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PERSPECTIVE

Improving and expanding hedgerows—Recommendations for a semi-natural habitat in agricultural landscapes

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Abstract

1. Hedgerows provide habitat, shelter and resources for many species including functionally important taxa and threatened species. Hedgerows store carbon both above- and below-ground and provide a range of other ecosystem services. Policies incentivizing increases in the extent and quality of hedgerows require evidence to determine how these increases may best support a wide range of taxa and to improve hedgerow habitat quality.
2. Here, available evidence for increasing hedgerow extent and improving their quality is discussed in the context of current conservation policy. Moderate evidence supports a substantial increase in average hedgerow extent from 4.2 km/km^2 to around 10 km/km^2 in the United Kingdom, to optimize support for many wildlife taxa, habitat connectivity and carbon storage.
3. Evidence also supports the development of wider and structurally denser hedges with more diverse structures and management approaches, and hedgerow networks that are well connected with each other and with other semi-natural habitats.
4. However, barriers may hinder the implementation of hedgerow policies, and there remain substantive gaps in the evidence base. Knowledge gaps include the current quality or condition of UK hedges, understanding in which landscape contexts new hedges would best be planted to support biodiversity, the role of hedgerows in connectivity as species' ranges change under a future climate, and whether an increase in hedgerow extent might increase the spread of invasive species, tree pests or diseases.
5. These gaps must be filled if conservation policies, including future agri-environment schemes, are to ensure that hedgerows reach their considerable potential in aiding nature's recovery and addressing climate change.

KEYWORDS
biodiversity, condition, connectivity, extent, habitat quality, hedgerow policy

1 | INTRODUCTION

Preventing the ongoing loss of biodiversity (Turney et al., 2020), and the services and natural capital supported by biodiversity (Spake et al., 2019), is an urgent global conservation priority. To inform this goal, we need to (1) understand how much semi-natural habitat is needed to support biodiversity and whether this varies across taxa and species, (2) define good quality in a habitat and (3) explore barriers and knowledge gaps that might hinder the expansion or improvement in the quality of a semi-natural habitat.

Hedgerows are a key semi-natural habitat in managed agricultural landscapes in Europe (Montgomery et al., 2020), North America (Heath et al., 2017), China (Yu et al., 1999) and elsewhere. Hedgerows provide habitat, shelter and resources for a wide range of species, including plants (Litza & Diekmann, 2020), birds (Carrasco et al., 2018), mammals (Froidevaux et al., 2019) and invertebrates (Staley et al., 2016), and support functionally important taxa such as pollinators and natural enemies of pests (Montgomery et al., 2020; Morandin et al., 2016). Along with field margins, hedgerows produce the most nectar compared to other farmland habitats (Timberlake et al., 2019), providing 3% of nectar at national scales (Baude et al., 2016), and supporting pollination services to some crops (Image et al., 2022). Hedgerows support threatened species, with 82 conservation priority species (red-listed in Great Britain), relying partly or entirely on hedgerow habitats (Staley et al., 2020). Hedgerows capture and store carbon (Biffi et al., 2022; Mayer et al., 2022) and contribute to other ecosystem services (reviewed in Montgomery et al., 2020).

In this article, we consider evidence to support an increase in the extent and quality (habitat condition, Defra, 2007) of hedgerows, in the context of current conservation policy. Barriers and knowledge gaps, which need to be addressed for hedgerows to effectively support farmland biodiversity, are explored. The scope of this article is European with a focus on the United Kingdom, some of our conclusions will be more widely applicable. We use the Natural England Favourable Conservation Status definition of a hedgerow, 'Any boundary line of trees and/or shrubs over 20 m long and less than 5 m wide, where any gaps between the trees or shrub species are less than 20 m wide, and where native woody species form 80% or more of the cover. Any bank, wall, ditch or tree within 2 m of the centre of the hedgerow is considered to be part of the hedgerow, as is the herbaceous vegetation within 2 m of the centre of the hedgerow' (Staley et al., 2020).

2 | NATIONAL HEDGEROW POLICIES

The important roles delivered by hedgerows are recognized across a range of government and non-governmental policies. Hedgerows are a protected habitat in several European countries, including under Section 41 of the Natural Environment and Rural Communities Act 2006 in England. The removal of hedgerows is restricted (Tsonkova et al., 2019), for example, by the Hedgerows Regulations 1997 in England and Wales (https://www.legislation.gov.uk/uksi/1997/1160/contents/made).

The Committee on Climate Change (2019) include a 40% increase in hedgerow extent in the United Kingdom in their net-zero scenarios. Improving the quality (condition) and connectivity of hedgerows is recommended in the Nature Networks Evidence Handbook (Crick et al., 2020), as part of implementing the UK's 25-year Environment Plan (Department for Environment, Food & Rural Affairs, Defra, 2018). The National Farmers Union (2019) in the United Kingdom recommends growing bigger, wider hedges, and CPRE The Countryside Charity and The Organic Research Centre (2021) recently endorsed a 40% increase in hedgerow length.

