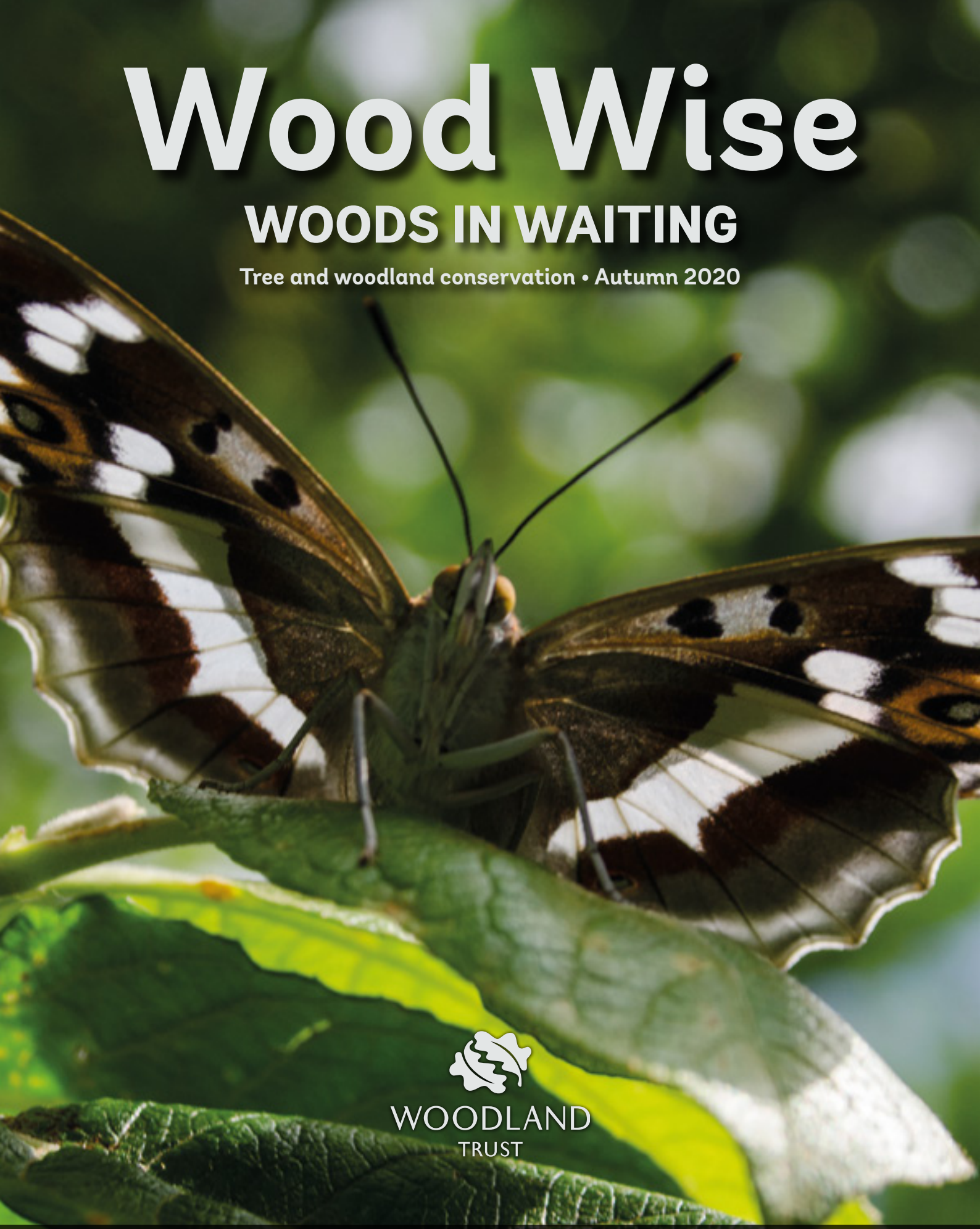
Wood Wise

WOODS IN WAITING

Tree and woodland conservation • Autumn 2020



WOODLAND TRUST

ADVANTAGES AND CHALLENGES OF NATURAL REGENERATION

NATURAL REGENERATION PROMOTES ADAPTATION

EVIDENCE ON LARGE-SCALE WOODLAND EXPANSION

UNLEASHING THE POTENTIAL OF NATURAL EXPANSION

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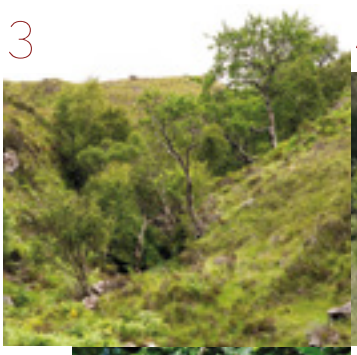

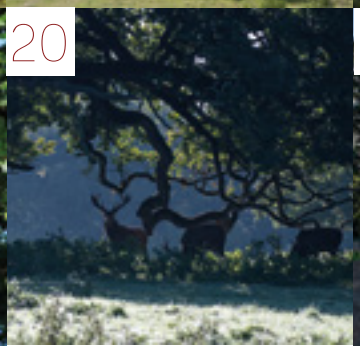

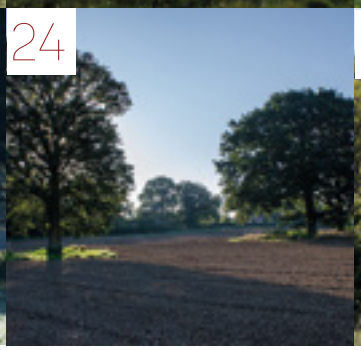

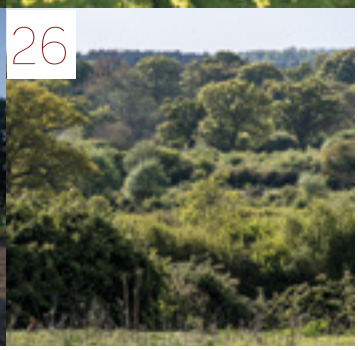

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Natural regeneration in dynamic woods and landscapes

Abi Bunker

As we face twin crises of climate change and biodiversity loss, the Woodland Trust's approach to woodland conservation and expansion adapts both by necessity and design and based on the latest science and evidence. Given the magnitude of some of these global challenges, it is remarkable in many ways how true to our origins we have remained, and how relevant our vision – 'a UK rich in native woods and trees for people and wildlife' – continues to be.

Now, as throughout our history, the Woodland Trust is looking at ways of addressing the challenges of the century: how to tackle climate change and achieve nature recovery at scale. Native woodland expansion across the UK has an important role to play in the solution but achieving this is going to require a spectrum of approaches for establishing trees.

The Woodland Trust has been working with others over the past 50 years to both plant trees and create the conditions for trees to plant themselves, and we're proud of all of the woods we've helped to create over the years.

