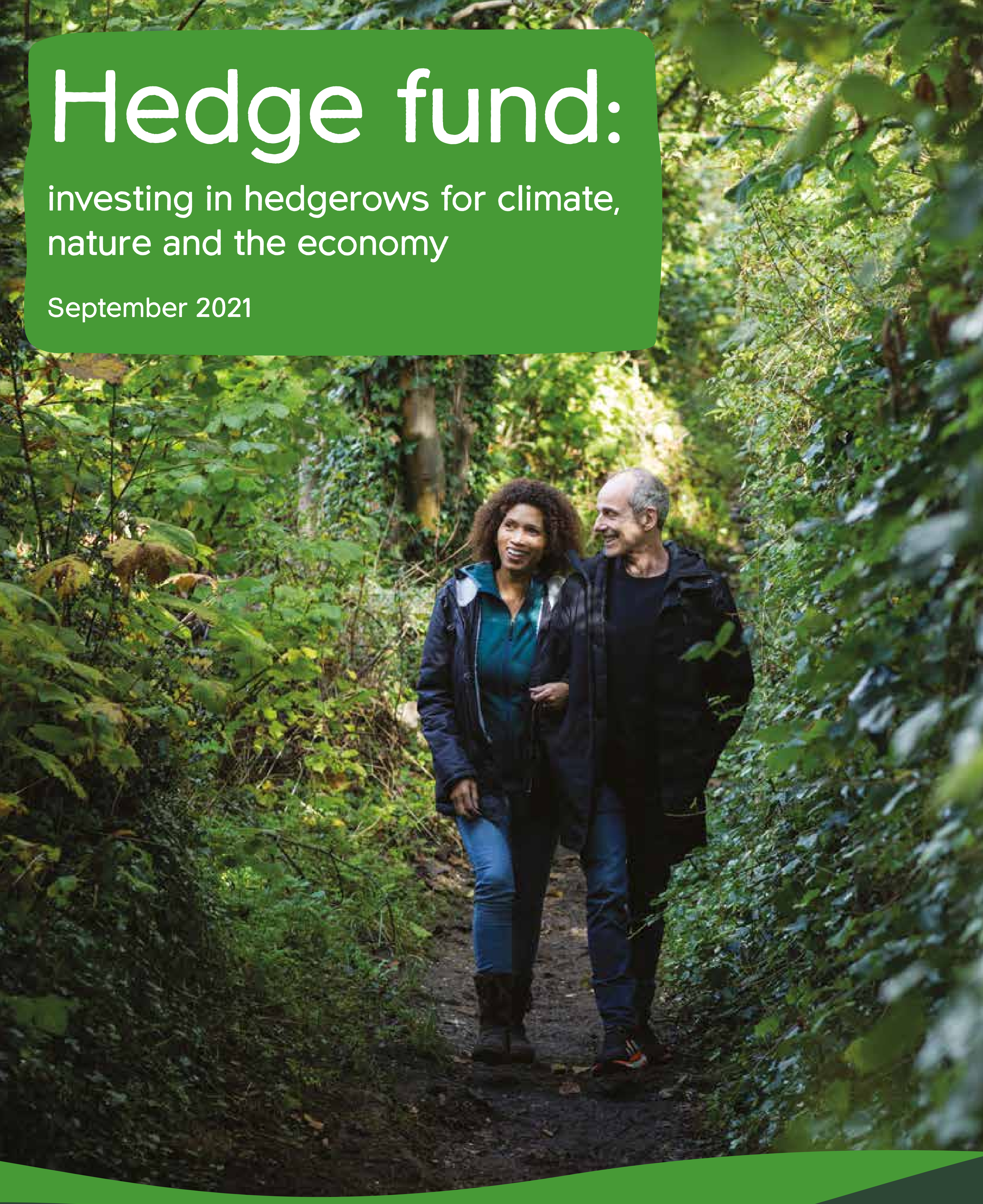
Hedge fund:

investing in hedgerows for climate, nature and the economy

September 2021



Research undertaken independently by

ORGANIC RESEARCH CENTRE

CPRE The countryside charity

Foreword

Lord Deben,
Chair, Climate Change Committee

I am looking over the fields outside my window and this is the first year that the hedgerows we have put back have begun to come to fruition. The countryside over which we look is now exactly as it was in 1850 before the hedges and trees were pulled out to make our pasture land into large arable fields. The destruction was not a wicked plot but a determination to make land more productive in order to feed our people during and after the war. Spurred on by Deficiency Payments and the Common Agricultural Policy, our yields rose and our wildlife diminished. As so often we overdid it – ignorant and careless of the effects it was having.

Since then, there has been a growing revolt as farmers and landowners, environmentalists and country people in general have begun to recognise how we have diminished the natural world and threatened species of every kind from mammals and birds to reptiles and insects. CPRE, the countryside charity's timely report concentrates upon the hedgerow and its pivotal role in habitat creation, soil protection, and the sheer beauty of the countryside. Reintroduction and proper maintenance of hedgerows transforms the all too sterile prairie land into the countryside, which for long we have loved. But, as this report shows, this is not about romance – the hard facts are that hedges contribute to profit as well as to wellbeing and CPRE is to be congratulated in putting the record straight.

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Executive summary and recommendations

One of the best ways to simultaneously tackle the climate crisis, boost nature and grow our economy is by restoring and increasing the UK's hedgerow network. Not only do hedgerows complement and enhance the unique character of our beautiful countryside, they are a haven for nature, remove carbon from the atmosphere and support sustainable local economies. But, shockingly, we have lost 50% of our hedgerows since the Second World War and they are still in decline.

The Climate Change Committee (CCC) recommends that the extent of our hedgerow network should be increased by 40% to support the UK government's goal of net-zero carbon emissions by 2050. In this research, commissioned by CPRE, the countryside charity, and undertaken independently by the Organic Research Centre (cpre.org.uk/ORC21), we provide an evidence-based overview of the impact of 40% more hedgerows for nature, climate and the economy. We then make recommendations on how the government, local authorities, farmers and land managers can maximise the potential of the humble hedgerow.

What's a hedgerow?

A hedgerow is defined as any boundary line of trees or shrubs over 20m long and less than 5m wide, and where any gaps between the trees or shrub species are less that 20m wide. Any bank, wall, ditch or tree within 2m of the centre of the hedgerow is considered to be part of the hedgerow habitat, as is the herbaceous vegetation within 2m of the centre of the hedgerow. Species-rich hedgerows contain five or more native woody species on average in a 30m length.

Economy

The analysis carried out for this report indicates that for every £1 spent on hedgerows, a return of as much as £3.92 can be expected as a result of some key ecosystem services and economic activities associated with hedgerows.

These include biodiversity enhancement, carbon sequestration and small-scale woodchip production, for local and domestic biofuel. The positive cost-benefit ratio suggests a compelling argument in favour of increasing the current hedgerow network in the UK. It is important to acknowledge that the nature of the costs and benefits are closely dependent on the location and management regime of hedgerows. It's also important to note that the benefits are expected to be even higher than this, as the value of £3.92 does not include the ecosystem services of water regulation and air pollution reduction – these were evaluated using a different approach and could not be aggregated in the composite figure.

Biodiversity

In its expanse, the hedgerow network is our largest 'nature reserve'. Just as our capillaries branch and penetrate the body to supply all cells with food and oxygen, the UK's hedgerow network must remain healthy in order to branch and spread deep across our countryside and supply every village, town, city and rural area with the ecosystem services they need. Healthy hedgerows are teeming with life and vital for nature – of the 1,149 UK priority species, 130 are significantly associated with hedgerows. These include the charismatic hazel dormouse, the much-loved hedgehog, whose decline has been closely associated with hedgerow loss, and the brown hairstreak butterfly, which lays its eggs on blackthorn and is particularly common in hedgerows. Many of these species have a key role to play in pollinating crops and as natural predators for crop pests. It is clear that continued hedgerow loss will hasten the decline of these species. Increasing the hedgerow network will aid their recovery.

Climate change

With as much as 5% of carbon sequestration on farms attributable to hedgerows, the role of UK hedgerows should not be undervalued in international efforts to mitigate climate change.

Indeed, the restoration and planting of new hedgerows will be an important part of the UK's international obligations to reduce national emissions by 80% before 2050. There is huge scope to increase the overall carbon sequestration and storage of UK hedgerows by allowing our hedgerows to become wider and taller. An ORC field study found that **a hectare of hedgerows between 3.5m and 6m wide could sequester as much as 131.5 tonnes of carbon per year.**

Air quality

Urban trees are commonplace as they are seen as a good tool for cleaning our air by filtering out pollutants, providing cooling shade and boosting biodiversity. But evidence indicates that hedgerows are superior to trees in urban street pollution management in 'canyon' streets, or 'high sided' streets — that is, streets with tall buildings. Unlike trees, when hedgerows are planted between public walkways and traffic, they do not constrain air flow. In cities hedgerows also act as a superior local barrier to airborne pollution because of their low and dense foliage. In open roads, again, hedgerows have their foliage at the correct height to act as a barrier to pollution whereas other greenery, such as trees, do not. Hedgerows can even block noise pollution from busy roads. These clear benefits would suggest that hedgerows, not just trees, should be the default solution for urban roadside pollution and noise control.

Cultural services, public health and wellbeing

Hedgerows are the vital stitching in the patchwork quilt of the country, lending beauty and character to the landscape. They provide tangible signs of the changing seasons, while at the same time giving a strong sense of continuity. They also make a significant contribution to local distinctiveness and a sense of place.