Governments pay landowners for sensitive management or restoration of hedgerows, and for planting new hedgerows, through agri-environment schemes (AES) in several countries. Within the European Union, the Common Agricultural Policy includes the restoration and maintenance of existing hedgerows in the agricultural landscapes (Tsonkova et al., 2019). In the UK, hedgerow management has been part of AES for over 20 years (Natural England, 2009), and is included in a pilot for the new Sustainable Farming Incentive AES (https://www.gov.uk/guidance/sustainable-farming-incentive-pilot). Hedgerow management under AES includes cutting hedgerows infrequently (e.g. once every 3 years; Staley et al., 2012), cutting in late winter, and restoring hedgerows through coppicing and traditional hedge-laying to encourage regrowth from the base (Staley et al., 2015). AES includes payments to plant new hedgerows, in the Countryside Stewardship scheme in England (Natural England, 2019) and elsewhere (e.g. USA, Morandin et al., 2016). In addition, cutting hedges between 31 March and 31 August is prohibited in the environment scheme (https://www.gov.uk/guidance/guide-to-cross-compliance-in-england-2022/key-dates-in-2022).

3 | WHAT EXTENT AND QUALITY OF HEDGEROWS ARE NEEDED TO SUPPORT BIODIVERSITY?

These policies support an increase in the extent and quality of hedgerow habitats in the United Kingdom. To inform this, we need to understand how much hedgerows would be optimal for as broad a range of taxa as possible, while minimizing possible negative effects on those species that favour open landscapes and considering other potential disbenefits. Currently, the total length of woody linear features in Great Britain is approximately 700,000 km (Carey et al., 2008). The average hedgerow extent, in landscapes where hedges are a frequent feature, is approximately 4.2 km/km^2 and varies across Great Britain (Figure 1).

Studies that have investigated the impacts of increasing hedgerow extent indicate mainly positive impacts for the taxa studied, although relatively few publications address this question. Doubling the total length of hedgerows substantially enhanced connectivity for European hedgehogs (*Erinaceus europaeus*), a priority conservation species (Moorhouse et al., 2014). Dicks et al. (2015) suggest 13.8 km of flowering hawthorn and blackthorn hedgerow (per km^2), in combination with habitats that flower later, would provide pollen

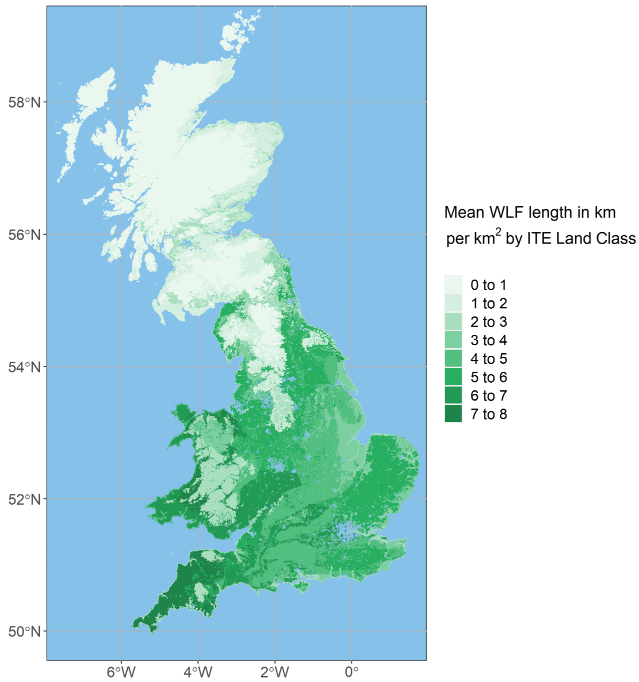

FIGURE 1 Map of the density of woody linear features (km/km^2) in Great Britain in 2007 (data extrapolated from the Countryside Survey randomly stratified sample). Derived from Brown et al. (2014).

and nectar to support healthy populations of six wild bee species. For birds, Fuller et al. (2001) found that species richness increases with hedgerow extent to 8 km/km^2, and then reduced >12 km/km^2. Carrasco et al. (2018) found maximum bird species at 1.2 km/km^2 after which it remains constant, and that hedges are keystone structures in promoting bird diversity. Besnard and Secondi (2014) recommend no more than ~9.5 km/km^2 of hedgerow to ensure large enough grassland patches are retained to support grassland bird species.

