potential benefits of woodland creation may depend sensitively on the size and shape of the new woodland, which other habitats are nearby and the movement range of the species. A common lizard population may benefit from the sunny south side of a new woodland if it were created adjacent to their heath but, were that same woodland created one close-grazed field away, it may be of little use to the lizard population due to the impassability of the intervening field.

To identify the consequences of woodland creation for these species, we must try to see the landscape from the species' point of view and understand how they move around it to access the habitats they need. We must consider both their day-to-day foraging movements (essential for individual survival) and larger-scale movements related to breeding congregations or dispersal of young (essential for population persistence). Doing this for a selection of species with different movement ranges and habitat requirements can give us a window into how a proposed woodland might function within the landscape, what additional resources it might provide within the habitat mosaic, and how well it might fulfil its multiple roles for different species when placed in different locations.

Building computer models capable of this is hard. It relies on years of accumulated species-specific expertise and detailed observational datasets to set parameters and check that the model's processes correctly simulate species' responses to habitat configurations. But the models themselves – virtual species whose behaviours approximately mimic our cumulative understanding of the species' real-life behaviour – can help to give those species a voice in decision-making. Given two alternative maps of a landscape, the model estimates what the proposed change might mean for that species.

Making decisions on the ground

Computer models can help us see the big picture context. They can show us how converting one field to woodland may affect water flow through the river catchment as a whole, or how the foraging distribution of bats roosting in nearby villages might shift to take in this extra resource and how much their numbers might be boosted as a result.

Computer models are not good at capturing place-specific deviations from the norm – those little features and peculiarities too small to be noticed by our broad-brush human-scale mapping that mean this habitat patch is better than that apparently identical patch, or the novel survival solutions that a species may have found in one place that are not recorded anywhere else.

This semi-natural ancient woodland is part of an extremely valuable habitat mosaic that collectively supports a wide range of species.

This knowledge is inaccessible to remote computer simulations based on averages. But it can be acquired through intimate first-hand experience of a place, and fragments of this knowledge are held by all those individuals who interact with and immerse themselves in their landscapes. Incorporating this communal knowledge of local specifics, of how the local community (in its fullest sense) is connected to and uses its landscape, is essential when tailoring decisions within specific landscapes.

With landscape change comes responsibility

No matter what our motivation for woodland creation may be, the fact remains that any change to the landscape will impact all those who use and rely on it – both human and non-human individuals. Many of the changes we have made to landscapes have been made with the aims of a human minority in mind. Woodland creation need not be a selfish act. Human society at large can benefit from woodland creation, many woodland and non-woodland species can benefit, given careful choice of planted tree species, and many more still can benefit where natural regeneration is used, with its valuable and transient successional scrubby stages. It even has the potential to benefit the long-term habitability of our planet.

But exactly who benefits and who loses out – by how much and in what ways – crucially depends on where woodlands are created. We must choose wisely where we encourage woodland creation, considering the needs of woodland-averse species and respecting the importance of other habitats, which may offer more suitable carbon storage or water retention possibilities in many places and are crucial for landscape-level biodiversity. By seeing woodlands in context, we may conclude that the odd scattered tree or an open woodland may be a more sensitive compromise than closed-canopy tree cover in some situations. Above all, we must consider the wider consequences of creating new woodlands from multiple perspectives, taking into account the multiple roles woodlands play as part of dynamic living landscapes.

We must consider the potential consequences of woodland creation from multiple perspectives and take into account the many varied roles woodlands play as part of dynamic living landscapes.

Integrated woodland design: an effective route to quality woodland

Richard Hellier and Robin Gray

We're currently in a time of unprecedented ambition for woodland creation at rapid pace. Woodland creation schemes are increasingly challenging and growing in scale, often in visually prominent places and on sites rich in diversity and inherent character. The need to integrate these schemes with complex landscape and visual sensitivities while meeting multifunctional objectives means there has never been a more important time to apply integrated woodland design.

Richard Hellier and **Robin Gray** are chartered landscape architects working as landscape and woodland design advisers in the Forestry Commission England's policy advice team. Both advisers have much experience in forestry, woodland design and community woodland with additional specialisms in landscape character, place-making, ecological and habitat design.

The landscape and visual resource

The British Isles has a great diversity of landscapes that are a combination of natural components (geology, landform, soils, watercourses, climate, flora and flora), human influences (land use, land management, and settlement), aesthetic qualities (visual and sensory perceptions), and cultural values (historic, social and personal associations)[1].

'Landscape is an area as perceived by people, whose character is the result of the action and interaction of natural and human processes.' - European Landscape Convention 2006 (Council of Europe)

An understanding of the landscape context and applying good design practice is fundamental to creating quality woodland that meets objectives, fits well, and enhances our diverse landscape character. The UK Forestry Standard (UKFS) requires that 'new forests and woodlands should be located and designed to maintain and enhance the visual, cultural and ecological value and character of the landscape'[1].

An integrated landscape approach is a way of conceptualising our surroundings and providing a useful spatial framework for thinking about and resolving a wide range of environmental, land use and development issues[2]. It is particularly appropriate for the design of new woodland.

This approach requires consideration of design, planning and a thorough understanding of the 'landscape and visual resource' i.e. the elements that comprise landscape character. A design for woodland creation always starts with a landscape. It must be holistic and span all landscape aspects. These range from future resilience to people's wellbeing, access, nature recovery and habitats, the historic environment, and resolving potential design conflicts. This is where integrated design comes in.

The shape of natural vegetation patterns provide a useful analogue for the design of naturalistic planting. This creates unity and an authentic spirit of place. Such environments are rich in visual and ecological diversity and are naturally resilient.

A holistic approach

Integrated design is a holistic approach that brings together specialisms often considered separately, in a coordinated way. It is particularly beneficial for woodland creation, as it involves a wide range of specialists from foresters, land agents and landscape architects to ecologists, historic environment specialists, the general public and statutory stakeholders.

Whatever the objectives and scale of the woodland creation, integrated design has three key elements:

1. Understanding and analysing the **landscape context** around the site where new woodland is proposed by undertaking a landscape character appraisal.
2. Applying seven **woodland design principles** throughout the design process to ensure important factors are consistently, comprehensively and holistically considered (see Box 1).
3. The **woodland design process** provides a logical, graphic and clearly explained route from project inception through to survey, analysis, synthesis and final design[3]. This iterative process adds to efficient working and is based on annotated plans, photos and perspectives. It is effective for inclusive engagement and delivers 'quality' woodland by resolving complex design issues using informed and spatially referenced visuals.