This report finds hedgerows to be a key component of public appreciation for the outdoors and enjoyment of rural landscapes. With most people spending between £1 and £3.50 on every outdoor recreational visit, the contribution of hedgerows towards regional economies should not be overlooked. There is substantial evidence to suggest the increased presence of green features in urban landscapes could have benefits to public wellbeing and enjoyment of outdoor urban space – and urban hedgerows account for around 10% of the nation's hedgerows.

Water and flooding

Flooding and soil erosion cause substantive costs to society. It is clear that planting hedgerows in some areas represents a valuable policy option to reduce the risk and damages of flooding events in the UK, which are being increasingly exacerbated by the climate emergency. Hedgerows also contribute to preventing soil erosion and nutrient loss, keeping our landscapes happy and healthy.

Jobs and growth

40% more hedgerows would result in **over 25,000** more jobs over a 30-year period for hedgerow planting and maintenance

For every £1 invested in hedgerows, as much as **£3.92** could be returned to the wider economy when the right hedgerows are planted in the right place

Recommendations

In order to achieve a 40% increase in the extent of the UK's hedgerows by 2050, CPRE, the countryside charity is making the following recommendations.

The government should:

1. Set a target to increase the hedgerow network by 40% by 2050 with extended protection under the Hedgerows Regulations to cover more existing hedgerows.
2. Design and deliver an environmental land management scheme (ELMS) that makes healthy hedgerows an attractive option for the agricultural sector.

Local authorities should:

3. Develop policies in local plans to ensure that hedgerow planting is integrated in new developments and that any damage to existing hedgerows is avoided (biodiversity net gain should never justify the removal of important hedgerows).
4. Work with local community groups to plant hedgerows in urban, and urban fringe (including Green Belt) areas, enhancing green infrastructure and directing funding to help deliver Local Nature Recovery Strategies.

Farmers and land managers should:

5. Maximise the environmental benefits of hedgerows by allowing them to grow taller and wider and ensuring flowering plants are allowed to grow around hedgerows at the field margin.
6. Maximise the biodiversity benefits of hedgerows by ensuring that no more than half of a hedgerow is ever coppiced for wood fuel and no more than 5% is coppiced in any year.

CPRE, the countryside charity, will:

7. Commission research into locations that could help achieve a 40% increase in the hedgerow network (through new planting and restoration), in a way that enhances and reinforces landscape character and delivers the maximum benefits for communities.

Next steps

If you would like to work with CPRE, the countryside charity on our campaign for 40% more hedgerows by 2050, please contact externalaffairs@cpre.org.uk

Introduction

The agricultural landscape makes up 73% of the UK's land mass and represents a long and interwoven history between labour and land.

Two-thirds of England has had a continuously hedged landscape for 600 years or more.[1] Some hedgerow systems date back to prehistoric times and most were well established by the Anglo Saxon period.[2] So much of our relationship with the land in the UK has evolved alongside the creation and maintenance of hedgerows — from how we manage trees, burn fuel, build homes, and stock animals, to how we mark parish boundaries, manage waterways and map pathways and roads.[3] Hedgerows are also fundamental to our efforts to mitigate UK land degradation and climate change.

Since 1945, the UK's hedgerow network has shrunk by about 50%, with the annual net loss of hedgerows reaching 18,000km in the early 1990s.[4] This is because of direct removal of hedgerows, resulting from perverse policy recommendations and subsidies, as well as through under-management, neglect and the effects of development. In addition, dominant hedge management practices seek to minimise workload and costs, often at the expense of hedgerows' value to wildlife and to wider society.

The Climate Change Committee (CCC) recommends that the UK hedgerow network should be increased by 40% to support the government's legally binding target of net-zero carbon emissions by 2050.[5] This report provides evidence for why this recommendation should be built into government policy. We believe that currently the full benefits of extending the UK hedgerow network are not being taken into account.

These include:

- biodiversity, including value for pollination and pest control
- climate crisis mitigation
- cultural services
- water quality and water regulation
- urban air quality

Hedgerows reach everywhere and everyone is exposed to them, from the rurally isolated farmer to the inner city dweller. It is for this reason we believe they deserve particular attention as a nature-based solution to the climate emergency and to increasing environmental and economic resilience.

Policy has an important role to play in this. Already, post-Brexit agricultural policy has shown a willingness to promote hedgerow planting by farmers and there may be more of this as the structure and detail of the new environmental land management scheme emerges.[6] But we feel the government must do more and make a policy commitment[7,8] to the ambitious hedgerow expansion plan outlined by the CCC in its influential report.

Our research provides the hard evidence to underpin such a policy change. It has been written independently by agricultural ecologists and economists in the UK's leading independent organisation for research in organic and sustainable farming, the Organic Research Centre (ORC). Researchers at the ORC have independently reviewed all available evidence on the ecosystem services of hedgerows and the economic benefits of the proposed 40% expansion of the network, as well as developing numerous new mathematical and economic models to quantify their impact. For the first time this report brings together evidence on the highly diverse environmental, societal and economic benefits that hedgerows and hedgerow expansion can bring.

The term 'ecosystem services' is one we refer to a lot in in this report. They are defined as 'the benefits people obtain from ecosystems. They can be provisioning (supplying products to people), regulating (eg regulating climate or disease), supporting (eg soil formation and nutrient cycling), or cultural (spiritual, aesthetic, educational)'[9].

We have found overwhelming evidence to demonstrate the benefits of expanding the UK's hedgerows by 40%. We also found such investments invariably return more in terms of ecosystem services than they cost to implement. Hedgerows enhance waterways, the wildlife we enjoy and need, the spaces in which we live and even the air we breathe.

Recommendation

Expanding our hedgerow network would be a natural solution to the climate and nature crises by increasing the nation's capacity to absorb carbon emissions, reduce air pollution and help reduce flood risk from extreme weather. Increasing hedgerows will also enhance our landscapes and provide habitats for wildlife. In line with the recommendation from the Climate Change Committee, the government should therefore set a target to increase the hedgerow network by 40% by 2050 with extended protection under the Hedgerows Regulations to cover more existing hedgerows.

Costs, jobs and wider economic benefits

The main costs associated with hedgerows relate to establishment and maintenance.

For the new hedgerow network, trees would be planted 40cm apart based on guidelines from the Woodland Trust. Standard cost figures[10] indicate planting and maintaining 100m of hedge costs around £1,000-1,200 to buy and plant the trees and £25 for trimming every year or every two to three years.

These costs can be partially offset by available grants. However, even considering grants, there would be an overall cost for the establishment and management of new hedgerows between 2022 and 2050 corresponding to £310 million, at a discount rate of 2%. As shown in Figure 1 below, a substantial share of the costs are for labour so would involve potential job creation. **Overall, more than 25,000 full-time equivalent (FTE) jobs would be created over the 30-year period for hedgerow planting and maintenance,** if we consider the standard values of 10-15m per hour for planting and 5-8km per hour for flailing[10].

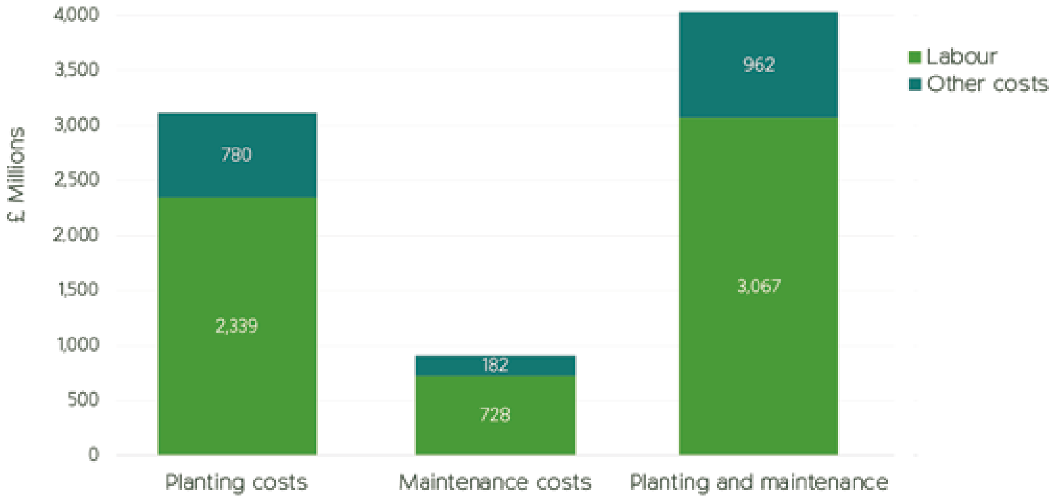

Figure 1.
Costs to plant and manage 259,886 km of hedgerows in the UK (+40% of the current hedgerow network on lowland), with the breakdown of labour and other costs.

These costs, used in many of the economic analyses undertaken here, are summarised in Technical Appendix 2.

Despite the associated benefits this could bring to rural economies, public funding does not cover all of these costs at present. They are instead carried by private individuals, usually farmers, who are not fully compensated for the ecosystem services they provide to wider society.

Expected return on investment for hedgerow planting

The analysis carried out for this report indicates that **for every £1 spent on hedgerows, a return of £3.92 can be expected** as a result of some key ecosystem services and economic activities associated with hedgerows, including biodiversity enhancement, carbon sequestration and woodchip production for biofuel.

Both farmers and the wider public community benefit from these services. The crop yield increase and insecticide cost reduction mainly bring economic benefits to food producers. The use of woodchip for biofuel, if strictly limited to local and domestic use, would also provide some economic benefits. All citizens benefit from the climate change mitigation derived from carbon sequestration.