Planting trees has always been a feature of the Woodland Trust's woodland creation work, for several important reasons. Tree planting engages people of all ages and social groups with the natural environment, often creating a life-long connection with woods and trees. This action can and has been truly life changing for many people. Putting trees in the ground can also be a very effective and efficient way of establishing woodland quickly and successfully, particularly where there is no nearby native tree or shrub seed source.

At the same time, given patience, care and management, the woods and trees of tomorrow are often biding their time as seed, ready to naturally colonise land given the right opportunity, creating rich, diverse landscapes that abound with life, as the articles in this edition of Wood Wise illustrate.

Both strategies can offer very tangible and quick return, whether funded by government grant schemes, charitable donors or businesses seeking to make a difference. In a time of ever-increasing need, and competition, for vital funding for our natural environment, creating the conditions for trees to recolonise can be highly cost-effective. However, there is currently no grant support to help landowners utilise natural regeneration, highlighting the need for funding schemes to deliver both planting and natural regeneration across the UK.

This latest edition of Wood Wise, Woods in waiting, explores why there is no 'one size fits all' approach to woodland creation. Natural regeneration offers an important additional strategy to tree planting, to expand tree and woodland cover in the UK. Done well and with the right funding and policy support, tree planting and natural regeneration can complement each other and create the nature and carbon-rich landscapes of the future.

Through working with others, including Knepp Wildlands in West Sussex, the Woodland Trust has brought together scientific and expert voices from the sector to help design and promote more natural solutions for native woodland expansion throughout the UK. These experts address the need for natural regeneration, the science behind it, and the practical and policy challenges of making it a reality. We aim to inform, provoke thought and stimulate discussion between experts, policymakers, practitioners and funders on how best to utilise natural regeneration to help create the wooded landscapes we need in the future.

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.

Forging a new path

Charlie Burrell

Charlie Burrell is the owner of Knepp Castle, vice chair of Rewilding Britain and the inspiration behind the Knepp Wildland Project.

For people who care about nature, the idea of returning land to deep, verdant forest has particular appeal – so different from the depleted, parcelled-up landscapes around us. It feels wonderful to stick a spade in the ground, to give life to a tree and think about the future. But is planting trees the only, or even best, way to get trees back in our landscape?

It's certainly big business – from commercial forestry companies to government grant aid. But are the trees being planted resulting in the treescapes of our imaginings? In the year to March 2019, the UK planted around 22 million trees, mostly conifers and mostly in Scotland. If we're not careful, we could be creating ubiquitous species-poor plantations of single-generational trees. Important habitats, such as peatlands and wildflower meadows, have recently been lost this way.

Planting is almost invariably high carbon. Everything in the process from propagation to transport to planting in plastic tubes is carbon intensive – a cost that is rarely set against the estimated carbon benefits of the growing trees themselves. And rarely is a distinction made between trees planted for nature – to grow old and senesce – and forestry, where the trees will be cut down and used before they reach prime carbon-sequestering age.

Then there's the risk of importing disease. Chalara, or


Charlie Burrell, Knepp Wildland

ash dieback, entered the UK from commercial nurseries in Holland this way. We should certainly question whether the planting approach is best for the trees themselves: if it will help them cope with pollution, disease, floods, droughts, and climate change.

At Knepp we've seen how easy it is for trees to establish by themselves. Of course, they're designed to do this. Our modern land management systems have just been preventing them from doing so. But in the Southern Block at Knepp, thorny scrub protects oaks planted by jays; sallow, birch and field maple blown by the wind; and crab apple and wild service dispersed by birds and small mammals. A landscape is emerging that looks like the ancient 'forests' of the past – a kaleidoscope of habitats characterised by open-grown trees, groves and grazing lawns.

Biodiversity has rocketed. Last year, a breeding-bird survey suggested Knepp may have the densest population of songbirds in Britain. Nightingales, turtle doves, purple emperor butterflies and all five UK species of owl are proliferating here. It's quite possible too that carbon sequestration above and below ground in natural regeneration could be much higher than in conventional plantations when all the associated carbon is calculated.

For the trees themselves, growing from local seed (possibly with regional adaptions), with their thorny nursery providing the micro-climate; and their roots in functioning soil, tapping into mycorrhizal fungi and bacteria, and benefitting from a wealth of nutrients; seems the likeliest scenario to boost immunity and resilience.

Here, we hope these diverse, multi-generational, open-grown trees will grow into mature, carbon-sequestering giants, their limbs and themselves falling eventually to the ground, returning their carbon to the soil.

If we're to provide landscapes that will enable wildlife to travel with moving climate zones, we need rewilded corridors – with trees – to create the connective webbing between biodiversity hotspots. Natural regeneration would be perfect for this, as well as for creating biodiverse treescapes for the future.

The challenge is how to get natural regeneration high, if not top, of the tree-establishing agenda. It will involve a complete change of mindset. The rehabilitation of thorny scrub for a start is currently regarded with zero tolerance by most land managers. A change in the funding paradigm; a different way of engaging people with establishing trees, other than spades in the ground; and the guts to confront and dispel the vested commercial interests in propagating species-poor plantations is required.

But the wisdom, the millions and millions of years of evolution, is on natural regeneration's side. So I introduce, with great excitement, the following articles from some of our greatest ecological thinkers and woodland specialists in the UK who bring insights and intelligence to bear on this issue. They will perhaps help us forge a new way forward for our beloved trees. Natural regeneration is a simple route to complexity. As the late, great, Oliver Rackham said: 'The easiest way to create a wood is to do nothing'.

Natural regeneration: history, ecology and the importance of meaning

Jonathan Spencer

It is not necessary to plant trees. Trees will, over time, grow on any land where opportunity, and a pause in grazing pressure from livestock, rabbits and deer, allow. So much can be learnt from naturally regenerated woodlands about the past and hence the future of our tree and shrub species under various conditions. In the face of uncertain climate change, this knowledge has increased importance.

Jonathan Spencer is an independent ecologist, with wide professional interests in the history and ecology of woods and forests; the conservation of their historical character and wildlife; and in forest resilience, silviculture and management.

A consequence of benign neglect

In 1793, almost 230 years ago, only 4% of the county of Surrey was woodland. Now it is one of the most wooded counties in England with over 22% woodland cover, rising to over 40% in some places such the Surrey Hills Area of Outstanding Natural Beauty. Virtually all of these trees have arisen spontaneously on heathland and farmland, in gardens and parks, neglected corners of land and abandoned railway lines since the mid-19th century. The decline of traditional grazing on heaths and commons, and the gentrification of the county, has created a land full of trees, with canopy cover so thick that by many international definitions, Surrey would be classed as a forest.

A large majority of these trees arose by spontaneous regeneration due to benign neglect, with the remainder the result of deliberate planting of woodland, and of trees in gardens, parks and hedgerows. Seedlings from planted trees have spread generously into neglected lands, taking advantage of non-native plantations, local woods, gardens and lost corners afforded protection from grazing and browsing animals. So pronounced was this tendency across the Weald that Humphry Repton (1752–1818) commented: "every berry soon becomes a bush and every bush a tree". Surrey and Sussex are landscapes of default, nested within landscapes of human design.