The design approach embraces site characteristics just as much as those within the wider landscape context (see Box 2). Important features and distinct zones that are both suitable and less suitable for woodland planting need to be identified, appraised and mapped, such as non-woodland priority habitats, veteran trees and scrub, historic monuments, or views and viewpoints. Opportunities can then be explored to create connectivity between them to retain functionality for people and wildlife and retain links outside the site. It is often inappropriate to avoid and buffer sensitive features alone, and detailed consideration of how the woodland will fit and function post planting is essential in the design process.

Box 1. UKFS Woodland design principles

Spirit of place gives an overview identifying what makes a place and setting distinctive. This enables woodland design to conserve and emphasise the special qualities. Identifying the defining characteristics early is an efficient way to design woodland that enhances landscape character.

Unity enables new woodland to be designed to fit within its landscape context, and also applies to site design. This considers how various woodland components fit together and function well. It covers connectivity and interlocking, responding to landform and landscape patterns.

Landform considers the design of woodland in relation to topography in terms of shape and scale and as a response to soils, exposure and hydrology. This influences areas of open ground, edge treatments and appropriate species choice.

Pattern of enclosure recognises the associated sensitivity and importance of hedges, treelines and stonewalls to landscape character, biodiversity and historic environment, and considers opportunities for integrating woodland.

Scale applies at a variety of levels, enabling woodland integration within the landscape context and also the design of internal woodland structure and spaces over time.

Shape is a powerful aspect of design at all scales, especially in open areas of prominent topography such as uplands. Generally, well designed naturalistic shapes fit better within semi-natural landscapes and have visual and ecological benefits on woodland edges.

Diversity in terms of structural, visual and ecological diversity is desirable but it is important to get the balance right from numerous perspectives. Considerations include other semi-natural habitats, planting mixes, public access, creating woodland mosaics and fitting within a landscape context.

Box 2. How to create quality woodland that complies with UKFS Landscape

Consider woodland design from the **'big picture, landscape scale'** then work down into the complexity and detail, such as habitat specifics and tree species selection.

Undertake an **integrated, place-led approach**, where all UKFS elements are considered as a whole, not in isolation. Quality woodland creation grows from and enhances landscape character that has evolved over time and has many sensitivities.

Take account of **landscape context** covering both the site and its setting by undertaking a **Landscape Character Appraisal**. This includes good quality analytical visual material to feed into the design concept plans.

Apply the seven **woodland design principles**, informed by the landscape context, as essential tools to ensure landscape and visual aspects are appropriately addressed – a UKFS requirement.

Utilise the **woodland design process** and produce required graphic outputs that clearly show the evolution of the design. The process is iterative and sequential and produces design concept plans for effective engagement, which are supported by the analysis of the landscape context and site.

Respond to the **spirit of place** (local distinctiveness) by conserving and emphasizing special qualities such as a combination of naturalness, views, habitats, historic features and characteristics that make a place unique, memorable and inspiring.

Diverse woodland structure and patterns deliver rich landscapes for people and wildlife.

Landscape Character Appraisal				
Woodland Design Process				
Setting objectives	Survey	Analysis	Synthesis	Finalisation
Owners aspirations Objectives: • Economic • Social • Environmental UKFS compliance	**Landscape and visual baseline survey** Desk and field survey reference to National Character Area profile and local Landscape Character Assessment.	**Evaluation** Involves analysing survey work to identify key factors which have the greatest influence on meeting plan objectives and UKFS compliance. **Landscape appraisal** Including **site zoning**	**Design concept development** Develop one or more potential woodland design options using landscape and visual analysis, objectives and design principles. **Tool for engagement** with community and stakeholders	Production of woodland masterplan with species mix and the detailed design showing treatment of internal and external edges, open space, arrival points and feature areas (specific habitats, distinctive landmark planting to aid people navigating large woodlands).
Outputs				
Working Proposal Sketch Plan Woodland design principles applied throughout process	**Landscape context plan** with analytical narrative of Landscape context. Scale 1:20,000	**Site appraisal plan** with analysis, site zoning and supporting annotated photos. Scale 1:5000	**Design concept plan(s) and perspectives** with options to show how new woodland fits and functions with the site and landscape context. Scale 1:5000	**Final woodland creation design plan** Detailed design for key areas.

Figure 1. Summary of the woodland design process

Blending the past, present and future

Many woodland creation schemes are proposed on 'marginal' lands from designated landscapes to urban fringes. These areas often have an array of important features and characteristics that are locally distinctive, valued by people, important to biodiversity and rich in landscape character. Such scenarios highlight the need for an integrated design approach that blends the past and present with the future vision in a coordinated, informed and creative way.

With a changing climate there is rightly an emphasis on silvicultural design focused on resilient tree species. There is also a need to carefully design species assemblages, species proportions and edge planting from the point of view of authenticity based on National Vegetation Classification, site character and conditions. This will reinforce spirit of place and unity, but future resilience must always be considered.

Meeting challenging multi-functional objectives and facing complex issues demands good inter-disciplinary working. Designing 'quality' woodlands is a nuanced, multi-dimensional process that considers both objectives and existing character from a holistic, contextual and 'functionality' perspective. It looks at aspects such as connectivity and 'interlocking' and the perceptual, spatial, operational and management aspects of woodland design, together. Combined with a set of graphic and analytical design outputs (see Figure 2) and applying design principles, this is the essence of integrated woodland design.

What next?

The Forestry Commission actively promotes integrated woodland design to facilitate the understanding of its benefits, to upskill the sector and to improve the quality of woodland design practice. This will lead to more efficient working through better engagement in the design process, and improved quality of woodland creation.

As more woodland and trees are planted in some of our most valued landscapes, there will be increased public interest and scrutiny. Working with UKFS guidelines with skilled application of the design tools is the most effective way to deliver the softer and more nuanced objectives of woodland creation. Enhancing the rich character of valued places, delivering robust and diverse habitats, and engaging and delighting people are critical alongside meeting planting targets, carbon sequestration and building resilience.