The positive cost-benefit ratio suggests a compelling argument in favour of increasing the current hedgerow network in the UK. But it is important to acknowledge that the nature of the costs and benefits are closely dependent on the location and management regime of hedgerows. For example, to calculate this aggregate figure we analysed the costs and benefits of hedgerows planted at the border of a crop which relies on insect pollinators and is managed for woodchip biofuel on a 15-year coppice rotation.

The benefits are expected to be even higher than this, as the value of £3.92 does not include the ecosystem services of water regulation and air pollution reduction that were evaluated using a different approach and could not be aggregated in the composite figure.

Recommendation

Investing in the future management of hedgerows will support skilled jobs such as hedgelaying and create new jobs by planting hedgerows where they enhance landscapes. In turn, this could create up to 25,000 jobs, supporting both urban and rural economies. Beyond 2024, the environmental land management scheme (ELMS) must be well funded to support the 40% hedgerow expansion target by 2050. **The government should therefore design and deliver an ELMS that makes healthy hedgerows an attractive option for the agricultural sector.**

Hedgerows and biodiversity

If you want the city you live in, or the field you get your food from, to remain healthy and productive in the face of environmental change, you need these places to contain a variety of living things.

The UK's hedgerows make a fundamental contribution to the maintenance of the country's biological diversity.

We calculate there are 649,715km of 'managed' hedgerows in the UK (see Technical Appendix 1). They would stretch 16 times round the Earth if extended in a straight line. But it is the twists and turns of the hedgerow network that are key. Just as our capillaries branch and penetrate to supply all cells of the body with food and oxygen, so the UK's hedgerows branch and penetrate deep across the land to supply every village, town, city and rural area with the ecosystem services they need to remain healthy and functioning.

Of the 1,149 UK priority species (those in serious decline) identified by the 2007 Species and Habitat Review,[11] 130 are significantly associated with hedgerows.[12] These include the charismatic hazel dormouse, Muscardinus avellanarius, whose decline is associated with aggressive hedgerow management practices adopted in recent years, and the brown hairstreak, Thecla betulae, that lays its eggs on blackthorn, which is particularly common in hedgerows.[13] Hedgehogs, Erinaceus europaeus, are a species associated with grassland and edge habitats including hedgerows and the deterioration of hedgerow quality and loss has been indicated as responsible for their recent population decline[14].

So hedgerows are fundamental to the UK's biodiversity and their decline over recent times[15] has contributed to UK biodiversity decline. Conversely, a 40% increase in the network, as proposed by the CCC,[5] would undoubtedly make a positive contribution to UK biodiversity.

Analysis of ecosystem services

• Pollination and crop yield

One of the most comprehensive studies of hedgerows and pollination was conducted in Holland on open field strawberries.[16] Researchers considered small plots of strawberries next to grassy field margins, isolated hedgerows and forest-connected hedgerows. They showed that pollinator abundance was greatest at forest-connected hedgerows, intermediate at isolated hedgerows (around 17% below connected hedgerows) and lowest at grassy banks (around 33% below connected hedgerows). This translated into significantly higher strawberry quality and yield, with plants located at forest-connected hedgerows having a commercial value of 14.95€ per 1,000 strawberries, compared with 9.27€ for plants grown on grassy margins.

Another study showed there were twice as many pollinators at the field margin of Californian tomato fields when hedgerows were added - and this was the same in oilseed rape crops. These differences generally hold up further away from the margin but, interestingly, absolute pollinator numbers diminish very rapidly with distance in tomatoes while they are maintained at distances of up to 200m in oilseed rape[17].

Hedgerows are also predicted to stabilise English populations of ground-nesting bumblebees in spring because they provide nesting habitat and floral resources, such as pollen and nectar.[18]

Researchers often consider hedgerows and flower strips together as a complex[18–20] since many hedgerows have a woody canopy and herbaceous undergrowth. Indeed, field studies conducted in southern England have demonstrated that the value of hedgerows as a pollinator resource sometimes depends not on the woody resources themselves but on the flowering plants underneath.[21,22] Generally speaking, hedgerows become much more valuable to pollinators when presented as a complex of habitats and when they connect larger, diverse habitats together.

But while hedgerows may commonly boost pollinator numbers, this does not always translate into increased crop yield. It all depends on whether the plant is pollen-limited or not. Pollen limitation, where extra pollination makes a difference, occurs in between 62% to 73% of plant species[23,24] and leads to a 42% increase in the average number of seeds per plant.[24] If a plant species is not pollen-limited, then supplying extra pollinators through measures such as hedgerow planting will have no impact on seed set and yield.

In the UK, the one species that has been definitively established as pollination-limited is the apple. The fruit set of Kent-grown Cox and Gala apples doubled in hand-pollinated trees compared to open-pollinated trees.[25] Pollen limitation is suggested in oilseed rape and broad beans grown in northern and southern England but this is not definitively established[26]. Oilseed rape is pollen-limited across some sites in Europe, with a maximum increase of 6% harvestable mass as a result of hand pollination.[27] This also suggests that broad beans may be pollen-limited since there is a good synergistic crop rotation between beans and oilseed rape.

So expanded hedgerow planting in agricultural areas should focus on improving habitat connectivity and allowing flowering plants to grow around hedgerows to improve the impact. New hedgerow planting would also be likely to increase yields if focused on areas producing pollination-limited crops such as apples, oilseed rape and broad beans.

• Pest control

Hedgerows have the potential to produce cost savings on pesticides. By harbouring the natural enemies of crop pests, which disperse into nearby fields, hedgerows offer a self-regulating ecosystem service, with potential environmental and economic benefits through reduced pesticide use.[28, 29,30,21]

Hedgerows and their herbaceous understory function in this way by providing microclimates for overwintering of beneficial insects and food resources for adult and juvenile insects.[31] They also provide connectivity between habitats. Hoverflies are boosted in numbers when their hedgerow is connected to forest.[32] Bats (major predators of night-flying insects) follow hedgerows while commuting to forage sites by exploiting the moths that also follow these routes.[33]

Not all hedgerows are equal in terms of their ecosystem service. The value of a hedge as a reservoir for ground beetles is much higher for old hedges with their greater range of niches.[34] Foliage density can be an important characteristic,[35] as can plant species composition, structural diversity, leaf litter and the range of associated habitats such as banks and ditches.[31] Hedgerow management will, therefore, almost certainly have an influence on natural predator levels, though this has not so far been investigated in the UK.

Evidence for the linkage between hedgerows, natural predators and reduction in levels of crop pest infestation is also scant in the UK, though studies from elsewhere point to their potential impact. A study in northern California showed a reduction in aphid levels in tomato fields with hedgerows as a result of predatory ladybird numbers[36] with effects extending up to 200m into the field. A meta-analysis of 18 studies across North America and Europe suggests that the presence of flower strips improved pest control by 16%,[37] while landscapes with 9% or more of non-crop habitat was found to support enough ladybirds to control aphid infestations.[38]

Insectivorous birds may also contribute to pest control, as suggested by a number of studies of North American bird species.[39] Habitat heterogeneity, which is promoted by features such as hedgerows, increases the efficiency of insectivorous bird predation in French vineyards.[40]

Further investigation of the relationship between hedgerows and crop yield is needed in the UK.[31] In the Californian tomato fields mentioned above, hedgerow planting costs could be recouped within 16 years through savings in pesticide use, or only seven years if pollination services are also taken into account.[41] The potential negative impact of hedgerows harbouring overwintering pests such as grain aphids[42,43] also needs investigating. This could be addressed by avoiding certain hedge species, such as spindle and bird cherry.[44]

• Connectivity for biodiversity

Hedgerows provide corridors for animals to move between patches of high quality landscape. This is important in the UK's fragmented lowland agricultural environments and cities. Moths, bumblebees, bats, birds and mammals such as the hazel dormouse and hedgehog all prefer to follow hedgerows.[45] Birds in hedgerows move around three times more than in open fields[46] while East Anglian juvenile marsh tits struggle to disperse between woods that are more than 200m apart unless they are connected to hedgerows.[47] Hedgerows provide a migratory route for woodland animals in the face of climate change while hedgerow trees provide a 'genetic migratory route' for woodland trees.[48,49] Hedgehogs' reliance on hedgerows has been particularly well studied. Hedgerows can also help animals and plants to disperse between small patches and so reduce local extinction risk. Modelling has shown that doubling the amount of hedgerow could improve population connectivity - though trebling it would provide little extra benefit.[50] Filling in hedgerow gaps, which can act as barriers for movement of species such as bats[45] and the hazel dormouse,[51] can also have a significant impact.

• Biodiversity implications of a 40% increase in UK hedgerows

Existing fields studies, while suggestive, do not provide definitive evidence of a role for hedgerows in lessening the impact of habitat fragmentation.[52 53] It nevertheless seems logical to assume that a 40% expansion of the UK hedgerow network would principally benefit those organisms of intermediate mobility that are on the cusp of achieving the 1 to 20 migrants per generation required to maintain genetic integrity in isolated populations.[54] Further research is needed to identify such species and the role of hedgerows in their migration.

One major review of hedgerows and habitat connectivity[52] and species movement does conclude that evidence is largely anecdotal and there is little definitive evidence that hedgerows are important in this respect. This is because few studies of hedgerows have provided the 'irrefutable evidence of the connective corridor alleviating the dysfunctional genetics that can occur in small, isolated populations of animals[53].