The same can be seen elsewhere in the UK, most notably where land was of poor quality and where traditional farming collapsed in the 19th century. In the early 20th century, the expansion of more efficient farming on fertile land left the heaths and commons, steep slopes and unprofitable clays to decline through lack of use.

Extensive areas of secondary woodland arose in this way, from both natural succession to woodland and from deliberate 'improvement' and afforestation. Such woods and forests are found on soils as varied as the steep chalk and limestone slopes of the Downs, the Chilterns, the Cotswolds and the Peak District; in parkland landscaping around grand houses on greensand and other 'poor grounds'; and in the semi-

Charlie Burrell, Knepp Wildland

natural colonisation of heaths and commons by pine, birch, sallow and oak.

Benign neglect, wartime stringencies, social change, developments in technology, markets, fashion and individual finance are often followed by rapid tree recruitment and succession; leading to new semi-natural woodlands, their character determined by soils and past land use. They account for a very large proportion of woodland found across the lowlands of southern, western and upland England and parts of Scotland. The expansion of woodland has, ironically, been one of unintended consequence, driven by a combination of social change, agricultural improvement and enclosure and the urbanisation of much of southern England. Trees were planted, but by far and away the largest driving force was the trees themselves and the protection afforded them from grazing, browsing or disturbance. Livestock were largely removed, deer were largely absent, and much land largely left alone.

The downland above Broughton in West Hampshire illustrates these slowly unfolding processes. The old drovers' roads up to the treeless downs are clearly shown on the OS map of 1817. These droveways were fenced off at enclosure by beech hedges in the early 19th century, which are now lines of tall, veteran beech trees. The walk takes you up past Smiths Plantation, a small patch of enclosed land planted with beech on thin and otherwise uselessly steep soils, and now a semi-natural woodland of beech and yew. Further along the same scarp, planted beech stands now host many trees and shrubs of more natural origin: wayfaring tree, spindle, privet and thorn, alongside ash, maple and whitebeam. These are good examples of how planting, in this case with beech, leads to woodland of more semi-natural character whose original purpose (presumably as a useful crop of beech timber) has long been forgotten, but which is now greatly valued for other reasons, not least the wonderful character of the planted beeches. And trees and shrubs continue to press on the open downland, regenerating onto the chalk grassland where such tree recruitment is rather less welcome.

It is not the whole story of course. Extensive planting of fast-growing conifers on land in the uplands and in western Britain has created new landscapes and thriving forest industries. These plantations have evolved over time and some now hold considerable ecological and conservation interest, particularly where native trees, such as birch, aspen and sallows, have regenerated within and between more commercial stands. Now, in these plantations as elsewhere, there is a growing desire to use natural processes; with Douglas fir, western hemlock and western red cedar freely seeding to produce continuous-cover silvicultural systems.

Ecology and history intertwine

The ecology of trees and the history of any parcel of land interact. An ecologist will explore first the ecological parameters that give rise to the community of trees present at any one site and will present opportunities for tree establishment in ecological terms. What can the soil characteristics of the area support? What is the grazing pressure and what animals are browsing the trees? The forester, essentially an applied ecologist specialising in the establishment and management of trees, will consider site suitability for various tree species and their future utility. The historian will look at the origins of existing woodland and consider why and how they have arisen: when did it arise there on that parcel of land and why? When considering new opportunities for woods, the historian will consider the past historic landscape and the appropriateness of trees and woodland in such a landscape.

All three perspectives hold important and valid positions. The interplay of history, the past use and present circumstances, the nature of the soils, their past treatment, and the ecology of the plants and other wildlife that are now found in such woods, all generate meaning within these woods.

New meanings?

Natural regeneration can be a clear asset and an occasional nuisance. Much can be achieved by the way it is encouraged and nurtured. Woods, trees and natural regeneration had strong purpose in the past and will

again in the coming century. Those aligned with the forestry tradition (in Stourhead, Windsor, Cirencester, Cowdray, Coed y Brenin and the Cairngorms, for example) are witness to its value. Those aligned with the emerging rewilding agenda are alive to its potential.

The uncertain future that is now rapidly unfolding will challenge our young trees as they mature over the coming century. It is already challenging our imagination as to what we think the role of these woods and trees might be a century hence. History suggests that the woods and trees we establish now will have an agenda of their own, alongside the purposes we think we have attributed to them. Our aims and ambitions may well be comparatively short-lived or forgotten, and change with time, while the agenda of various tree species is very long term; written in evolutionary and ecological terms and conditions.

It would be wise to acknowledge from the outset that, given time, all of the woods we establish this century will eventually accrue meaning. It may be that they only reflect the planting fashions of the times; it may be that they provide important lessons for a future generation of woodland ecologists and foresters. Most likely they will find an economic role in the emerging low-carbon economy. However, we are not in a position to decide too precisely in advance what this meaning might be; it is far too early to tell. Meaning is too elusive an objective to worry about closely defining. But we can provide every opportunity for the processes of natural tree recruitment and woodland development to proceed and unfold. This not only contributes to natural capital values and the more traditional forest values of these new woods, but imbues them with interest, worth and a sense of place. Future nature and human requirements will determine the rest.

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Charlie Burrell, Knepp Wildland

Traditional grazing with longhorn cattle helps maintain a mosaic of woodland, scrub and grassland

Breaking down barriers

Emma Goldberg

Recently, practitioners have been increasingly asking about planting on nature reserves, driven by concerns about adaptation to a changing climate and fears over losses of trees to pests and pathogens. But there is a whole spectrum of options for increasing the resilience of our woods. We just need to be alive to the possibilities and the various advantages that come with them.

Emma Goldberg is a forestry and woodland senior specialist at Natural England, the Government's advisory body for the natural environment in England.

Charlie Burrell, Knepp Wildland

When establishing woodland in the UK, planting is the cultural norm, the expectation, but this isn't the case across mainland Europe. There, foresters define two types of tree establishment: 'Artificial regeneration' is "the renewal of a tree crop by direct seeding (sowing), or by planting seedlings or cuttings"; while 'natural regeneration' is "the renewal by natural seeding (self-sown seed), sprouting, suckering or layering"[1]. What is striking about this terminology is that it calls into question why planting is needed, and what purpose it serves.

Natural regeneration versus planting

Establishing woods by natural regeneration holds various advantages. A healthy ecosystem should be self-sustaining: it enables adaptation to pests and diseases and climate change; it can confer resilience to stressors (e.g. drought) through establishment of better tap roots; and it is (potentially) cheaper than planting, although management interventions will still be necessary (e.g. herbivore control). In new woodland creation, natural regeneration will give a natural composition, albeit most likely with fast-establishing pioneer species which will develop depending upon a variety of environmental factors[2]; with the length of time needed to achieve this unpalatable to some.