Alongside new publications by the Forestry Commission and the Woodland Trust on planning and designing new woodland creation, there will soon be an additional resource on how to create good quality woodland. The Forestry Commission England's Landscape team is producing online design guidance to supplement UKFS guidance based on casework. This will undertaken alongside upskilling and training in both forestry, woodland creation and landscape sectors in the forthcoming months.

Figure 2. Integrated woodland design works from the landscape and visual character upwards, growing out of the distinctive identity that defines a site and its context. The process is holistic considering all factors in a coordinated way; it resolves how things look and how things function. The sketches below show the integration of woodland into three key landscape scenarios:

The integrated approach shapes woodlands and treescapes by blending the understanding of place, with objectives and a coherent and engaging vision. This enables an informed and transparent evolution of cherished landscapes to meet the needs of the future.

Urban fringe - distinctive, legible and wildlife-rich destinations for visitors.

Lowland - the integration of historic enclosure pattern and other features is important.

Upland - the integration of woodland with the landform and vegetation patterns is important.

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Creating woody habitats to enable nature's recovery

Clare Pinches and Adrian Jowitt

Clare Pinches is a principal scientific analyst at Natural England and has a long held and keen interest in evidence led conservation. Her current work is focused on ensuring the woodland creation target is delivered in ways which support nature's recovery. **Adrian Jowitt** is a principal advisor at Natural England. He has been with Natural England and its predecessors for 23 years in a wide range of delivery and policy work areas. For the last five years he has led on woodland policy.

Judith Parry/WTML

Where and how we establish new wooded habitats will profoundly influence their value for nature. Taking an evidence-led approach, and translating it into the right incentive mechanisms, will enable land managers to turbocharge the recovery of both woody and non-woody wildlife, and at the same time help reach net-zero greenhouse gas emissions.

The establishment of new native woods, trees and woody shrubs has a pivotal role in supporting the recovery of nature, injecting much needed structural complexity into our landscapes. However, where this new woody habitat goes, critically influences its ability to enable nature's recovery.

New networks for nature

Establishing new wooded habitat contiguous to existing native woodland expands and buffers the existing resource and can enhance connectivity where fragments are linked. Size matters too: evidence suggests that to maximise the species richness of lower and higher plants, and woodland birds such as marsh tit, woodlands must be at least 40 hectares. Larger woodlands with variation in habitat structure are needed to support populations of wider-ranging species or those with specialist requirements and low dispersal abilities, such as some saproxylic beetles[1].

Of course, not all new trees and shrubs will or should be established as woodlands. Tree cover outside woodland amounts to 565,000ha in England making up 4.3% of total land area[2], most of which are native broadleaves.

These treed habitats, be they hedgerows, areas of scrub, in field or riverside trees, wood pastures or orchards, have significant nature value contributing to habitat diversity within our landscapes. They also enhance landscape permeability for both woodland and non-woodland species.

Open grown trees, developing in the absence of competition from others, have a more complex form and when retained in perpetuity provide a significant carbon store. The more heavily branched architecture of these trees provides ample opportunity for wood decay features. Indeed, wood pasture is the richest habitat for priority species in England by virtue of the mosaic of habitats it encompasses and diversity of saproxylic invertebrate species it supports. Large scale expansion of trees outside woods, including through extensively managed agroforestry systems, offers considerable value for nature and a way of integrating many more native trees within our landscape without a drastic change of land use.

Creation of new open wooded habitats has been used to inspiring effect on the Eastern edge of the Lake District National Park. Where the M6 motorway arcs its way between Borrowdale and the Tebay Fells, local landowners and those with commoners' rights have been working in partnership with the Woodland Trust and Natural England to bring about a woody transformation on both sides of the road. Extensive areas of wood pasture and thorny scrub now reach up the previously bare fells from the existing riparian woodland and open wooded habitats in the valley bottom, creating a rich tapestry of high-nature-value habitat respectful of the local landscape.

Wood pasture in Low Borrowdale, Cumbria. Naturalistic, low-level grazing by domestic cattle produces patchy and ecotone-rich vegetation in wooded ecosystems.

The return of the native

If we are to tackle the nature and climate crises simultaneously, most new wooded habitat needs to comprise native tree and shrub species. This doesn't reflect parochialism or a resistance to change in the face of the climate crisis. After all, most of our native tree species are at the northerly limits of their ranges; therefore, the projected climate of 2080 falls well within that currently experienced in their climate envelope[3]. It simply reflects the ecological reality that native species are better suited to enabling the recovery of our native wildlife.

Native species such as oak can self-seed when given the opportunity and support far higher species diversity than non-native trees.

Thousands of years of co-evolution mean they support far higher species diversity than more recent non-native arrivals. At least 2,300 species are known to be associated with native oak alone, of which 326 are entirely dependent[4]. Non-native conifer plantations nevertheless have an important role for timber production to reduce our dependency on imports.

Structural complexity and natural colonisation

The maxim "it's a marathon not a sprint" is relevant to establishing new wooded habitat of high value for nature. We must be careful not to miss critical opportunities to recover nature in our dash to achieve net zero by planting trees at pace and at high density. This is because in woodland systems, biodiversity value tends to be highest in the early open-canopy and in the old growth stages. While we can do little to hasten the establishment of new old growth woodland – our efforts here being better focused on optimal management of existing woodland and mature trees – what we can do is incentivise activity which creates and sustains the early and mid-successional open canopy conditions perfectly placed to benefit nature now.

Recent studies such as those at the long-established Monks Wood wilderness sites[5] show that natural colonisation offers considerable benefits, especially on sites close to existing native woodland or alongside old hedgerows which can provide a ready source of seed or suckers. Structurally complex mosaic habitats of scrub, open habitat and young trees, provide plenty of 'edge' habitat and a diverse array of niches for invertebrates and birds. An abundance of thorny shrubs such as bramble, hawthorn, blackthorn, gorse and dog rose, which flower profusely under the relatively open canopy, supply food for insect pollinators and berry eating birds. Moreover, these conditions are maintained for longer as canopy closure is slower than in a planted woodland. Consequently, naturally colonising areas can provide vital habitat for a wide range of non-woodland wildlife, including critically threatened species such as turtle doves, all enroute to establishing native woodland[6].

Natural colonisation will not be appropriate everywhere – it may simply take too long in some situations, for example in dense bracken where thorny shrubs and trees are out-competed. Planting is likely to be the most appropriate method where trees need to be established quickly, where trees are required in a particular location on a site, or where a specific tree species composition is required to meet objectives.