Studies based in the UK that have considered migration between patches and genetics (without considering hedgerows specifically) have concluded that landscape fragmentation is only a serious problem in less mobile species. For example, there are no genetic signs of fragmentation in woodland patches of the highly mobile wood mice that are happy both in woods and lowland arable.[55] Interestingly, the genetic health of urban wood mice is considerably worse than rural ones as the dense infrastructure of cities present formidable barriers to such animals. This suggests that urban hedgerows could potentially have a role in increasing population viability of urban species. UK lowland herbaceous plants and relatively immobile wood crickets do, however, show signs of poorer genetic health due to fragmentation in the agricultural landscape.[56,57]

Studies of the genetics of UK lowland habitat patches that are and are not connected by hedgerows are needed to clarify hedgerows' role in genetic health of populations. However, it seems logical to assume that a 40% expansion of the UK hedgerows network would mainly help those organisms of intermediate mobility that are on the cusp of achieving the 1 to 20 migrants per generation required to maintain genetic integrity of isolated populations.[54]

A 40% hedgerow expansion will increase a whole range of species including those beneficial to agriculture[58], but it is difficult to predict the precise impact on any one species because no species is associated exclusively with hedgerows. However, inspired by field studies that compare the incidence of organisms in stretches of hedgerows relative to empty field patches of the same size, we have derived a mathematical relationship to predict how hedgerow expansion could impact on local abundance of organisms (see Technical Appendix 3). Some of the different scenarios are shown in Figure 2.

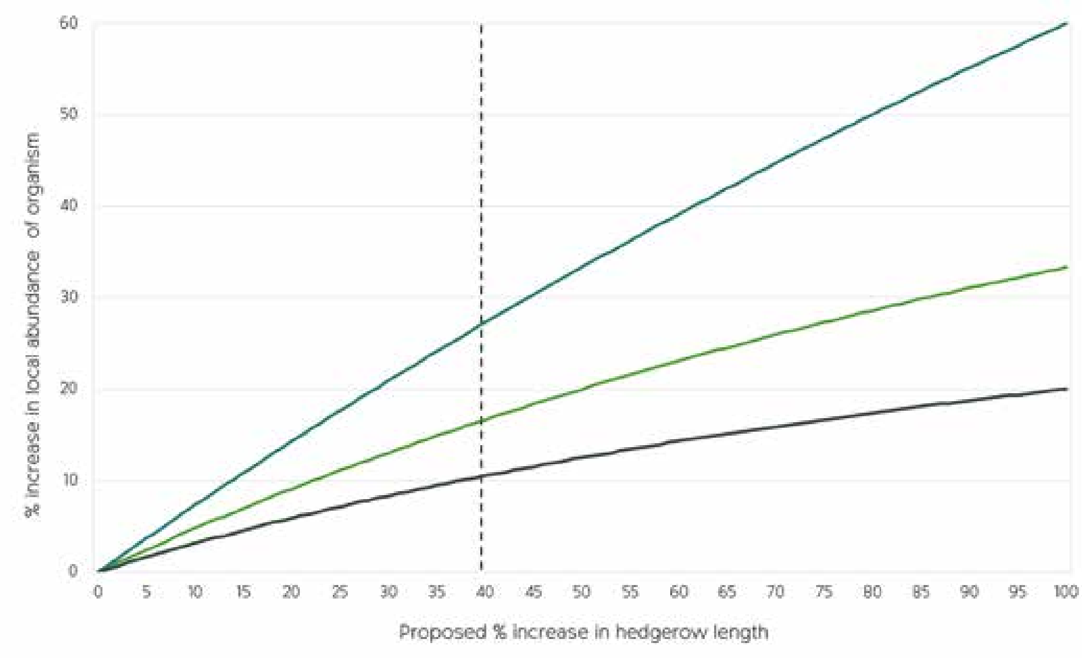

Figure 2:
Predicted increase in the local abundance of an organism with a percentage increase in the length of a hedgerow. The black line assumes that the presence of a hedgerow (relative to its complete absence) increases the incidence of an organism by 50%. The green line assumes the presence of a hedgerow doubles the incidence of an organism, and the turquoise line indicates a quadrupling. A 40% increase in the hedgerow network, as recommended by the CCC, is shown by the dotted line.

Applying this new relationship to some real field studies, we can expect earthworms at ORC's Elm Farm field site in Berkshire[59] to increase in local abundance (under the hedgerows) by around 17% as a result of a 40% increase in hedgerows. Pipistrelle bats (P. pipistrellus) in the vicinity of hedgerows would be likely to increase by roughly the same 17%.[59] The hedgerow-associated population of Lycosid spiders in southern England would be around 35% more abundant and the number of bees would expand by about 5%.[21] For hedgehogs, habitat connectivity is the critical factor. Here, if fields have little hedgerow (25%), doubling its extent increases the small number of hedgehogs undertaking long distance migrations (2,000m) by around 50%. If fields already have substantial hedgerow (50%), increasing its extent makes little difference to migration.[60]

Evaluation of economic benefits

The strategic planting of hedgerows on arable land has the potential to pay for itself where crops benefit from improved pest management and pollination services.

In order to calculate the economic benefits of improved biodiversity in hedgerows, we modelled the long-term costs and revenue using a discounted cash flow approach for three crops — oilseed rape, field beans, and apples — which are known to be pollination-limited in the UK. To estimate the economic benefit of hedgerows as a form of natural pest control, we evaluated the difference between pest control costs with and without hedgerows. According to Defra (2018)[61], the presence of natural predators can reduce the use of insecticides by 30% within five years of establishing hedgerows next to fields of crops.

As for pollination, the assumption is that establishing hedgerows on selected crop land would offer economic benefits through increased yields. In a study[41] undertaken in the US, for example, yields of rapeseed were 21% higher in fields with hedges, compared to those without. Recent field trials in the UK found oilseed rape yields increased by 18% as a result of pollination services[21] and assorted bean varieties between 15-30%.[62] For our calculation, we used a more conservative figure, based on findings by Klein et al (2007),[63] who observed that in most cases, crop yields increased by at least 10% as a result of improved pollination services.

Taking into account both a 30% cost reduction for insecticides because of increased natural pest predators and 10% yield increase because of improved pollination, the net present value (NPV) for apples from 2022 to 2050 at a discount rate of 2%, is positive (even without grants). The NPV for oilseed rape and field beans is also positive, assuming that current grants continue to offset the costs connected with hedgerow planting and management (see also annex for NPV values for oilseed rape, field beans and apples). (Please refer to Technical Appendix 4 for NPV values for oilseed rape, field beans and apples and additional data used within this analysis and a visual presentation of results for field beans.)

Our economic analysis shows that on average, for every £1 of investment made in hedgerow planting and management, £1.73 of economic benefits are generated for farmers due to increased crop yields and a reduction in insecticide use.

Recommendation

Good stewardship of hedgerows will maximise their potential for crop pest management and pollinators. It is even better if hedgerows connect to other habitats such as woodland. For pollinators it's also best that flowering plants are allowed to grow around hedgerows at the field margin. Allowing hedgerows to grow taller and wider will increase carbon storage potential, along with maintaining veteran and other mature trees in hedgerows.

Farmers and land managers should therefore maximise the environmental benefits of hedgerows by allowing them to grow taller and wider and ensuring flowering plants are allowed to grow around hedgerows at the field margin.

For the quantification of costs and benefits we use a net present value (NPV) approach, as recommended by the System of Environmental-Economic Accounts (SEEA)[64]. NPV is the value of all future cash flows (positive and negative) over the entire life of an asset discounted to the present. A positive NPV indicates that the value of the revenues is greater than the costs, which means that the investment is providing a profit. The discount rate is the rate of return used to discount future cash flows back to their present value. For the evaluation of the NPV associated with the ecosystem services (biodiversity and carbon sequestration) provided by hedgerows, we choose a value of 2% following the guidelines by Goulder and Williams (2012)[65]. A higher discount rate is chosen when the time horizon considered increases, such as the case of woodchip. For some ecosystem services it was not possible to calculate the NPV as annual data of benefits and costs from 2022 to 2050 were not available, in which case we have used other approaches documented in literature such as a replacement cost approach for the evaluation of the benefits provided by hedgerows in flood risk control. Cost-benefit analysis generally controls for inflation. A discount rate is instead used to aggregate all future revenues and costs into a net present value.

Case study

Rob and Paula Wolton, farmers, Devon

Rob and Paula Wolton own a 120-acre beef and sheep farm set in the heart of Devon. The soils are heavy clay, acidic and very wet and it is challenging land from which to produce food. Given this context, the thick species-rich hedges which surround each of their many small fields are of particular value to their business and have enabled them to remain on the land and care for it.

Many of these hedges not only perform their traditional function of serving to keep livestock in or out of fields — wire fencing is kept to a minimum — but also provide real benefits to the sheep and cattle through supplementary forage and opportunities for self-medication. The cattle can often be seen browsing on tender foliage and eagerly eat any hogweed in the margins — known to help reduce intestinal worm burdens. Rob and Paula have never experienced any bovine TB on their farm, which is consistent with evidence that hedge-rich farmland has less incidence of this disease in dairy cattle compared to hedge-poor farmland[132].

Their hedges also provide most of the firewood they use to heat the farmhouse, producing a good supply of logs of an ideal size for their wood stoves — while the harvesting and processing keeps them fit, they say! The firewood crop saves money and is a source of renewable green energy.

Rob and Paula have also taken up hedgerow options within an environmental stewardship agreement. They currently benefit from a higher level stewardship deal, with hedges providing the lion's share of the payments they receive. Without these, they say, the farm would barely break even.

But above all, their hedges give them enormous pleasure.

> “ Throughout the year they enrich our lives through their beauty and as superb wildlife havens ”
> says Paula.