There are also several sound reasons to establish trees by planting. First, where the seed source for the desired tree or shrub species is absent, and is unlikely to arrive on site without planting. This is usually the case with establishing timber trees, but planting may be necessary for nature conservation purposes too, especially if species are known to be lost from the site. Second, speed of establishment: planting tree saplings can significantly reduce the time required for the initial phase of establishment. This is relevant where the objective is carbon sequestration. Third, putting trees into the ground increases the probability of successful establishment. Finally, especially in a new wood, planting confers choice over the (near) final composition of the wood. But defining it as 'artificial' highlights the issue: it immediately suggests that something's wrong with the status quo; that the woodland isn't functioning as it should.

Natural regeneration versus planting doesn't need to be a binary choice: some enrichment planting or direct seeding could help diversify a single-species wood while retaining most of the trees as a seed source for regeneration potential. Small-group planting in establishing a new wood may also give a 'boost' in species and speed of establishment. Although the outcome can be slower, that needn't be a deterrent where nature conservation is the objective. In fact, open, scrubby woods with more nectar-bearing shrubs may be richer in wildlife than woods with more densely planted trees. It may take twenty or more years for a 'convincing' wood to establish.

This can be problematic where nature conservation is not the sole objective. One possible solution is to employ systems like continuous-cover forestry. This is an uneven-aged form of forestry where a few selected stems are felled on a regular basis, rather than clear-felling stands on a longer rotation. Because of the selective felling, the resultant forest visually appears more naturalistic.

Resilience to future changes

In terms of the resilience of woods, the importance of genetic variation cannot be overstated. The truth is, the human brain is not wired up to intuitively understand large numbers. A popular internet meme illustrates this succinctly: "one million seconds is about 11 days; one billion seconds is just under 32 years". Similarly, it is difficult to comprehend the genetic variation within a population of trees: the forest is filled with trees, each tree produces seeds, and each seed is produced by the random product of the seed tree and pollen that has arrived from different sources. Each seed has a unique combination of genes. They may start to ripen, say, in late May and will continue to ripen until November. They fall, or are dispersed, within the local area, and then more magic happens: the seeds that germinate successfully will do so depending on the site conditions the following year. In a wet spring, some will do well. In a dry spring, a different subset will be successful. Some will derive from early germinated seeds, while others will derive from later ones. The sheer number of seeds, each holding different genetic variation and varying even year on year, means that woodlands contain an amazing genetic resource and are able to respond to changes, both incremental and sudden. In terms of resilience, this variation is key. Because of it, trees have a great ability to adapt to pests and diseases and can show a measurable response in one generation[3].

The likelihood of 'adaptive escape' from pathogens is increased by five factors:

1. a large initial population size
2. high genetic variability of the initial population
3. high reproductive rate
4. high initial level of resistance to the pathogen
5. the 'ecological opportunity' for regeneration to take place in the presence of the pathogen – in other words, the pathogen will remove individuals that are unable to defend against it, leaving behind the individuals better able to cope; therefore, making the population increasingly resistant.

This adaptive escape also extends to climate change. There is advice to try to combat the effects of climate change by augmenting the genes within a population by collecting seeds from a site with conditions more similar to the future that we expect to face. However, there is far more variation within a woodland than a seed collector can gather in two weeks in late

Overgrazing by wild herbivores can significantly impede natural regeneration

September from a few specimen trees. These seeds are typically collected from strong performers (usually in terms of tree height and girth), but will be grown in nursery conditions where the selection pressures on the seedlings are reduced and differ markedly from conditions within the wood. From a practitioner's viewpoint, it may seem woolly at best, or downright foolish, to 'do nothing' in the face of threats from a rapidly changing climate and increased pests and pathogens. This, however, does not take into account the genetic resource already active in the wood.

Natural England advocates the use of 'local provenance' planting stock. This is based on the importance of genetic diversity and local adaptation, although it suffers the same disadvantage as collecting seed from other provenances: the limitations of collecting a small number of seeds, and the inability of selection pressures to act in situ. Furthermore, it is well documented that as far back as the Middle Ages, caskets of acorns and beech nuts were traded or gifted from other countries[4], which appears to make something of a mockery of a requirement for local provenance (although it's far less likely they traded in seeds of shrub species). If, however, we stop thinking about genetic purity (an uncomfortable subject at best) and start thinking about gene flow, and the function that it serves the ecosystem, there is a strong argument to continue this requirement where enrichment planting is undertaken.

Practical challenges

A critical issue currently facing woods is a higher deer population than at any point in history[5]. High deer numbers are an impediment to planted woods as well as natural regeneration, although it's much simpler to protect planted individuals with tree guards. So, while natural regeneration may carry the advantage of economic savings in establishment, both approaches require deer fencing and deer management. Deer management is the most effective means to make woods more resilient.

Dominance by woody shrubs, such as elder or hawthorn, is a potential initial outcome of natural regeneration which could remain in stasis for some time due to shading out other species. This is more likely to occur in areas remote from suitable seed sources and in small areas of land. However, depending upon the objectives, this would still provide an abundant source of nectar as well as foraging and nesting opportunities.

A separate issue is that trees and shrubs may establish that are non-native and potentially invasive, such as rhododendron – a serious threat to native woodland. It's important not to conflate natural regeneration with minimum intervention management: natural regeneration is simply a tool for establishment. Choosing natural regeneration does not mean that no management can take place, and that anything that grows should be left to establish. A site manager can decide to accept what arrives, or remove it, and possibly to manage the seed source. This would be necessary to protect a valued habitat composition: for example, on a designated site. Outside of designated sites, however, there is a case for accepting anything that arrives naturally, promulgated by George Peterken[6] as a 'future natural' species composition, which may give rise to resilient woodlands.

Managers rarely have single objectives, and our choice for establishing a woodland needn't be restricted to either natural regeneration or planting. However, how we choose to proceed should be measured against our objectives. There's a spectrum of planting choices, from natural regeneration with a view to facilitating 'future natural woodlands'; natural regeneration with intervention to modify the species mix; ground preparation versus no ground preparation; direct seeding and planting with local provenance or planting with varied provenance; to planting non-native trees. There may be value in adopting more than one method on a single site to satisfy multiple objectives.

In summary, natural regeneration gives rise to a more self-sufficient woodland, with a more natural species composition and the ability to adapt to its environment and to threats and pressures. Where woods are being established or managed with nature conservation as a primary objective, it's the appropriate default. However, there are some important modifiers: managing deer and other herbivores is key; replacing lost species or diversifying the composition may be desirable; and removing invasive species may be necessary. Further selection or enrichment planting may be possible to satisfy additional management requirements. Establishing woods by natural regeneration is likely to be slower with less predictable outcomes, but can be extremely valuable for wildlife. It's important that we reflect and challenge our choices over time as we understand more about the threats and pressures, and the values we place on nature reserves.