High structural complexity can be created in planting schemes by retaining open glade areas, feathering woodland edges and varying the planting density and species mix to create tightly planted groves of trees and shrubs in some places, and open wooded habitats elsewhere. Whilst average stems per hectare is often used to specify woodland creation, and determine the success of establishment, evidence suggests a more meaningful indicator of a site's wildlife value is variation in stem density across the site[7]. By incorporating vegetation of diverse vertical height and a significant thorny scrub component, the habitat mosaics and transitions created via natural colonisation can be successfully mimicked to provide a diverse range of niches and sequential food resources.

Restoring natural processes

Consideration should also be given on how to restore natural processes in newly established woody habitats to build resilience and enhance their conservation interest. Reinstating the natural hydrology of a site by blocking surface drains or re-naturalising water courses prior to trees being established provides numerous

Drone image of Monks Wood wilderness experiment showing natural colonisation on a once arable field. Taken in May 2021 it shows an abundance of blossoming hawthorn.

benefits, including natural flood management and improved water quality. Creating wetland features in this way, or by establishing ponds, can greatly enhance a site's conservation value, providing important habitat diversity for invertebrates, amphibians, reptiles, plants and birds.

Crucially, we must recognise that naturally functioning, wildlife-rich wooded habitat takes years not days to develop. Policy and incentives must reward patience, and embrace, or at least allow for the inherent unpredictability of a more natural-process-orientated and less deterministic approach to woody habitat creation. This of course demands that we relinquish control, and (whisper it) become a little less focused on the trees, instead focusing on the glorious messiness and richness which more naturally functioning woody ecosystems can and must deliver.

Informed decision making

Natural England is working on a range of initiatives alongside conservation partners to improve the reliability and accessibility of environmental data to inform decision making; we must be clear sighted on where existing nature-rich habitat and important populations of rare and declining species are within our landscapes. Working with local environmental record centres we are currently updating the Ancient Woodland Inventory to incorporate sub-2ha woodlands. We are also working with the Botanical Society of Britain and Ireland (BSBI) and the Woodland Trust to use plant indicator mapping to identify areas of remnant semi-natural habitat not captured on our Priority Habitat Inventories.

These projects will help us identify where increasing tree and woodland cover can enhance biodiversity and where it should be avoided to protect and restore open habitat elements of the Nature Recovery Network (a national network of wildlife-rich places). Only by operating in a fully informed way can we properly realise the Lawton principles of better, bigger, more and more joined up habitat[8] and create new nature networks fit for the challenges of the future.

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Pete Leeson/WTML

Wood pasture creation in the Lake District National Park. Tree cages are erected to exclude browsers and 3 to 5 woody species planted inside so that eventually the species most suited to the site conditions will reach maturity.

Biodiversity response to native woodland creation in the Scottish Highlands

Emily Warner

Woodland expansion is often cited as a tool to tackle the ecological crisis and conserve biodiversity. But it is important to understand what species newly created woodland supports, and how its biodiversity value changes over time. We investigated this in new native woodland in the Scottish Highlands.

Emily Warner is a NERC funded PhD student in the Department of Plant Sciences, University of Oxford, researching the response of biodiversity and ecosystem functions to woodland creation.

The UK Government has plans to increase woodland cover from 13% to 17% by 2050 to deliver multiple benefits, including carbon sequestration, timber production and biodiversity conservation. Much of this expansion is likely to occur in the uplands, where conflict with other land-uses can be lower. In recent times, more tree planting has occurred in Scotland than the other UK countries, with a focus on production forestry. However, the upland landscapes of Scotland would have previously been extensively covered in native woodland; climate change, human-driven deforestation and grazing pressure have driven declines over the last 5,000 years. Today, high grazing levels, mainly by deer, are preventing natural colonisation from the remaining remnants of native woodland. In this now predominantly non-wooded landscape, there is a vision for a new future, where lower grazing levels will allow native woodland to expand.

A research opportunity

In 1990, a large-scale project aiming to expand native Caledonian pinewoods began in the central Scottish Highlands, led by Trees for Life, the Forestry Commission Scotland, and the National Trust for Scotland. Caledonian pinewood is of limited extent in the Highlands, making it a priority for expansion. Over the last 30 years, this partnership has created a series of woodland creation sites in Glen Affric and Glen Moriston. The sites were fenced, reducing (but rarely completely excluding) deer browsing, and then planted with native Caledonian pinewood species. Initial planting densities ranged from 119 to 1,549 trees per hectare. In our study plots we recorded densities of 1,100 to 5,100 trees per hectare, reflecting the initial planting and subsequent natural regeneration.

We used these sites to learn more about how biodiversity responds to native woodland creation in upland areas, specifically looking at plants, carabid beetles and birds[1]. Sites were aged between 6 and 28 years at the time of the study, enabling us to explore change over time in these three species groups.

Two of the reforestation sites in West Affric on either side of the valley.

A reforestation site alongside the River Affric. The impact of grazing exclusion is clear when comparing vegetation inside and outside the fence.

Plants, carabid beetles and birds were chosen to assess the response of different aspects of the ecological community to woodland creation. To understand the effect of woodland creation relative to the prior land-use, we surveyed non-wooded areas associated with each woodland creation site. Plots in these non-wooded areas were our controls, allowing us to understand the change from non-wooded to wooded despite the lack of data collection prior to the woodland creation project. In Glen Affric a remnant of Caledonian pinewood (the target habitat) remains, providing a reference point for the desired outcome.

Response of biodiversity

We found on average four bird species in woodland creation plots compared to one species in non-wooded plots, while mature pinewood plots contained seven species. In contrast, similar numbers of plant and carabid beetle species were found across the non-wooded, woodland creation and mature pinewood plots.

Species numbers in the different habitats can give some insight into the value of woodland creation sites for biodiversity. However, it is important to consider species identity. Are the same species supported by each type of habitat or do some habitats support unique species? We found that for plants and birds the woodland creation communities were intermediate between the starting and target habitats, suggesting that species composition is transitioning away from that found in non-wooded areas towards mature pinewood areas. For carabid beetles, the ecological communities were similar in woodland creation and mature pinewood plots, which differed from non-wooded plots. This was likely due to a high proportion of species (7 out of 24) being unique to non-wooded plots and the particularly high frequency of specific species (e.g. *Carabus glabratus*) in woodland creation and mature pinewood plots.