A single hedge on the farm has been found to benefit over 2,000 species and these include many that are nationally scarce and some that are under threat. A particular delight is the large population of hazel dormice. Without hedges, the farm would be greatly impoverished, say Rob and Paula. Worse still, it would not be economically viable without great intensification and consequential environmental damage.

Hedgerows and the climate emergency

It is clear that hedgerows play a vital role in the UK's international obligation to reduce emissions and should be part of a national strategy to make our agricultural system more sustainable.

With as much as 5% of carbon sequestration on farms attributable to hedgerows,[66] their role should not be undervalued in international efforts to mitigate climate change. The process takes place above ground through the sequestration and storage of carbon in hedgerow biomass[67], as well as influencing storage of soil organic carbon (SOC) below the hedgerow with dense woody root systems and the protection of soil from disruptive farm practices such as tilling.

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• Carbon sequestration and storage

Carbon sequestration and storage in above ground hedgerow biomass varies according to tree species, hedgerow density, maturity and height, which are in turn influenced by management practices. The majority of UK hedges are managed by trimming every one to three years.[68] As such, their widths and height are often kept within the reach of tractor and flail, resulting in a typical width of 2m.[69,70] Furthermore, 90% of hedgerows contain hawthorn and 50% contain blackthorn.[69,70] A study by Axe et al[67] found that a blackthorn and hawthorn hedgerow managed by flail could sequester and store between 32.2 and 42 tonnes of carbon per hectare of hedge.[67,69]

Besides the planting of new hedgerows and extending the national network, there is significant scope to increase the overall carbon sequestration and storage of UK hedgerows by increasing hedgerow width and height. An ORC field study[71] found that hedgerows between 3.5m and 6m wide could sequester as much as 131.5 tonnes of carbon a year (with lower estimates at 45.08 tonnes of carbon a year). Emission modelling by the Royal Agricultural University found that extending UK average hedgerow width to 3.5m and height to above 2.5m could as much as double overall carbon sequestration and storage in above ground hedgerow biomass.[68]

Hedgerows are believed to store as much as half their biomass below ground.[67] Carbon storage is also greater in soils that are next to hedgerows compared with soils farther into the field. The differing inputs and decomposition rates brought about by hedgerows to the soils in their vicinity is thought to increase carbon stocks by as much as 114% compared to treeless areas.[72] There is also data to suggest that hedgerows play a significant role in soil carbon levels at the landscape level by limiting soil erosion.

Landscapes with a high density of hedgerows (200m of hedgerow per hectare of agricultural land) were found to have soil organic carbon (SOC) stock levels reaching 117 tonnes of carbon per hectare, with 38% of this effect being attributable to hedgerows.[73] By contrast, on land with a low density of hedgerows (50m of hedgerow per hectare), the mean total of SOC stock was 84 tonnes of carbon per hectare, with the contribution of hedges only 13%. This highlights the critical role hedgerows play in climate change mitigation. Their continued removal at farm level has significant implications for carbon sequestration and storage at a landscape level, potentially as much due to the loss of soil regulation services as to the loss of woody biomass.

A conservative estimate of carbon sequestration has been adopted for this report given that detailed information regarding additional factors influencing carbon sequestration and storage in hedgerows are unknown at a national level. The age of the hedgerow will determine the sequestration rate, with new and old hedgerows estimated to sequester 0.54 and 0.46 tonnes of carbon per hectare per year respectively.[71] Soil type, and its interaction with seasonal weather events, may also influence the source-sink status of soils underneath.[74] And species diversity can have a significant impact on above ground carbon sequestration. Hedgerows with greater internal density boost species diversity and can positively impact hedgerow carbon sequestration by extending the duration of active photosynthesis due to differing species-specific growth periods.[75,76] High hedgerow integrity (internal density) is linked to species diversity and can positively impact hedgerow carbon sequestration by extending the duration of active photosynthesis due to differing species-specific growth periods[75,76]. Further research is required to understand the impact such variables may have on national hedgerow carbon sequestration.

In a high ambition, 40% increase scenario, applying known ratios of managed and unmanaged hedgerows in the UK[77] as well incorporating the suggestion that 30% of hedgerows in the new network be brought into management for biofuel - a conservative estimate has been made for this report, which suggests a 40% increase in the UK's hedgerows would have a sequestration potential of 1.9 million tonnes of carbon. This is the equivalent of up to 7.1 million tonnes of CO2 . If we incorporate an average for below ground soil carbon storage of hedgerows[74] into this figure, the total rises to as much as 5 million tonnes of carbon — potentially the equivalent of 18.5 million tonnes of CO2. For this carbon model, it is assumed that the total extent of unmanaged hedgerows remains the same, and all new hedge creation is linear between 2022 and 2050.

• Hedgerow woodchip use for biofuel

The production of woodchips from hedgerow coppicing is an important example of the ecosystem services offered by hedgerows. Traditionally managed for wood fuel production as well as other wood products,[78] the increase in wood burner technology and efficiency, as well as the drive to reduce fossil fuel consumption, has led to a growing interest in making fuel from hedgerows to serve the needs of the farm as well as local enterprises.[29]

One objection to this might be that rotational coppicing and woodchip production conflicts with long-term above ground storage of carbon and therefore the potential to mitigate the climate emergency. While it is true that uncoppiced hedges sequester larger quantities of carbon, the carbon substitution value of replacing fossil fuels with renewable energy also needs to be considered. Some carbon budget analyses have shown that hedgerow bioenergy, if used appropriately and at a small scale, can reduce overall greenhouse gas emissions[79,80]. However, this must still be put in context of the wider debate around the long-term sustainability of bioenergy, as large-scale bioenergy use - particularly forest biomass - has a drastically negative effect on the climate.

In contrast to the more industrialised forms of biofuel production, hedgerow use as biofuel is highly geographically dispersed and is a great opportunity for small-scale farm businesses, which can also enhance landscape character. It also involves only very local transportation of fuel. Hedgerow use for biofuel can also incentivise farmers to manage their hedgerows[78,79], reduce hedgerow management costs and, if done properly, improve habitat for wildlife[78].

Hedges for biofuel use would ideally be at least 5m and preferably 7m in height, with stems 10-20cm in diameter. Hazel, sweet chestnut, willow, ash, sycamore, alder, birch and elm are particularly suitable species. Flailing should occur in winter to encourage vigorous regrowth and farmers should also consider other hedgerow uses such as nut and berry production.[78]

As a general rule, no more than half the hedge should be managed for wood fuel, and no more than 5% on average coppiced in any year.[81] It is also important that veteran and other mature trees in hedgerows be maintained for their value to wildlife and landscape character.[79]

Were up to 30% of our expanded UK hedgerow network to be brought into small scale management for local and domestic woodchip biofuel, this would bring both an economic return on investment to the farmer as well as an innovative source of cleaner energy.

Soil fertility

England's post-Brexit system for incentivising farmers to deliver public goods places a heavy emphasis on soil health and fertility[5] and there is growing interest in the use of woodchip from hedges for soil improvement. Applying freshly chipped wood has the advantage of on-farm sourcing while not requiring space for composting.[82] Building on early work carried out in Canada and the US, which demonstrated positive effects on soil biological activity and soil organic matter (SOM),[83,84] more recent research on farms across the UK suggests a similar effect on nutrients and SOM when compared to compost applications.[85]

Case study

Ross Dickinson, farmer, Dorset

Racedown Farm is a 400-acre family farm in Dorset. The farm has predominantly grade 3 soils with above average wind speeds and an average altitude of 600ft. Because of these factors, the hedge growth rates are below average for southern England. The farm has some 12 miles (19.3km) of hedges of which 10 miles are allowed to grow and are then managed by coppicing on a 15-20 year rotation.

As much as possible of the material from this coppicing is sold to the public through Ross's small log business (around 150 tonnes a year). In 2018, a 200m length of hedge was analysed in detail to establish if this type of hedge management was economically viable. All costs and income were recorded. Labour was charged at a living wage and machinery costs were based on contractor rates. The total cost to the point of delivery to the public was around £3,300. The income from the sales of the hedge material and the saving engendered by not flailing for 15 years was £4,900. This left a profit of £1,600 from this 200m length of hedge.

Using different machines generated four usable or saleable products — kindling twigs, cobs (for very small log burners), small diameter logs and conventional logs. The total saleable material from this stretch of hedge amounted to 21 tonnes in 15 years. This yield of firewood produces 88 Megawatt hours (MWh) of viable energy.

This approach provides diverse wildlife habitats, produces sustainable, renewable energy, maintains the long-term integrity of the hedge and gives the rural workforce a living wage with a small profit.

Evaluation of economic benefits

Generating wood fuel, a renewable source of energy, from hedgerows can be a productive part of farm management. Our assessment of wood fuel's economic benefits builds on recent work carried out by Smith et al (2021).[79] The best results in terms of biomass output and economic value are obtained when hedges are coppiced at 6-7m high with some stems more than 15cm diameter, which is reached within 8-20 years.[86] So our assessment was modelled on a 15-year coppice rotation over a 60-year period.

As shown in Figure 3, coppicing hedgerows for wood fuel production can provide a profit for farmers. The calculation is based on using medium-scale machinery (tree shears), which, according to the literature is more convenient than using chainsaws and brackle heads.[86] Grants for coppicing, corresponding to £4 per metre, were also taken into account.

In line with Smith et al (2021),[79] this is especially true when woodchips are used on farms to replace heating oil, in which case the Net Present Value (NPV) corresponds to £1,156 per 100m of hedges. Selling woodchips into a local market has a smaller financial benefit, with a NPV of £357 per 100m.