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Naturally regenerated woods support a diversity of wildlife and should be the default for nature conservation. Clockwise: cricket-bat orb-weaver spider, beautiful demoiselle damselfly, slow worm, fieldfare, red fox, ferret-polecat, grass snake, purple emperor

Phil Formby/WTML

Woodland Trust's Ben Shieldaig: Scots Pine woodland with pine and birch regeneration in the foreground

Natural regeneration promotes genetic adaptation

Joan Cottrell

The Government has ambitious plans to increase woodland cover in the UK and this involves important decisions on preferred species of trees and shrubs, how new trees are established (via natural regeneration or planting), and what land can be used for this expansion. The familiar mantra 'the right tree in the right place' is an acknowledgement that species are adapted to grow in particular conditions. Depending on management objectives, natural regeneration is one means of promoting well-adapted and resilient woodland expansion.

Joan Cottrell is the science group leader for the Gene, Species and Habitat Conservation Programme at Forest Research.

A tree species is not a single entity as populations differ depending on where in the distribution range they come from. A population of a given species is, therefore, adapted to the conditions in which it grows. This aspect of diversity – within-species diversity – needs to be considered when deciding what plant material to use to extend existing woodlands or establish new ones. Poor understanding of within-species diversity can lead to inappropriate choice of material when planting woodlands. One option is to promote natural regeneration to extend our existing woodlands, which removes the need to choose what material to plant and harnesses natural processes to determine what survives on a given site.

It is vital that we recognise, understand, and conserve the within-species component of diversity. We need to consider three key processes that allow individual trees and tree populations to survive and adapt to current and future conditions.

1. Phenotypic plasticity

Phenotypic plasticity represents the process whereby a tree can alter many of its traits in response to the environment in which it is growing. For example, during particularly dry seasons, trees alter the structure of their leaves and tend to produce smaller leaves in which the stomata (pores) are reduced in size and are more densely arranged. This provides a means whereby the individual tree can maximise its ability to manufacture photosynthates during optimal years but can alter its structure in order to conserve more water when conditions are particularly dry. This process will assist existing individuals to respond to the drier environment predicted in the future and increase their chances of survival. However, an individual's phenotypic plasticity is finite and if conditions exceed the plastic limits of the individual, it will die.

2. Genetic diversity and genetic adaptation

Tree populations are known to contain high levels of genetic diversity which provides the raw material for genetic adaptation. Several characteristics of trees promote the maintenance of high levels of genetic diversity. These include prolific and frequent production of flowers so that the seed crop of a single tree can be the product of a multitude of fathers, growing both in the immediate neighbourhood as well as a considerable distance away. Trees also tend to be intolerant of self-pollination so that outbreeding predominates. The flowers and the seed are held high above the ground so that pollen and seed are favourably positioned for long-distance dispersal to sites which may experience very different environmental conditions from those of the mother tree.

The genetic diversity present in a population is shaped by the mixing caused by this local and long-distance geneflow. The population is replenished with a continuous supply of genetic material adapted to a

An oak tree bears many acorns, each one containing slightly different genetic material

range of conditions. This ensures that genetic diversity is maintained at a high level and adaptive variation from elsewhere is continually being introduced into the population. However, natural selection operates on this diversity and promotes the survival of individuals that are best suited to the prevailing site conditions. These individuals then breed and produce the next generation. This process allows the population to become adapted to the site on which it is growing, even if these conditions change. The end result is that populations become differentiated from one another while continuing to maintain a high level of genetic diversity. This has two important consequences: populations are adapted to the local site conditions yet maintain high levels of adaptive variation which provides them with the means to genetically adapt to novel threats and conditions.

3. Genetic control of adaptive traits

The majority of adaptive traits are controlled by a large number of genes, each of which makes a small contribution to the expression of a trait, such as growth or drought tolerance. As this is the case, the large number of seedlings produced by a single mother tree pollinated by a multitude of fathers, are all individuals and are subtly different from one another across a range of adaptive traits. This large variety of seedling individuals presents natural selection with a broad palette of material from which to choose the most appropriate individuals for the current site conditions. Those individuals will have the particular combination of genes that confer on them the most appropriate characteristics across a range of traits to survive and breed in the conditions in which they grow. If conditions remain the same, it is likely that seedlings produced by a mother and father from within the wood to which they are locally adapted will have a selective advantage.

What happens if conditions change?

Our woodlands are currently facing unprecedented threats which are predicted to increase in the future. Exotic pests and diseases are becoming an increasing problem in our woodlands. In addition, conditions are predicted to alter under climate change, including a significant rise in temperature. In some places in the UK, these warmer temperatures may improve growing conditions for certain tree species, but elsewhere in the country, increased occurrence of extreme weather events, such as floods and drought, are likely to make conditions more challenging.

However, it is important to note that many of the site conditions, such as photoperiod, will remain the same. So, the idea of predictive provenancing, in which material is introduced to the UK from more southerly countries which currently experience the predicted future UK temperature conditions, may not produce the intended benefits. Such material may be adapted to warmer conditions, but its phenology (for example flowering or leafing period), which is partly controlled by photoperiod, may be out of step with the day length experienced at the introduction site. Traits such as bud

Charlie Burrell, Knepp Wildland

Long-distance dispersal of pollen and seed contributes genetic material from sites that may be better adapted to changing conditions. Top to bottom: hazel catkins, hawthorn fruit, whitebeam fruit and Scots pine male flowers

burst and leaf senescence are known to be under the control of both temperature and photoperiod. This mismatch in phenology may result in damage to the trees themselves. For example, trees that come into leaf too early may be damaged by infrequent weather events, such as late spring frosts. Phenological mismatching may also impact on wildlife and future seed production: for example, when flowers emerge before their pollinators.

To adapt, local material growing in situ will, in the first instance, harness its phenotypic plasticity to cope with these novel conditions. This may involve trade-offs: for example, growth rate may reduce for the material to become more drought tolerant or more resistant to novel diseases. In the longer term, genetic adaptation will occur via natural selection of the individuals best suited to the novel conditions while retaining their adaptation to the features of the environment that have remained the same. The consistent long-distance geneflow may help in this process by contributing genetic material from populations adapted to different conditions elsewhere.

Current understanding of resistance to Hymenoscyphus fraxineus (ash dieback disease) illustrates the importance of knowing the amount and distribution of genetic diversity in predicting the ability of our populations to adapt to novel disease threats. It was initially thought that common ash populations may lack resistance to the ash dieback pathogen and it was suggested that hybridisation with other exotic ash species might be required to introduce resistance. However, it is now known that small numbers of resistant individuals exist in almost every ash population and, on the basis of this, scientists consider that, in the long term, ash in the UK will evolve resistance to the disease via natural selection of resistant individuals. Providing there is plentiful natural regeneration, this increase in resistant individuals in a population can occur very quickly in situations where a strong selection pressure, such as that of ash dieback, is imposed.