Specialist species

The presence of specialist species in new woodlands is an indicator of quality habitat creation. For birds, such species include tree pipit and willow warbler, and plants include wood anemone and common cow-wheat, which are ancient woodland indicator species. On average, two specialist plant species and two specialist bird species were found per woodland creation plot. Mature pinewood plots supported the most specialist bird species, on average three per plot, including species only found in this habitat, such as the crested tit. Just one carabid woodland specialist was found and was present in the mature pinewood only.

The presence of specialist birds in woodland creation plots likely reflects the mobility of this group, enabling them to colonise the new habitat. The number of specialist bird species per plot increased with age of the habitat, indicating its increasing quality over time. We estimated that within three to four decades the young woodland would support as many specialist birds as the mature pinewood.

Caledonian pinewood has a characteristic plant community, comprised of a thick moss layer and ericaceous shrubs such as blaeberry, cowberry, and heathers. There were similar numbers of these species in non-wooded and woodland creation plots, both of which were lower than in mature pinewood plots. The plant species present are thought to have originated in the soil seedbank, and the ericaceous shrubs in particular were likely to have been present before the woodland creation took place. Over the long-term it is hoped that the ground vegetation community in woodland creation areas will become more like that found in mature pinewood. However, rarer and more sensitive specialist species may take longer or fail to disperse into the new sites.

Implications for future woodland expansion

Our study shows that newly created woodland in Scotland's upland landscape can effectively support woodland specialist species within the first three decades of creation and it is anticipated that the habitat will continue to develop. Ongoing monitoring is important to confirm that the woodland creation sites are progressing as expected and that less mobile species are establishing within the habitat[2].

In our study landscape, a combination of low-density

Woodland regeneration alongside Caledonian pinewood in Glen Affric.

native tree planting and grazing exclusion has been an effective initial conservation action. Although grazing has had a clear negative effect on the wider landscape, our study indicates that there is good potential for woodland expansion once this pressure is removed. Similar methods of woodland creation could see a return of woodland habitat in equivalent areas across the Scottish uplands, supporting native woodland biodiversity.

However, valuable parts of the plant community that are most sensitive to grazing, for example bog blaeberry, herb paris and bog rosemary, may not remain in refugia or may fail to return even with grazing exclusion, which is often not fully effective. We predict that the positive trajectory of the developing woodland habitat will continue, but its ultimate biodiversity value will depend on wider landscape factors such as the prevalence of target species within an area.

It is key to consider the impact of woodland expansion at the landscape scale. All plot types in our study (non-wooded, woodland creation and mature pinewood) supported unique species, highlighting that complete transition to mature tree cover at the landscape scale could lead to a loss of some species. Several carabid species were associated with open habitats and although no bird species were uniquely found in the non-wooded plots, species such as meadow pipit and skylark nest in open habitats.

A future in the Scottish uplands where there is a better balance between grazing and tree regeneration, producing a dynamic and heterogeneous matrix of habitat types, could provide the most benefits for biodiversity. Lower grazing pressures at this landscape scale, instead of exclusion of deer from small pockets, would also benefit the most sensitive and currently rarest species, allowing them to rebound in the expanding woodlands.

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Overlooked but essential biological interactions in woodland creation

Andy Taylor, Lion Martius, Kerri Milligan and Paige Brown

Germinating tree seedlings and transplanted nursery trees must form symbiotic associations with soil fungi to survive and thrive. Tree establishment is therefore heavily influenced by the availability of these fungi, which reciprocally is determined by the distribution of suitable host plants *in situ*. Heather and grass moorlands can be largely devoid of symbiotic fungi suitable for trees, so how can we ensure successful tree establishment across these landscapes?

Dr Andy Taylor is a senior researcher at the James Hutton Institute in Aberdeen who spends his time investigating the multitudinous roles of fungi in our ecosystems. **Lion Martius, Kerri Milligan and Paige Brown** are masters' students at the University of Aberdeen.

Plant roots are inhabited by a wide range of soil fungi, the presence of which usually goes unnoticed. However, one fungal group forms very intimate associations with roots and is crucial for plant survival. These intricate fungus/plant structures are called mycorrhizas, literally 'fungus roots' (myco = fungus, rhiza = root). The evolutionary and ecological importance of these symbiotic associations cannot be overstated; quite simply, terrestrial life depends upon them.

Mycorrhizal associations are based on the fungi extracting nutrients from soil and transferring a proportion of these to the plant in return for sugars derived from photosynthesis. The vast majority of land plants form mycorrhizal associations, and most are obligate, meaning that neither the plant nor the associated fungus can survive without the other. Fossils dating back around 420 million years indicate that the evolution of land plants and the development of all terrestrial ecosystems has taken place under the influence of this interaction between fungi and plants.

Considerations for woodland expansion

There are three main mycorrhizal types to consider in relation to woodland expansion in the UK: the ericoid association, the ancient association (arbuscular) formed by most herbaceous plants and many trees, and the ectomycorrhizal association formed by most forest trees in northern Europe. These three associations could, for the sake of simplicity, be considered to be spatially segregated along gradients of decreasing availability of mineral nutrients and increasing reliance upon organic sources of nutrients, from arbuscular to ectomycorrhizal to ericoid associations.

The plants and fungi involved in these associations are, in general, exclusive to forming only one association. In addition, they are often associated with particular ecological conditions, which each helps to generate and maintain. The ericoid mycorrhizal association is an excellent example of this. Ericoid mycorrhizal associations are found on plants within the family Ericaceae and involve a small, select (but as yet largely unknown) group of fungi. In general, the litter from ericaceous plants is rich in tannins and phenolics, which accumulates on the soil surface binding up nutrients and creating conditions that make it very difficult for non-ericaceous plants to establish. However, the ericoid mycorrhizal fungi can utilise the litter and hence supply the host plant with the necessary nutrients. Plants lacking the ability to form ericoid mycorrhizas or an ability to form alternative associations that can compete with the ericoid fungi for nutrients will find it extremely difficult to establish in ecosystems dominated by ericaceous plants (e.g. a heather moorland).

Ectomycorrhizal tips formed between the fungus *Russula paludosa* and Scots pine. A broken tip (bottom left) exposes the dark root structure completely surrounded by the white mantle of fungal tissue. The white dots are heaps of dead fungal cells on the mantle surface.