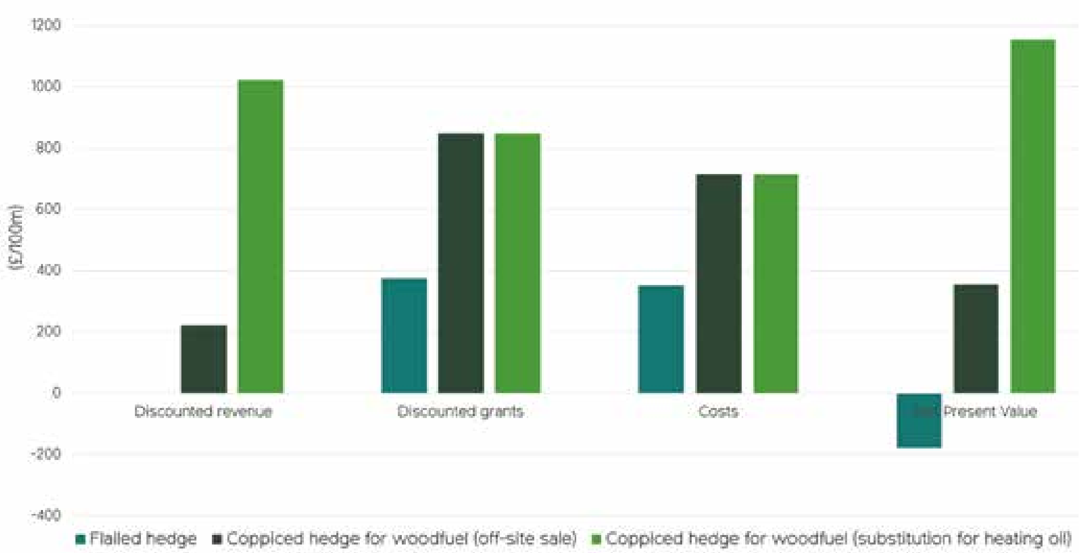

Figure 3.
The net present value (NPV) at 4% discount rate for hedge flailing and a coppice hedge system at two different woodchip processes over a 60-year period (based on Smith et al 2021[79]).

The Climate Change Committee recommended an increase of 10% or 30% in hedgerows for bioenergy production. We calculate that a 10% increase would lead to a reduction in greenhouse gas emissions (GHG) of 304 Gg CO2e[79] every year, because of the lower emission factor of woodchip combustion compared to heating oil[87]. A 30% increase would result in 912 Gg CO2e annual emission reduction.

At a national level, the Climate Change Act (2008) establishes a target of 80% reduced emissions by 2050 as well as an agricultural sector target of 3 million tonnes of CO2 by 2022[133]. For those targets to be met, Defra has strongly recommended that efforts to mitigate the climate emergency be stepped up across the sector.[133]

Calculating a shadow price of carbon (known in the US as the social cost of carbon) enables governments to gradually increase the accountability of polluting companies for greenhouse gas emission (GHG), in order to meet national and international climate change mitigation commitments.[89] A shadow price is representative of the costs associated with providing negative emissions technology in the future. Assuming a shadow carbon price is implemented through taxation and the auctioning of emissions allowances (carbon credits), a central price of £75 per tonne of CO2 is recommended for 2030 (an increase from £50 per tonne of CO2 based on 2020 pricings) and a central price of £160 per tonne of CO2 for 2050.[90] Using these figures for the years 2022-2050, we calculate that increasing the UK hedgerow network by 40% over that period would have a total NPV of £1.8bn at a discount rate of 2% in carbon sequestration services.

These findings begin to reflect the true value of public investment in hedgerows as part of a national strategy to combat the climate emergency.

Additional data used in this analysis can be found in Technical Appendix 5.

There is also a growing interest in the economic value of hedgerows for wood fuel production, following rises in oil cost and concerns about climate change. We found that **for every £1 of investment in hedgerow management for wood fuel, £2.62 of economic benefits are generated for farmers if woodchips are used on farm to replace heating oil, or £1.5 if woodchips are sold into a local market.** This would give a substantive boost to the rural community and contribute to creating a bio-based circular economy.

There is also a strong economic case for investing in hedgerows as part of the UK's climate change mitigation effort – our findings show that for every £1 of investment in hedgerows, we would see a return of £1.60 as a result of increased carbon sequestration. The environmental land management scheme is a vital funding stream to plant and restore hedgerows – helping to increase the extent of hedgerows by 40% by 2050.

Recommendations

Expanding our hedgerow network would be a natural solution to the climate and nature crises by increasing the nation's capacity to absorb carbon emissions, reduce air pollution and help reduce flood risk from extreme weather. Increasing hedgerows will also enhance our landscapes and provide habitats for wildlife.

In line with the recommendation from the Climate Change Committee, the government should therefore set a target to increase the hedgerow network by 40% by 2050 with extended protection under the Hedgerows Regulations to cover more existing hedgerows.

Managing hedgerows for wood fuel through coppicing provides an opportunity to rejuvenate old hedgerows, restoring not only their economic role but their value to the wider landscape.

Farmers and land managers should therefore maximise the economic benefits of hedgerows by ensuring no more than half of a hedgerow is ever coppiced for wood fuel and no more than 5% is coppiced in any year.

Hedgerows and cultural services

Hedgerows are the vital stitching in the patchwork quilt of the country, lending beauty and character to the landscape.

They provide tangible signs of the changing seasons, while at the same time giving a strong sense of continuity. They also make a significant contribution to local distinctiveness and a sense of place. That is why hedgerows are of great cultural significance to many people in the UK. For many, they are 'emblems of rustic tranquillity' and for some, a place to watch wildlife hopping around in hedgerows from a window.

Here we consider two cultural aspects of hedgerows that can potentially be evaluated for their economic benefits: their value to the landscape for both local people and tourists, and their potential to benefit mental health.

Aesthetic preferences and visitation

Fifty-one studies of people's aesthetic appreciation of western and northern European agrarian landscapes, including many conducted in the UK, have recently been meta-analysed.[91] Hedgerows ranked fourth behind historic buildings, a mosaic land cover, and the presence of livestock, and alongside dominant forest/natural cover. While appreciating that landscape preferences may vary dramatically in different socio-cultural groups,[92] Swanwick's (2009) review[93] of UK preferences essentially agrees that hedgerows are among a suite of landscape features that the public see in a positive light.

Social scientists have begun using social media technology and image geotagging to assess how such landscape preferences influence people when they visit places. A study of Panoramio, Flickr, and Instagram posts on European locations (including those in the UK)[94] found mountains and hills are of the highest aesthetic value followed by proximity to water and the presence of hedges and tree lines.[94]

It remains difficult to establish the economic value of different landscape features. Ultimately, we do not believe it is currently possible to produce a firm economic evaluation of UK hedgerows' influence on tourist numbers but in section 7.3 we present an analysis of the possible economic spin-offs from a 40% increase in the UK hedgerow network.

Mental health benefits

Mental illness costs the UK £105 billion a year in terms of service costs, lost productivity at work and reduced quality of life.[95] There is no data to evaluate the precise economic impact of hedgerows on these aspects of mental illness but hedgerows almost certainly do benefit mental health. This is of particular relevance to city dwellers who may have restricted access to such amenities (see case study).

There is around 156,000km of urban road in the UK[96,97] and 59,065km of urban hedgerow (see Technical Appendix 1). This is the equivalent of 0.38km of urban hedgerow for every kilometre of urban road. In a following section we investigate the implications of the urban hedgerow network for pollution control but the almost ubiquitous presence of hedgerow in the UK's cities has equally significant implications for improving mental health. Almost everyone who lives in a city (and that is 84% of the UK population[98]) is exposed to this green infrastructure every day of their lives.

Studies assessing passive, everyday exposure to green infrastructure seem particularly relevant to hedgerows. Access to residential green space for Danish children is associated with a lower incidence of adult psychiatric disorder.[99] A correlative analysis in Auckland, New Zealand, using Geographical Information Systems (GIS) and psychiatric records concludes that both useable and observable green space in the urban neighbourhood leads to decreased anxiety/mood disorder treatment counts.[100] Finally, a laboratory study with UK subjects demonstrates that treadmill exercising while exposed to a pleasant urban scene (a city skyline, with harbour, and trees lining the latter) had a more positive effect on self-esteem than exercising without this scene or exercising with an 'unpleasant urban scene'.[101] This study, while artificial, is important because it separates the effects of exercise and sensory exposure to green space.[88] It also suggests that the green element of 'green exercise' makes a significant contribution to mental health.[83]

We believe a 40% increase in the urban hedgerow network has the potential to deliver great benefit to mental health – even more so than localised green infrastructure such as parks. Everyone in the city will benefit from the extra and expanded hedges - both in mental health terms and physically through improved air quality and so on. With the larger population and higher density of people, hedgerow planting in urban areas has the potential for larger impact than elsewhere.

Case study

Lauren Smith, London

Lauren Smith currently lives in London but grew up in Harpenden, Hertfordshire, which, although a commuter town, is situated in beautiful countryside. The landscape of London is quite different to Harpenden but one similarity between the two places is hedgerows.

They line the pathway outside her house and can be seen in and around Clapham Common where Lauren walks regularly. Not only do the hedges provide physical privacy for the house, they also help to reduce the noise of the road and provide some shade for the garden.

Having grown up in the countryside, Lauren knows how important hedgerows are for wildlife. Although not as diverse as in Harpenden, the hedgerows in London do still provide a habitat for urban wildlife, including birds and insects, and act as wildlife corridors between houses and roads. They also play a role in capturing air pollutants, making the living environment safer and more pleasant to be in.