Opinions differ regarding what we should be doing now to prepare for an uncertain future. Where natural regeneration is a viable option, management is essential to promote the production of plentiful material on which natural selection can operate. This involves the promotion of seed production, the creation of space within woodlands for seedling establishment, and the control of herbivores so that enough of the established seedlings survive. Where natural regeneration is not a viable option or does not meet management objectives, planting stock will be required to achieve woodland expansion. When sourcing planting stock it is important to enquire about its provenance, i.e. where the plant material comes from, in order to assess whether it meets requirements.

Further reading

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A wilder approach – what works?

Rebecca Wrigley

The UK is one of the least wooded parts of Europe. We need to address this, and increase our tree, shrub and woodland cover, for many compelling reasons. But we have a challenge on our hands. How do we start the process of expanding our wooded habitats? Do we simply stand back and allow nature the space to work its woodland-creating wonders? Do we kick-start the process then stand back? Or do we get stuck in and act as nature's guiding hand? Rewilding Britain commissioned a review of the evidence on what approaches work best in which situations.

Rebecca Wrigley is chief executive of Rewilding Britain and has a wealth of experience in engaging local communities in decision making about the land and its resources.

Barriers and facilitators

In many cases, trees and shrubs readily colonise land when free to do so. Some species colonise consistently. Some take longer. Some seem not to arrive even after a long wait. We still lack a basic understanding of what limits the dispersal of some tree and shrub species.

The circumstances at a site can play a big part in whether trees and shrubs take hold. A thick thatch of tussocky grasses can be a formidable barrier. But wild boar can break up the thatch and give seedlings a toehold[1]. Cattle can serve a similar role, pulling apart the thatch and creating bare soil into which seeds fall and germinate. Mechanical 'scarification' can kick-start recolonisation by exposing ground to pioneer species such as willow and birch[2].

However, even if trees and shrubs get to a given site and germinate successfully, they have to contend with the hungry mouths of large herbivores. In the UK we have an over-abundance of native and non-native deer, all in search of woody plants. At very high density, larger deer can all but curtail any tree and shrub growth[3]. At lower density, deer tend to sculpt the growth of trees and shrubs, not prevent it. That's just as nature intended it. Trees and shrubs are well adapted to withstand light grazing and browsing pressure.

Sheep are a different matter. Large areas of our uplands are heavily grazed by sheep which prevents any natural regeneration of woodland or woody shrubs. Our upland National Parks are bare and often ecologically bereft as a result[4]. Any strategy for increasing tree cover should start with rural support measures to reduce grazing pressure on sensitive upland ecosystems and encourage their restoration.

One of the biggest barriers to natural regeneration is our misunderstanding of scrubland, which is too often seen as wasted space and untidy. In fact, thorny scrub is a nursery for regenerating trees and a brilliant mosaic habitat in its own right[5]. Many ecological surveys find higher biodiversity in the different habitats of scrub than in adjacent closed-canopy woodland. The old days of conservation volunteers spending weekends scrub bashing must be left behind – scrub is to be welcomed, not feared. If we abandon our hatred of scrub, the trees will plant themselves.

While closing the gate on a field and walking away will, in most cases, mean a rapid reversion to scrub and then to patchy woodland, this is not guaranteed, and the speed and type of establishment depends on many factors. Natural regeneration is best understood, therefore, as part of a broader rewilding agenda where natural processes are allowed to take place over larger landscapes rather than ecological restoration being directed towards specific outcomes.

Lessons from around the world

Looking at other countries, we find evidence in favour of natural regeneration. In Eastern Europe and the former

Charlie Burrell, Knepp Wildland

The UK has an over-abundance of native and non-native deer, all in search of woody plants

USSR, a huge natural regeneration experiment has been taking place since the collapse of the Soviet Union. More than 58 million hectares of former croplands in Russia and Kazakhstan have been abandoned since the disintegration of the collective farming system. Virtually all of this area has been subject to 'spontaneous reforestation', without a stake or tree guard in sight. Even after just a couple of decades, reversion to pine and deciduous forest means that these areas are absorbing huge quantities of carbon, estimated to total nearly 50 million tonnes per year (equivalent to 150 million tonnes of carbon dioxide) in Russia alone[6].

Similar evidence comes from coastal southern Norway, which a century ago was as deforested and bare as many parts of Scotland. Now, flourishing broadleaved forests clothe the lower slopes of mountains – including many species that are extremely rare in Scotland. This is an important case study for how natural regeneration might proceed in Scotland and Cumbria if left unimpeded by sheep and deer grazing pressure, and other forms of detrimental management such as 'muirburn' (the deliberate burning of hillsides)[7].

The Norwegian experiment suggests that, given enough time, Scotland could return to the same thriving ecosystem with little intervention bar the removal of grazing pressure. Norway challenges our perceptions of where forest should be: grasslands and woodlands are more integrated (rather than being fenced off from each other). Treelines are also much higher than most people

A treecreeper takes advantage of the bounty of insects at Knepp Wildland


Wild Ennerdale

Naturally regenerated trees clothe the hillside at Wild Ennerdale in Cumbria

suppose. Dwarf birch would likely survive in Scotland at 600–900m under natural conditions, as would dwarf willow and other broadleaved species[8]. These montane ecosystems are extinct in Scotland because of centuries of continued grazing pressure, not because of climatic unsuitability.

Britain's rainforests

Under natural conditions, the UK would be a rainforest nation. Our islands are squarely located in the temperate rainforest biome, and fragments of this extremely rare habitat still exist in West Wales and Scotland – the so-called Celtic or Caledonian Rainforest. Rainforests were once extensive on the maritime slopes of westward-facing uplands, thanks to a climate which delivers moderate to extreme precipitation frequently throughout the year[9].

Caledonian pinewoods, Celtic broadleaved woodlands and sessile oak woodlands – which exhibit a high richness of epiphytes like mosses, ferns and lichens – are considered Europe's true rainforest relics. In Britain, such rainforests once supported European bison, wild boar, wolf, lynx, elk, red deer and European brown bear. Some of Wales' Celtic Rainforests are considered to be among the best examples of natural oak woodland in Europe. But even these small fragments are threatened by grazing pressure, the introduction of non-native conifers and invasive species, such as rhododendron. Their value is now recognised by Celtic Rainforests and managed jointly by Snowdonia National Park Authority, the Woodland Trust, RSPB, Natural Resources Wales, and other partners.

These remaining tiny fragments of our rainforests should be prioritised as centres of origin for large-scale natural regeneration. The same is true of ancient woodlands across the rest of the UK, which are small and fragmented. They urgently need to be allowed to expand over as much of their former landscapes as possible.

As soon as we stop destroying trees – by ploughing, strimming, cutting and grazing – they will plant themselves in their many millions. Britain will then begin to look more like the ancient wildwood that once ranged across these islands.

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What's stopping natural expansion?

Ben McCarthy

A mere 13% of the UK is wooded, of which only about half is native woodland. So what has stopped our woods naturally expanding and what do we need to do to create more wooded landscapes that are good for nature, climate and people?