There is the potential for other disbenefits of expanding the extent of hedgerows, for example through the increased spread of invasive species, tree diseases and pathogens (Feber, 2017). In Northern Ireland, 5%–30% of hedgerow trees recently showed signs of disease (Spaans et al., 2018). Grosdidier et al. (2020) found ash trees isolated in hedgerows had less severe development of ash dieback than trees in forests, potentially due to differences in microclimate, although the initial incidence of the disease was equally high in both habitats. To our knowledge, no studies have modelled whether increased hedgerow extent would result in a greater spread of tree disease and pathogens; this remains an evidence gap.

The biodiversity studies above indicate that several taxa would benefit from an increase in hedgerow extent in the United Kingdom to around 8–13.8 km/km^2. Given the potential for some negative consequences of increases at the top end of this range (9.5–12 km/km^2), an increase in the average extent to around 10 km/km^2 might maximize benefit to farmland biodiversity generally, while minimizing negative effects for grassland birds. This would require a substantial increase in the length of hedgerows and the number of associated trees. However, the requirements of specialist species that use hedgerows or surrounding habitats vary, and may not always coincide with the hedgerow structure or extent that supports the greatest species richness or taxon abundance (Fuller et al., 2001). When hedgerow expansion is planned in specific regions or landscapes, careful consideration should be given to the needs of particular conservation priority species.

Hedgerow quality in the United Kingdom is currently assessed using a standard condition survey (Defra, 2007). This includes assessments of hedgerow size (height and width); amount and size of gaps; presence of non-native species; width of undisturbed ground and herbaceous vegetation; and presence of indicators of nutrient enrichment, with thresholds defined for each criterion to determine whether a hedgerow is in good condition (Table 1). A substantial evidence base supports the use of these criteria. For example, Graham et al.'s (2018) review showed that wider hedges with more diverse structures and few gaps benefit a range of taxa.

In 2007, the Countryside Survey found that 48% of hedgerows in Great Britain were in good condition in relation to size, gappiness and the absence of non-native species (Carey et al., 2008). When the width of undisturbed ground and herbaceous vegetation were included, only 12% of hedgerows next to arable land (where margin width is most significant) were in good condition (Carey et al., 2008). In line with other priority habitats, at least 90% of hedgerows are required to meet the structural, functional and other favourable conservation status criteria for the hedgerow habitat to be considered in good condition or quality (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/925416/2a_Status_of_threatened_habitats_2020_accessible.pdf). From the most recent (2007) data, hedges in England are far below the threshold for good condition.

Since hedgerow condition was defined in 2007, new evidence supports the inclusion of additional criteria for an updated definition of hedgerow favourable conservation status to support wildlife, at both local and landscape scales (Table 2; Staley et al., 2020). Many conservation priority and farmland indicator species need multiple structural components within hedgerows to complete their life cycle (Wolton et al., 2013). Hedgerow networks with a diverse structure, reflecting a range of woody plant ages and management techniques, provide the widest range of niches for wildlife. For example, the presence of dead and decaying woody vegetation provides habitat for many fungi and animals and affects bird breeding success (Hinsley & Bellamy, 2000). Continuity of hedgerow canopy is also important for some bats and small mammals which avoid hedgerows with gaps (Feber et al., 2019).

4 | BARRIERS AND KNOWLEDGE GAPS TO IMPROVING HEDGEROW CONDITION AND INCREASING EXTENT

An expansion of hedgerows, together with an improvement in hedgerow condition or quality, may be hampered by barriers to implementation. While schemes such as AES offer payments for hedgerow planting and sensitive management, landowner decisions

TABLE 1 Criteria and thresholds currently used to determine whether a hedgerow is in good condition. Adapted from table 5 in Staley et al. (2020) and Defra (2007).

Attribute		Threshold		Notes
1	Size	1.1	Height > 1.0 m	Average height excluding bank
		1.2	Width > 1.5 m	Average width across canopy
		1.3	Cross-sectional area > 3 m^2	Width × height
2	Gaps	2.1	Along length < 10%	Ignore gateways
		2.2	No gaps > 5 m	
		2.3	Gap between ground and base of canopy < 0.5 m	Not applicable to lines of trees, only to shrubby hedgerows
3	Undisturbed ground	3.1	>2 m from the centre line of hedgerow	Not applicable where the hedge bordered by roads, tracks, etc.
4	Herbaceous vegetation	4.1	>1 m somewhere between the centre line and the start of cultivated ground	Applies only to perennial vegetation Not applicable where the hedge bordered by roads, tracks, etc. Pasture fields automatically qualify
5	Non-native species (see also 15 below)	5.1	Woody species <10% non-native	Only applies to recently-introduced species—archaeophytes count as natives
		5.2	Herbaceous species <10% non-native	As for woody species
6	Lack of nutrient enrichment		<20% combined cover of nettles, cleavers and docks	Cover of these species along the side of the hedge being assessed

about environmentally beneficial farming practices can be influenced by a range of social, attitudinal and other contextual factors (Brown et al., 2021). Primary concerns raised by farmers in relation to AES management of hedgerows are loss of productivity, and wanting hedges to look neat/tidy (although attitudes around neatness of hedges vary and may be changing; Mills et al., 2013). Van Vooren et al. (2017) found that productivity losses immediately adjacent to a hedgerow may be compensated for by gains further into the crop but will vary with parcel, hedgerow size, aspect and crop. One possibility which may help to address implementation barriers would be to plant new hedges along the lines of relict hedges that are in the process of disappearing (Carey et al., 2008) or previous hedgerow lines.