Problems start when introducing plants which form one association into areas dominated by another, particularly if the latter is further up the gradient of organic dependence. The obligate nature of the association means that germinating seedlings or nursery plants, which are often grown in conditions devoid of mycorrhizal fungi, will need to acquire suitable mycorrhizal fungi to survive. Many current woodland expansion schemes often involve planting pine and birch onto heather and grass moorlands, which entails introducing ectomycorrhizal-forming plants into an ecosystem controlled by either the ericoid or arbuscular association. If there are no existing ectomycorrhizal fungi on the roots, the pine and birch seedlings may survive for a year or two as they internally recycle the nursery abundance of nutrients, but unless the trees acquire suitable ectomycorrhizal fungi, they will most likely die.

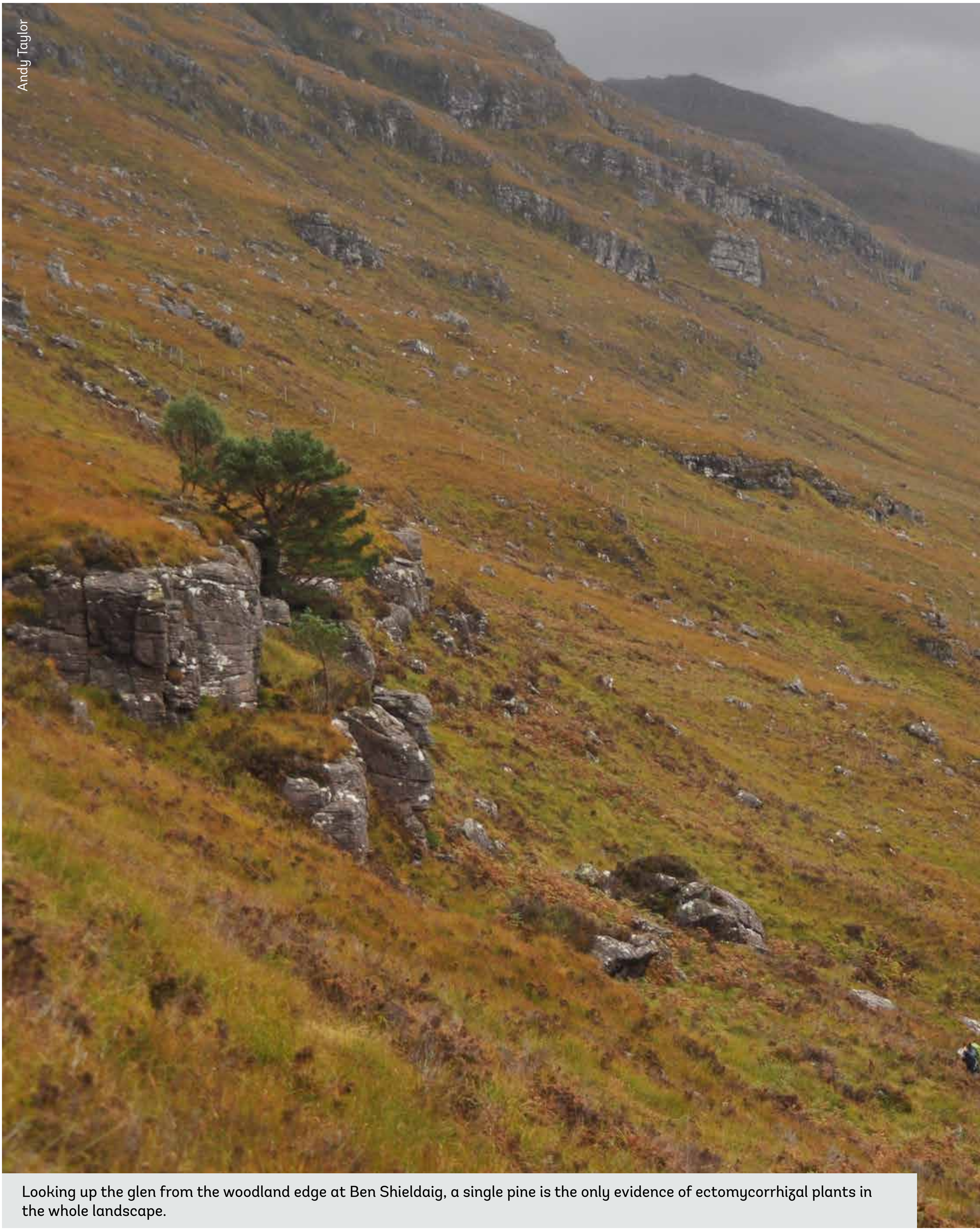
If the plants are close enough to the woodland edge to come into contact with the roots and associated fungi from established trees, they will become colonised and most likely thrive. If they are too far from the woodland edge, then spores released from the fruiting structures of ectomycorrhizal fungi associated with established trees will be the major source of possible inoculum. However, the chances of spores and germinating seeds being in the same place at the same time will become less likely with increasing distance from the woodland edge.

Tapping into an existing fungal network is the most effective way for seedlings and planted trees to acquire ectomycorrhizal fungi. But in heather and grassland systems apparently devoid of ectomycorrhizal trees how can this be achieved?

Investigations at Ben Shieldaig

Ben Shieldaig, a 1,540ha estate located on the west coast of Scotland, hosts remnants of old Scots pine and birch woodlands. The Woodland Trust plans to expand these existing woodland patches onto treeless areas through planting and by encouraging natural regeneration. Yet the majority of the site is covered by heather and grasslands with plants forming ericoid or arbuscular mycorrhizal associations, respectively – not suitable for ectomycorrhizal trees. But nature has a solution.

A typical plant of creeping willow (*Salix repens*) growing through other vegetation. Such plants act as reservoirs of ectomycorrhizal fungi on Ben Shieldaig.



Looking up the glen from the woodland edge at Ben Shieldaig, a single pine is the only evidence of ectomycorrhizal plants in the whole landscape.