Lauren really values these urban hedgerows not only because of their diverse and varied benefits for human health and wildlife but also because it reconnects her with where she grew up in Harpenden.

Evaluation of economic benefits

There is substantial evidence to suggest that hedgerows — in conjunction with other landscape features — do influence people's overall appreciation and engagement with the natural environment.[102] So increasing the UK's hedgerow network could see a significant economic return in terms of outdoor recreation.

The most comprehensive survey of outdoor public recreation is Natural England's annual MENE (Monitor Engagement with the Natural Environment) report which found that 25% of survey respondents listed 'to enjoy the scenery' as a reason for outdoor recreation. Based on this figure as well as van Zanten et al's (2014)[91] landscape preference study, we calculate that hedgerows have a potential 4.75% influence on public outdoor recreational trips. The UK sees 1,413 million outdoor recreational visits a year.[103] Using Defra's 2020 political advocacy figures of £1-£3.5 per outdoor visit[104], a 40% increase in UK hedgerows could be worth more than £60 million a year in terms of its impact on outdoor recreation.

Given the lack of empirical data, however, we accept that the influence of hedgerows could lie anywhere between 1% and 5%. The values have therefore been plotted for each in Figure 5.

Our analysis also found that increasing the urban, and urban fringe, hedgerow network by 40% could see a significant reduction in air pollution and associated health costs of around £5 million each year.

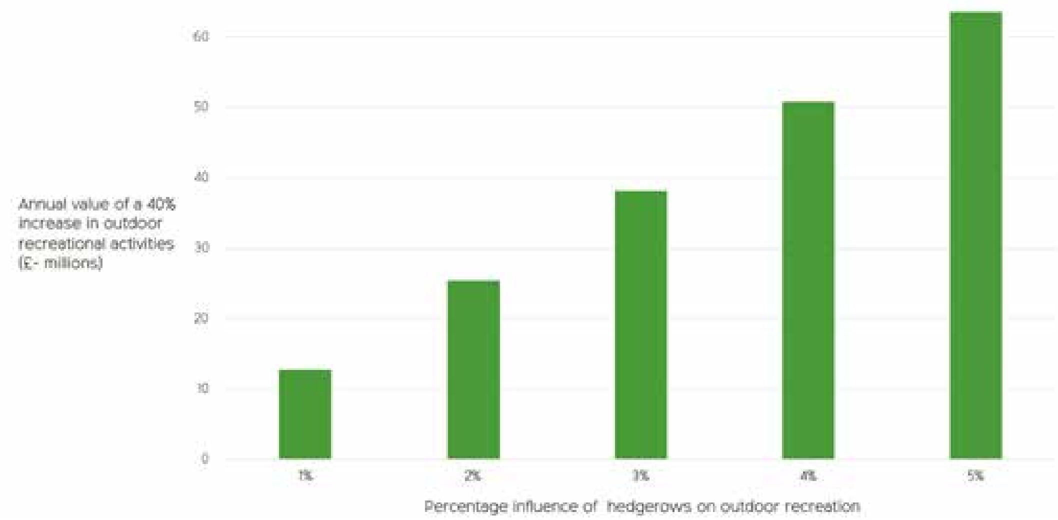

Figure 5. Estimated yearly economic values for difference levels of influence of hedgerows on outdoor recreational activities.

Hedgerows and water

Flooding can occur when land with degraded soil becomes saturated, leading to excessive overland flow and deposition into catchments.

Hedgerows are thought to alleviate this flood risk through a range of mechanisms.

Studies have also shown that hedgerows planted on agricultural hillside help reduce soil erosion and nutrient leaching. As we demonstrate below, UK lowland hedgerows have properties that should offer similar gains.

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• Flood risk reduction

Due to transpiration, soil under hedgerows tends to be dryer than surrounding soil and takes longer to reach saturation following rainfall.[105] Hedgerows also intercept a significant amount of rainwater and prevent it reaching the ground.[106] In addition, hedgerows have higher values of 'saturated hydraulic conductivity' (Ks) - that is, the ability of a soil to transmit water when conditions cause a directional flow.

This means that when surface-moving water meets a hedgerow, it encounters a type of filter that slows water flow and retains soil and nutrients within it. Even when saturated, water can pass through hedgerow soil whereas other types of soil with lower Ks, such as degraded arable soil, are simply overwhelmed when they reach saturation point, with the excess water deposited en masse in catchments.

The implications of these processes for flooding and stream flow have been examined in two major systems in Wales and France. In the Pontbren catchment in Wales careful placement of tree strips on hill slopes was shown to reduce the size of flood peaks by 40%.[107] A banked hedge network in Brittany within a 32ha catchment and with hedges at a density of 106m per hectare (64m/ha perpendicular to slopes) reduced peak flow within the stream by between 25% and 50%.[31,108] Modelling work suggests that even hedges at a lower density of 27m/ha would reduce annual stream flow by 10% with the optimal density being 60m/ha.[31,109] UK hedgerows currently have a density of 33.4m/ha (arable) and 52.5m/ha (pasture). This would increase to 46.8m/ha and 73.6m/ha respectively with a 40% expansion of hedgerows (see Technical Appendix 1).

From this evidence it is clear that a 40% increase in the UK hedgerow network within particular catchment areas could have a significant impact on downstream flood risk. Careful placement of hedgerows is essential, however. There have been examples of inappropriately placed trees in catchments making flooding worse and, as a generalisation, trees within catchments are better at reducing minor than major flooding.[110]

• Preventing soil erosion and nutrient loss

The important role hedgerows can play in preventing soil loss can be seen very clearly when they are planted on hills. This practice tends over time to lead to the formation of terraces immediately behind the hedgerows as the hedges accumulate soil. The process was studied in the Massif Central, France.[111] The hedgerows planted perpendicularly along slopes in this region are at least 160 years old and some may date from the 16th century. It has been shown that the depth of material stored within each hedgerow-formed terrace is between 0 and 0.63m. It has also been shown that trace elements can accumulate in terraces at levels up to 20% greater than elsewhere.

Even very modest 'hedgerows', in the form of grass hedges in US cotton farming, can reduce soil loss by a factor of 0.62 relative to equivalent no-till fields without hedges, with a four-year average loss of 1.8 tonnes per hectare in the hedge-containing fields. This compares with a soil loss for conventionally tilled fields of 30.8 t/ha, showing the dramatic deteriorating effect that tillage can have on soil properties.[112]

Contour hedgerows in fields growing maize, sweet potato and wheat in the purple-soil area of China lead to a redistribution of soil components during run-off, with a pooling of clay particles behind the hedgerow and an accumulation of sandy particle below.[113] Loss of the soil's organic matter is slowed by contour hedgerows. These hedgerows also retain a large amount of phosphorus (along with certain soil particles and organic matter), with a concentration around 45% higher than before treatment.[113]

We know a lot about soil and nutrient loss in sloping terrace hedgerow systems but less about the traditional flat, lowland hedgerows system seen in the UK. However, one of the few studies of soil properties in relation to hedgerows indicates that soil organic matter and phosphorous are elevated immediately underneath hedgerows and that hedgerow soil has Ks values that would be likely to reduce soil loss.[114]

Evaluation of economic benefits

The strategic planting of hedgerows could not only reduce the cost of building expensive artificial flood protection in flood risk areas but also cut the costs of soil erosion and nitrate leaching.

Flood damage currently costs the UK around £1.4 billion a year.[115] At least a further £0.5 billion is spent every year on man-made flood defences and other water storage systems, which are estimated to reduce flood damage by around 30%.[116,117] This reduction is similar to what hedgerows can achieve at a density of 60m per hectare.[109] The UK's current hedgerow network has an average density of 50m per hectare, and a 40% hedgerow increase in targeted catchment areas could easily reach the recommended density values that would reduce potential flood damage by 30%. Establishing and managing these additional hedgerows would cost on average £140 million a year. So, assuming that hedgerows at the recommended density would reduce flood damage by a comparable size to man-made defences, we can deduce that they could save around £360 million per year. It is also worth noting that physical flood defences do not have the positive aesthetic value associated with most trees and hedgerows. Hedgerows also provide additional benefits such as carbon sequestration, improved air quality and enhanced biodiversity.

The financial cost of soil loss in the UK is £5.40 per tonne, which corresponds to the costs of removing sediment from domestic water supplies[118]. The cost of nutrient loss is £7.15 per kilogram of nitrogen, which represents the costs of the impact of nitrates on human health.[119]

Standard figures on soil and nutrient loss reduction associated with hedgerows are not available, presumably because the process is particularly site-dependent. However, simulation studies in the UK have shown that increasing the density of trees on arable farmland helps to reduce soil loss and nitrogen leaching.[120] Planting a tree every 40cm as part of a new hedgerow border for arable land could therefore have the potential benefit of:

- Reducing the costs associated with soil erosion by 41% by moving from an arable system without trees to a similar crop system with 78 trees per hectare, and by 53% if there were 150 trees per hectare.
- Lowering the public costs incurred on those lands through nitrate leaching by as much as 80%, when moving from an arable system without trees to an arable system with 150 trees per hectare.

Our analysis shows that for every £1 of investment in hedgerows in flood risk catchment areas, £2.50 of economic benefits are generated as saved costs.

Case study

Bid Webb, Andy Smith, and Hilary Ford, Scientists, Bangor University - Fferm Ifan

Fferm Ifan is a group of 11 National Trust tenanted farmers in Ysbyty Ifan, North Wales covering 2,456ha of upland agricultural land managed for sheep and beef cattle production. Research conducted between 2017-2018 investigated the effect of hedgerows and different soil types on soil carbon storage and hydrology throughout the year.