Ben McCarthy is head of nature conservation and restoration ecology at the National Trust. Having held senior positions with statutory and non-statutory organisations, he now provides national leadership to realise the National Trust's ambition for nature and nature-based climate solutions.

Charlie Burrell, Knepp Wildland

Management of landscapes has largely prevented the natural expansion of woodland and threatens surviving trees

Making up lost ground

Culminating with the pressures of the First World War when woodland cover dropped to around 5% of the UK's land area, the 1919 Forestry Act marked a step change in the ambition for the UK's woodland. With a newly created Forestry Commission tasked with promoting forestry and the production of timber, the focus was on ambitious planting schemes on land made cheap by depressed land values and changes to the rural economy that looked to serve an increasingly urban population.

To meet the national needs, a sustained period of planting was undertaken on an industrial scale where increased mechanisation and economically efficient returns were maximised by clear-felling and restocking of fast-growing non-native conifers. This trend continued well into the 1980s with much criticised tax breaks and other financial incentives resulting in the loss of precious open habitats, from the bogs of the Flow Country to the grasslands of the Brecks and heaths of Dorset, giving rise to a clarion call for 'the right tree in the right place' down the corridors of power.

Yet despite this policy approach, the UK is still lightly wooded when compared to our continental neighbours – a mere 13% compared to a European average of about 37% land cover. That equates to some three million hectares, of which only about half is native woodland. Increased tree cover will be essential in the fight against climate change, but this must and can deliver multiple benefits for people and wildlife also.

A more integrated approach

Unsurprisingly our woodlands today reflect the incentives and opportunities of yesteryear, with woodlands unevenly

distributed across the four nations. Scotland has 19% cover, Northern Ireland just 9%, and Wales and England 15% and 10% respectively.

While these post-war gains offered very real improvements to the timber industry and the UK's economy, they did so at considerable cost. Despite on-going increases in woodland extent, long-term declines in woodland biodiversity continue due to a lack of active management and a range of other factors, including disease, invasive species and atmospheric pollution.

In the uplands and northern regions, the legacy is so often a stark contrast of either large coniferous plantations or whole landscapes denuded of their native trees and woods, except for where they cling on in small, ageing copses, abandoned hedges or inaccessible gills. Yet in the lowlands of southern England, and beyond the protected forests of old, land-use change and the effects of urbanisation at the turn of the 19th century allowed woodland cover to increase almost exclusively through natural regeneration.

This same potential for natural regeneration can still be seen today as you travel across the country, with early successional species of bramble thicket and nursery thorn advancing along our road verges and railway embankments, nurturing scrub and trees as fast as the maintenance teams can cut them down.

Better policies required

The latent potential of natural succession exists, ready to augment and complement more targeted planting, yet has failed to advance in our agricultural landscapes which are so often stripped of wildlife. Current incentives require farmers to keep their land 'clear of any scrub' through grazing. This halts the succession of the dynamic transitional habitats that are so important for our biodiversity – creating what Frans Vera described as a 'kaleidoscope' of wild and natural landscapes.

A new, targeted approach to realise the opportunities that more sustainable land management offers in response to our nature and climate crises would mean we can unleash the potential of natural expansion from the trees that remain. The restoration and indeed renovation of our remnant trees would allow such 'shadow woodlands' to nurse landscapes back to life. The resulting wooded pastures and meadows would provide a more varied landscape, rich in wildlife, serving people through the benefits they delivered, such as carbon capture, soil conservation and more sustainable food production.

A more integrated policy framework to support *'right tree – right place – right method'* is required to restore our trees and woodland across landscapes as an integral part of restorative land management. To quote Sir Bob Watson, chair of the United Nation's IPBES* global assessment of biodiversity and land degradation: *"Governments have focused on climate change far more than they have focused on loss of biodiversity or land degradation. All three are equally important to human wellbeing".* Trees and woods will play an important role in the nature-based solutions to tackle all three.

Thankfully, the value of trees and woods is better understood today, and the benefits are increasingly being recognised in national policies that aim to expand tree and woodland cover and realise the public benefits they offer. This so called 'natural capital', underpinned by the wildlife that drives our woodland ecosystems, is now valued at £130 billion, with non-market benefits exceeding the market benefits of timber 12:1.

Our post-Brexit arrangements must invest in this natural capital and mustn't place too much focus on investment returns through greater production intensity. They must deliver more wooded and mosaiced landscapes in a way that brings multiple benefits, including for nature, through more widespread adoption of agro-forestry and agro-pastoral systems so our farmers and foresters can be rewarded for the public benefit they deliver.

By changing our land use and management, we can take advantage of the inherent potential of natural regeneration to play its part without the need for a tree guard. After all, as Oliver Rackham reflected: *'planting trees is thought of as the essence of conservation, rather than an admission that conservation has failed'.*

* The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem

Allowing trees to self-seed and establish would create landscapes rich in biodiversity while capturing and storing carbon

A framework for quality woodland creation

Saul Herbert

Native woodland creation can make a unique contribution to simultaneously tackling the climate emergency and nature crisis. Consequently, the Woodland Trust has aspirations to significantly increase the amount of woodland creation that we carry out. To ensure that our new woods and trees provide maximum benefits to people and wildlife, we are producing a definitive guide on our approach to woodland creation.

Charlie Burrell, Knepp Wildland

Saul Herbert is conservation outcomes manager at the Woodland Trust.

The Woodland Trust has a hand in around half of all the native woodland creation that occurs in the UK each year. This has resulted in a huge resource of collective knowledge and experience among our advisers and site managers, built up over more than 25 years of woodland creation work. We want to ensure that this is captured and recorded in a way that enables it to be shared with new colleagues, partner organisations and all those with whom we collaborate to establish new woods and trees.

To achieve this, we're working on a new guide that will set out our approach to woodland creation, whether on our own estate, with individual landowners or working with partners at landscape scale.

Our emerging approach

Woodland creation is complex. It occurs in different contexts: urban and rural, upland and lowland, pastoral and arable landscapes. Our guide will, therefore, cover every possible permutation of ways to establish new woods and trees: from individual hedgerow trees, urban street trees and trees in the farmed environment, through to large-scale woodland creation in the uplands.

Our rationale for establishing trees, on which our approach to woodland creation is grounded, is threefold:

1. to deliver conservation outcomes which support nature recovery and ecological resilience
2. to play a key role in mitigating climate change through sequestration and long-term storage of carbon
3. to deliver a multitude of other benefits to people's lives and livelihoods.

The approach is not intended to be prescriptive, but will provide a framework for quality woodland creation on which advisers and landowners can build, based on their own knowledge and experience. We want to encourage creativity and imagination in designing and establishing new woods and trees, and to observe and respond to natural processes as a site develops. This will ensure that we avoid generic prescriptions. Instead, we will work to create woodlands and restore landscapes with a strong sense of place that are well adapted to local conditions and are resilient to the impacts of climate change, pests and diseases.