Although most plants can only form one type of mycorrhizal association, there are important exceptions. For example, the genus *Salix* (the willows) can form both ecto- and arbuscular mycorrhizas. An initial survey at Ben Shieldaig noted that willows were scattered across the site outside the woodland areas. Their ability to form arbuscular associations allows them to spread freely across the site. This is key in facilitating woodland expansion, as once willow plants become established, any ectomycorrhizal fungal spores landing near them will also be able to colonise the roots. The willows could then potentially act as reservoirs, or islands, of ectomycorrhizal fungi in areas otherwise dominated by ericoid and arbuscular plants and fungi. Any birch or pine seeds lucky enough to germinate near the willows could therefore become colonised by the ectomycorrhizal fungi and survive and thrive. Our research at Ben Shieldaig investigated this idea, focussing on the distribution and co-occurrence of willows with birch and pine seedlings.

The great majority of the willows were found in groups, including mixed species groups, indicating that once growing, single plants facilitate the establishment of other plants. This wasn't simply a seed source effect as many of the groups contained different willow species. Interestingly, the willows were acting as natural nurseries for birch and Scots pine seedlings. Very few, if any, of the latter were found growing without a willow in close proximity. Additionally, the larger the group of willow trees, the greater the number of birch and pine seedlings found within it. An analysis of soil and site conditions did not find any abiotic factors which appeared to influence the occurrence of the pine and birch. These findings all point towards an important role for willows in supporting woodland expansion across Ben Shieldaig.

Implications for woodland creation projects

Until recently, the crucial roles of mutualistic fungi in supporting establishment and survival of tree seedlings have been ignored. The appearance of commercial sources of fungal inoculum is testimony to a reappraisal of these roles. However, working with nature *in situ* to improve tree survival rate and growth would save valuable resources. For example, at Ben Shieldaig, the overall dispersal capacity could be greatly enhanced beyond the existing woodland edge by creating large stepping-stone habitat patches of ectomycorrhizal trees (or other plants) centred around the willows which would over time produce tree seed and fungal spore inoculum across large areas.

Willows are not unique in their ability to support woodland expansion efforts. A small range of other non-tree hosts (e.g. bearberry) also support diverse communities of ectomycorrhizal fungi and could be used as nurse plants for planted tree seedlings.

What shall we do about tree shelters?

Charnett Chau, Andrea Paulillo, Nancy Lu,
Mark Miodownik, Paola Lettieri

The use of tree shelters (plastic tubes around tree saplings) in woodland creation is hotly debated. Environmentalists, foresters, and the public alike are concerned about the resulting pollution from plastic waste. Yet tree shelters significantly improve sapling survival rates and, therefore, the success of woodland creation projects, ultimately contributing to positive outcomes, including carbon capture from the atmosphere. So, what is the overall balance of these conflicting environmental impacts? And what is the best strategy to increase woodland cover in the UK whilst protecting the environment?

We are a multidisciplinary group of academics, including materials scientists, engineers, designers, and social scientists from University College London (UCL). Left to right: **Charnett Chau**, **Prof Mark Miodownik** and **Prof Paola Lettieri** are part of the UCL Plastic Waste Innovation Hub aiming to develop new ways of designing-out waste from plastic packaging (www.plasticwastehub.org.uk). In addition, **Charnett Chau, Prof Paola** and **Dr Andrea Paulillo** are part of the LCA group in the Chemical Engineering Department of UCL. **Nancy Lu** was a summer student that carried out the initial work on tree shelters for the Hub.

Plastic shelters emerged in 1979 and for decades they have been used as standard practice by woodland and farming communities to protect saplings from predation by animals such as deer, sheep and rabbits. By 1991, the annual production of shelters was predicted to be in excess of 15 million units[1]. It incurs an extra cost, but for most landowners, this is outweighed by the cost of losing a proportion of the saplings. The shelters are generally made of plastics, such as polypropylene. They are inexpensive, especially when compared to the cost of saplings[2], and have been shown to increase survival rates[3–5].

However, there are two environmental concerns about their deployment. Firstly, after their useful period, tree shelters are often left at planting sites (NB. the Woodland Trust removes tree shelters on their own estate). After five years, they become embrittled and disintegrate into small shards and microplastics, which are almost impossible to collect. This in turn creates plastic pollution in the environment for decades to come. Secondly, the resources used to manufacture and transport tree shelters affect the environment by producing greenhouse gases and other polluting substances.

Our research team at the Plastic Waste Innovation Hub at

University College London has carried out a life cycle assessment (LCA) on tree shelters to fully understand their environmental impacts[6]. This is allowing us to advise the sector on increasing woodland cover in the UK whilst also protecting the environment as much as possible.

The Life Cycle Assessment method

The LCA method is an agreed standard used worldwide to assess the environmental impact of products, processes and systems. For example, it has been used to understand whether electric or internal combustion engine cars are better for the environment. An LCA study adds up and interprets the environmental impacts occurring throughout the life cycle, from cradle (mining and manufacture) to grave (scrap), and not just those originating from the use phase (driving the car). This approach enables the identification of trade-offs between different environmental harms and life cycle phases, thus providing a robust framework for making evidence-based decisions. For example, electric cars perform far better than internal combustion engine cars in the use phase; however, when considering other phases, like the manufacturing of batteries and the generation of electricity, the environmental benefits are not as clear.

In our LCA study, just like in the electric versus petrol car example, we compared different ways of doing the same thing, in this case, how to reach a certain density of tree cover by (a) using standard plastic tree shelters, (b) using biodegradable tree shelters, and (c) using no tree shelters. We also considered variations of these scenarios, including one where the plastic tree shelters are collected after five years and recycled into new tree shelters.