The presence of hedgerows improved soil water storage capacity through the creation of soil pores mediated by roots, which altered soil structure. These porous zones beneath hedgerows can also decrease the speed of water flow across the landscape. Hedgerows also promoted the drainage of soil water, leaving soil significantly drier than nearby pasture during the 10 months of the study, regardless of soil type. When planted across a slope, hedgerows can also act as a physical barrier, interrupting surface water flow down the slope, impeding soil erosion and capturing fine sediment. On seasonally wet soil, hedgerows were found to act as a hydrological barrier beneath the soil surface, enabling water to infiltrate deeper and leaving a consistently drier pasture downslope.

Hedgerows create a microclimate that can alter soil temperature and moisture regimes to reduce soil organic matter decomposition and CO2 production. Typically, hedgerow ecosystems were found to act as net carbon sinks. However, it was observed that during drought conditions, hedgerows located on seasonally wet soil became net sources of carbon. In general, expanding hedgerow cover across UK farmland offers the potential to provide a net carbon sink. But soil type and drought frequency need to be taken into account when designing hedgerow planting schemes to ensure the potential for carbon sequestration is maximised.

Hedgerows and air quality

Urban hedgerows account for around 10% of the nation's hedgerows and they have a really special role in towns and cities.

Urban trees and hedgerows contribute to clean air by filtering out pollutants and altering air flow dynamics. While trees are valuable in cities, providing cooling, shade and boosting biodiversity, the evidence is that hedgerows are superior to trees when it comes to urban street pollution management in open and canyon (high-sided) streets.[121–126]

Analysis of ecosystem services

In street canyons, hedgerows (placed between pedestrians and traffic) do not constrain air flow while trees do[126]. Hedgerows also provide a good local barrier to airborne pollution while trees do not as the foliage is too high. In open roads, again, hedgerows usually have their foliage at the correct height to act as a local barrier to pollution whereas trees do not. Hedgerows can also have an impact on noise pollution from roads though often this needs to be combined with dense noise-blocking walls.[126] These effects are summarised in Figure 6.

Hedgerow plants with hairy trichomes and micro-ridges trap particulate pollution best, while those with certain stomatal characteristics (e.g. size, density) are more effective in preventing gaseous pollution. Plants with small leaf size and high leaf complexity are generally considered superior.[127]

Very little information is available on the distribution of UK urban hedgerows but casual observation would suggest that most are currently placed as boundaries on the 'wrong' side of pavements and paths — that is, not between pedestrians and vehicles as recommended for pollution control. This issue would have to be considered when expanding the hedgerow network by 40% and it could have implications for the character of many streets. Some streets and pavements may not be wide enough for the ideal positioning of hedgerows.

Built-up street canyon cofigurations

Description of flow and pllutant dispersion patterns in a street canyon with and without different types of vegetation: (a) vegetation free street canyon, (b) street canyon with trees, (c) street canyon with hedges, and (d) street canyon with green roof and green wall

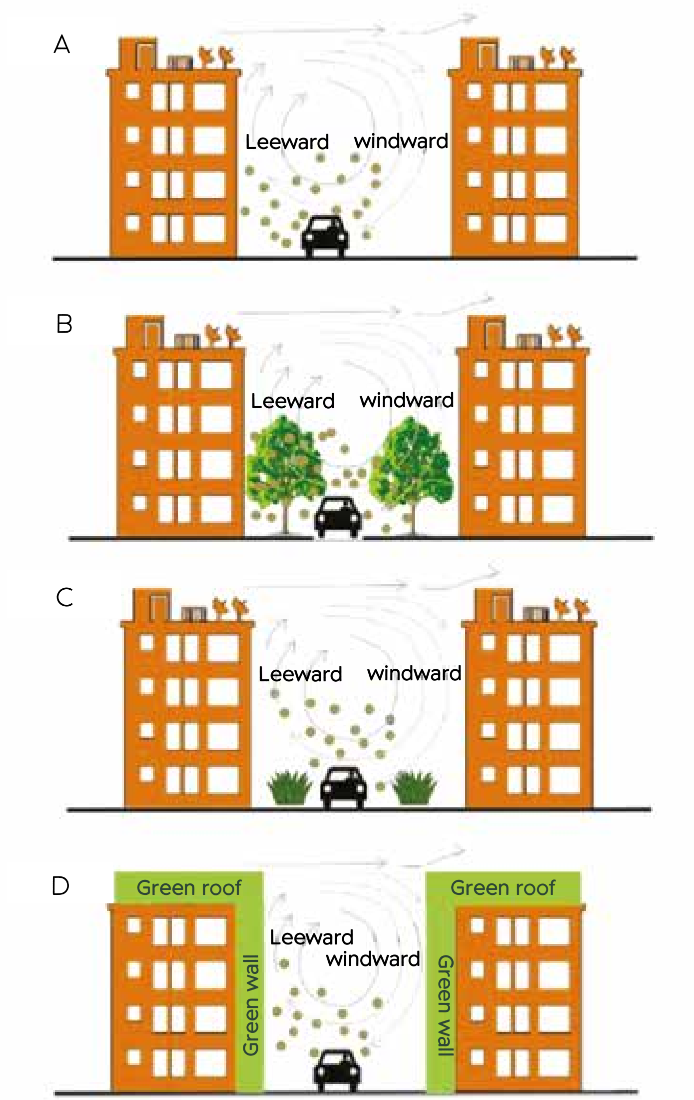
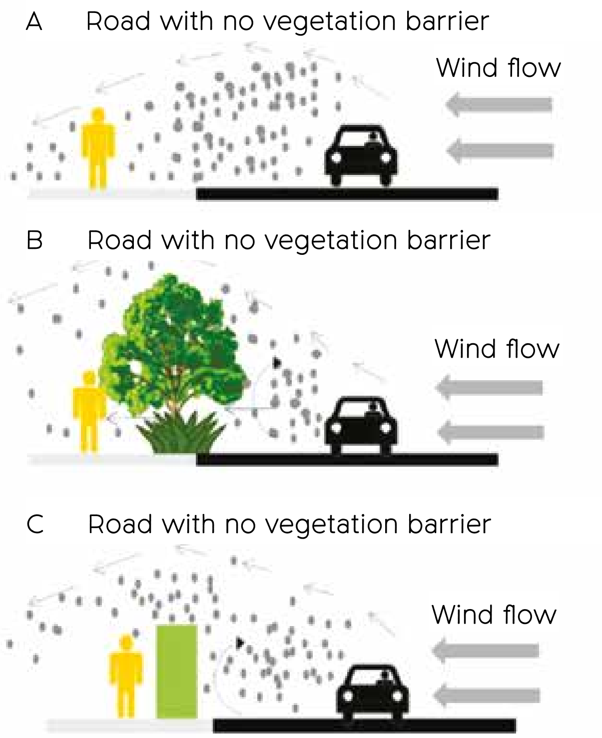


Fig 6. A summary of tree, hedgerow, and green wall impacts on air pollution in street canyons and open roads. Images reproduced with minor modifications from ref [126].

Open road configurations

Dispersion patterns of road pollutants under open road configurations (a) without vegetation barrier (b) with vegetation, and (c) with green wall



Evaluation of economic benefits

At the moment there is no hard information on what proportion of hedgerows in UK cities run along the roadside. Most are thought to be in residential gardens and parks[45] so we have assumed a low level of roadside hedges (5% to 20% of the urban network) and generated economic values within this range.

The particulate matter from airborne pollution that is most damaging to human health is PM2.5. We have based our calculations on a study conducted in Reading, in which various species of clean hedge plants were placed next to major and minor urban roads for 10 days in summer and the weight of accumulated material measured.[128,129] These values have been applied across the urban hedgerow network using a simple geometric model of hedgerow surface area[128,130] combined with statistics on major and minor roads in UK cities[96,97].

Assuming 5% of urban hedgerows occur along roadsides, we calculate that hedgerows sequester 38 tonnes of $PM^{2.5}$ a year. This equates to a damage reduction value[131] of nearly £3 million. An increase of 40% in the urban hedgerow network would save an extra £1.1 million. If we assume that 20% of urban hedgerows are along roadsides, we calculate that hedgerows sequester 151 tonnes of $PM^{2.5}$ a year. This equates to a damage reduction value of £11 million. Adding an extra 40% to the urban hedgerow network would produce a further £4.4 million in health and livelihood damage reduction.

A full description of our analysis, along with spreadsheet calculations, can be seen in Technical Appendix 6.

Recommendations

Hedgerows reduce air pollution when they are planted between roads and pedestrians rather than on the far side of pavements where roadside hedgerows are commonly planted. Increasing the urban, and urban fringe, hedgerow network will also provide vital habitats for urban wildlife such as hedgehogs.

Local authorities should work with local community groups to plant hedgerows in urban, and urban fringe (including Green Belt) areas, enhancing green infrastructure and directing funding to help deliver Local Nature Recovery Strategies.

We know that in some areas of England hedgerows are not the main field boundary and there are many places where hedgerows have been removed in the past and so may be most suitable for new hedgerow planting. Urban areas will also be vital for planting new hedgerows, enhancing local green spaces and improving the local environment.

CPRE, the countryside charity, will therefore commission research in 2022 into where a 40% increase in the extent of hedgerows could be planted and restored, in a way that enhances and reinforces the character of our landscape and delivers the maximum benefits for local communities.

Next steps

If you would like to work with CPRE, the countryside charity on our campaign for 40% more hedgerows by 2050, please contact externalaffairs@cpre.org.uk.

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