The guide will support our advocacy for greater use of natural regeneration as an important contribution to meeting ambitious woodland creation targets. UK tree nurseries simply cannot supply enough UK sourced and grown native trees to meet demand. As well as being a practical way to establish the thousands of hectares of new native woods needed over the coming years, natural regeneration can achieve numerous benefits for nature recovery and ecological resilience, as explained in earlier

articles. To this end, the guide will provide a framework for blending methods of establishment on a site, using planting, seeding and natural regeneration in innovative combinations.

A framework for success

The guide will set out the approach that we follow in all of our woodland creation work. This begins by getting a good understanding of a site. It covers everything, from physical attributes such as altitude, aspect and soils to practical considerations, including vehicle access, overhead power lines and tree safety issues. Of particular importance is gaining an appreciation of the existing conservation features of the site at this early stage – features such as patches of species-rich grassland and individual veteran trees can be adversely impacted by inappropriate tree planting.

The next phase is to develop a vision and a creation design for the site. Creating new native woodland can deliver a wide range of benefits for people and wildlife, from buffering and extending ancient woodland to carbon sequestration, reducing flood risk or providing opportunities for public access. The design process involves creatively combining the aims of woodland creation with the particular characteristics and opportunities presented by the site. It is at this stage that key decisions need to be made about how trees will be established.

In many ways, the 'creation' event is just a moment – a few hours or days in a process which takes decades to mature and develop. But the fingerprint of the methods used to establish trees, whether through planting, seeding or natural regeneration, is evident in woods long after they have established. It is key to defining the Trust's approach to ensure that we're focused on the long-term results of our work. Establishing native trees is the critical first step in developing woodland ecosystems that support a wealth of wildlife. Benefits for people – whether long-term carbon storage, urban cooling or simple enjoyment of an enhanced landscape – can take decades to realise.

Those aren't decades of passive observation though. Our approach will provide a guide for advisers and landowners on helpful interventions to nudge along the development of new woodland – anything from when to consider thinning dense stands, to enrichment planting, cattle grazing or installing bird and bat boxes to replicate the cavities found in mature and veteran trees. Allowing time and space for natural regeneration is an essential part of the development of any new woodland.

Carbon, plastics and natural resilience

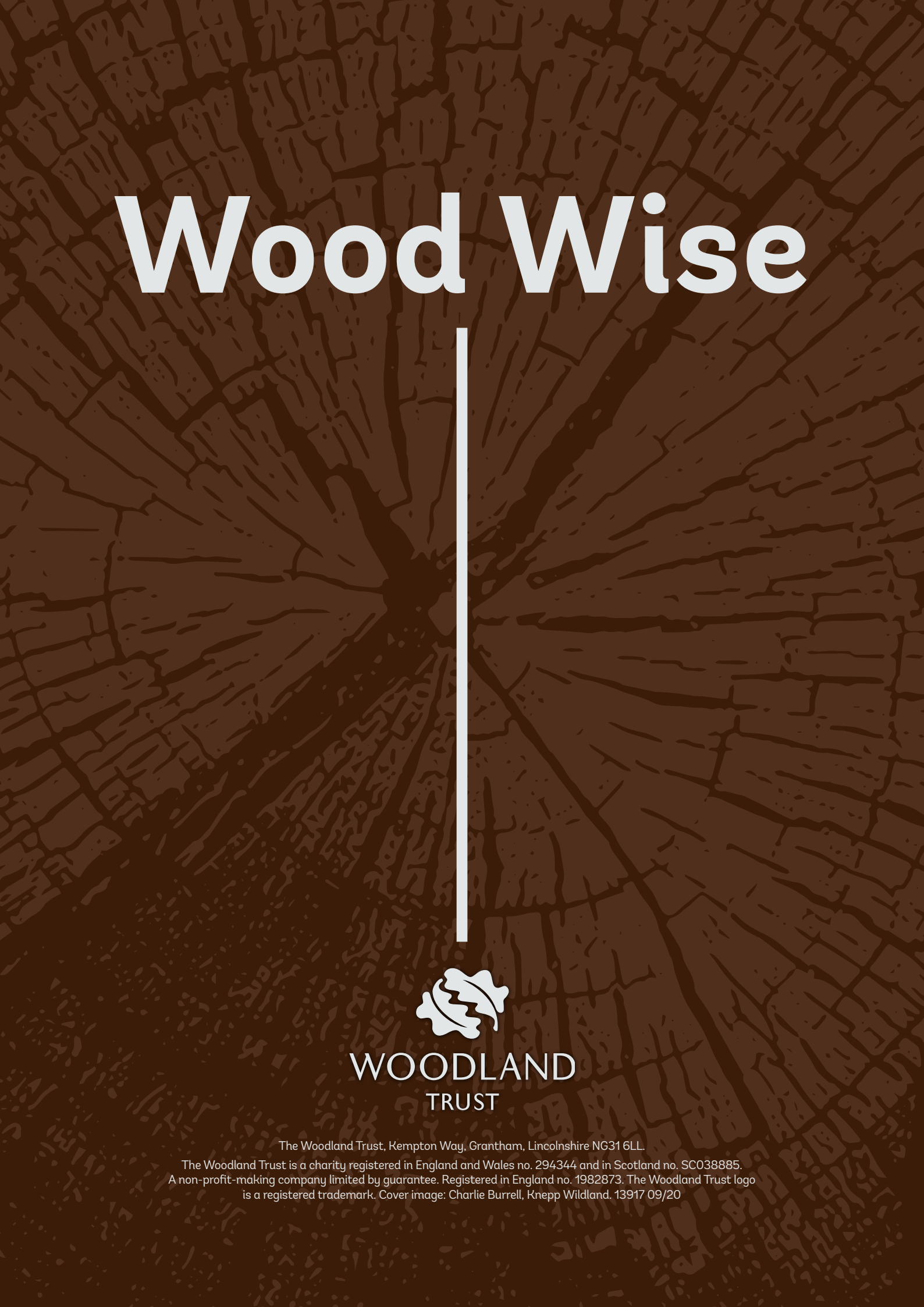
There are some particular current topics we will address, including sound guidance on creating and managing woodland to provide long-term carbon storage, and reducing reliance on plastic tree guards which protect young trees from herbivores. We are currently weighing up the evidence on alternatives to plastic tree guards, such as herbivore control, fencing and planting configuration, as well as the use of substitute materials for plastic guards, taking full account of the sustainability of alternatives.

Balancing tree planting with the use of natural regeneration is also key. We'll be considering not only how we can work to deliver more of our woodland creation through natural regeneration, especially on larger sites, but also how planting projects can be designed to accommodate and encourage natural regeneration within even the smallest of projects. This is particularly important as even though we base our planting on local provenance tree stock, nothing builds resilience and ensures that trees are well adapted to the conditions of the site better than the natural selection that occurs when trees are established through natural regeneration.

The guidance and tools for our approach are currently being tested, and will be published in early 2021.

Natural regeneration will make an important contribution to meeting ambitious woodland creation targets

Wood Wise



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