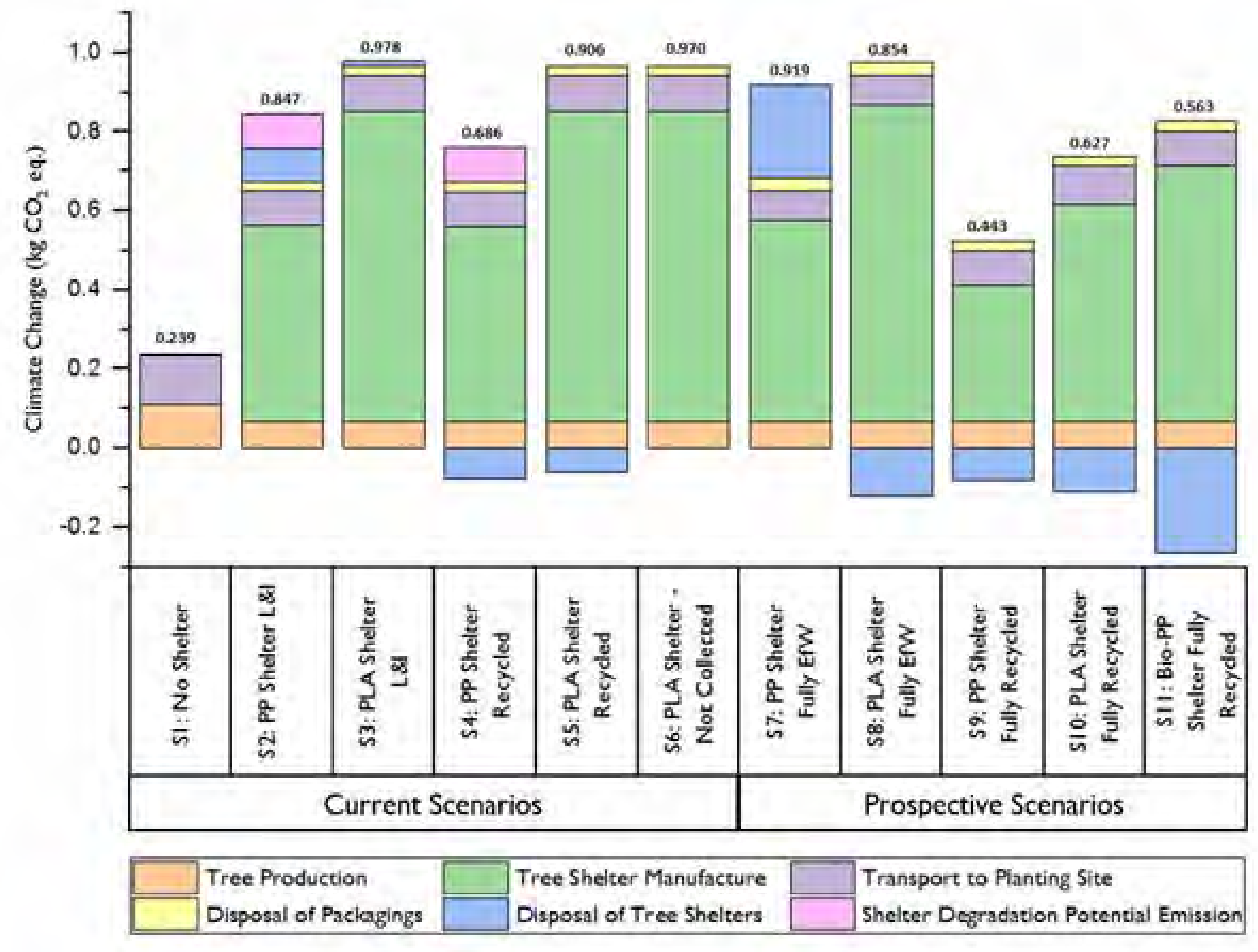


Figure 1. The climate change impacts for achieving one tree surviving past its five-year establishment period at the planting site. 'Current Scenarios' denotes the scenarios that are possible with and without shelters, and where shelters can only be partially collected after their useful period due to their degradation and fragmentation over time. 'Prospective Scenarios' envisages that shelters are fully recoverable in the future.

Interesting results

LCA results show that the amount of carbon dioxide stored in a tree through the first 25 years of growth far outweighs the amount of greenhouse gases emitted into the atmosphere through the manufacture, transport, use and decay of plastic tree shelters. So, the climate change impacts caused by the standard practice of using shelters are offset by net carbon storage by trees. In terms of plastic waste, the LCA revealed that this is not just limited to the tree shelters themselves; plastic waste is generated at all stages of sapling production, for instance, in the polythene wrapping for transportation. Individually, such plastic use might seem insignificant. However, the tree shelter plastic and packaging needed for the billions of saplings that must be planted to meet the UK's woodland creation targets can amount to thousands of tonnes of plastic waste.

In terms of tree survival, based on published literature we obtained survival rates of 50% without tree shelter protection, compared to 85% with shelter protection, so using no tree shelters leads to more predated saplings. However, LCA calculations show that if the predated saplings are replaced by periodic replanting, the overall carbon dioxide emissions are lower than using tree shelters to achieve the same woodland cover, despite needing a larger number of saplings and more transport to the site (see Figure 1). It also, of course, has the important outcome of no plastic pollution of the woodland. If, however, the no-shelter tree survival rates plummet to below 30%, the balance tips in favour of using tree shelters due to the carbon emissions from replacing saplings. Grazing land with sheep, for example, or woodland where the deer or rabbit population is very high, may cause survival rates below this threshold.

But what would happen if those plastic tree shelters were fully recoverable and collected from the woodland after five years for recycling? LCA results show that no-shelter tree survival rates can only drop to 38% before it tips the environmental balance towards using shelters. However, fully recovering shelters may be difficult in practice depending on the accessibility of planting sites and other factors. In addition, the viability of fully recycling into new shelters is compromised by their molecular degradation; hence part-recycling and downcycling are more likely.

Biodegradable plastic tree shelters are another alternative option. However, we found that tree shelters manufactured from polylactic acid or bio-polypropylene resins (using current manufacturing methods) do not perform better environmentally than normal plastic versions. These materials require more resources and energy to manufacture and do not biodegrade in a timely manner. Therefore, they are not yet beneficial to the environment.

The Woodland Trust is trialling a number of possible alternatives to plastic tree shelters at Avoncliff Wood, near Bath, as well as funding further research.

Recommendations

In low predation environments where survival rates for saplings are above 30% and access to planting sites is easy, using no tree shelters is the best way to grow woodland whilst minimising detrimental impacts to the environment. The major obstacle to adopting this approach is cost; the extra saplings needed are generally more expensive than tree shelters. Using shelters may be the best trade-off in high predation scenarios, but better tree shelters or better 'shelter-free' tree planting practices must be developed. An ideal shelter would have a low environmental impact in their manufacture and be recycled easily or biodegrade reliably and enhance soil health. Again, money is an issue, this time for funding the research and field testing needed to find a tree shelter that truly protects the environment. This is equally the case for alternative practices that can eliminate the chances of plastic and any other waste left in the environment.

For more information on our work at the UCL Plastic Waste Innovation Hub, please go to: plasticwastehub.org.uk.

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