Knowledge gaps may also hamper the successful implementation of the policies discussed above. Evidence for the type of landscape in which hedgerows best support a range of taxa, pollination or pest control, is lacking. Hedgerows may provide a more valuable forage resource for pollinators in intensively managed landscapes (Garratt et al., 2017), but there is a need for a broader evidence base on how the landscape context, hedgerows extent and habitat quality interact to affect multiple taxa.

The potential for hedges to facilitate population movement to mitigate climate change is not well understood (Davies & Pullin, 2006). Hedgerows are known to support regular movement (e.g. for foraging) for several mobile taxa, including insects (Dover & Sparks, 2000), mammals (Froidevaux et al., 2019) and birds (Hinsley & Bellamy, 2000), but less is known about the role of hedgerows in population dispersal. As discussed above, there could be a potential risk to increasing connectivity of hedges, which may facilitate the movement of invasive species, tree pests and diseases (Feber, 2017); these risks also need to be better understood.

High-quality or good-condition hedgerows are needed to support wildlife, yet national-scale surveys of hedgerow condition have not yet been repeated in Great Britain since 2007 (Carey et al., 2008). Current national data are needed to determine whether hedgerow condition has improved or declined over time, which condition criteria are being met, and whether management under AES has improved hedgerow condition. Large-scale hedgerow condition surveys are time-consuming using traditional field methods, and the proposed addition of extra criteria (Staley et al., 2020) would add to the time and resources required. While there is evidence to support the inclusion of additional criteria in defining good-quality hedgerows and hedgerow networks, there are gaps in our knowledge to define optimal thresholds for some of these criteria (Table 2).

The launch of a citizen science hedgerow survey aims to increase the number of hedgerow condition surveys and make these data comparable and easily available (https://hedgerowsurvey.ptes.org/). These surveys are opportunistic rather than a representative national sample, thus, the data may have limited value for assessing national trends. There is also the potential for remote sensing to provide data on key aspects of hedgerow condition, for example, unmanned aerial vehicle footage to quantify the height, width and flower abundance (Smigaj & Gaulton, 2021). More research is needed to determine the potential use of remote sensing data for hedgerow surveys in combination with field data.

5 | CONCLUSIONS

Hedgerow habitats have received considerable policy and research interest over recent years, as shown by reviews of hedgerow structure and biodiversity (Graham et al., 2018), wider ecosystem services

TABLE 2 Additional criteria proposed to determine whether hedgerows and hedgerow networks are in favourable conservation status to support wildlife at local and landscape scales. Adapted from table 6 in the Natural England Definition of Favourable Conservation Status for Hedgerows (Staley et al., 2020).

Attribute		Threshold		Rationale for inclusion and evidence gaps
7	Structural complexity within individual hedgerow		At least three out of the following five structural components present: • Shrub layer • Standard trees • Basal flora • Marginal flora • Ditch	Many hedgerow species need multiple structural components to complete their life cycles. 65% of priority species associated with hedgerows depend on two or more components, 35% on three or more components (Wolton et al., 2013)
8	Structural diversity across network		50% of hedgerows thick and bushy under a trimming regime, 20% growing up without trimming prior to laying or coppicing, 5% just layed or coppiced, 5% in early stages of re-growth, 5% as lines of trees, and 15% managed for safe access or screening	Thresholds are based on limited expert opinion. While there is good evidence that different species favour hedgerows in different states of growth, no evidence is available to enable relative proportions of these stages to be set with any confidence.
9	Connectivity across network	9.1	Less than x% of hedgerows not connected at one or both ends to other hedgerows or semi-natural habitats	No evidence available to set figures for x or y. Hedgerow density serves as a proxy measure for connectivity
		9.2	At least y number of nodes per km^2	
10	Plant species richness	10.1	A minimum of 3.7 woody species per 30 m sample stretch, on average	Shrub and tree diversity are important for resilience and linked to high species richness. No evidence has been found to suggest minimum or optimal levels of woody species. The average woody species richness 2007 (unchanged from 1998) is proposed
		10.2	Herbaceous species richness restored to 1978 levels (Carey et al., 2008)	
11	Standard hedgerow tree numbers, diversity and age, at a network level	11.1	An average of one mature tree present every 20 m to 50 m	Proposed as optimal for UK hedgerows (FWAG South West, 2017)
		11.2	At least x different species of tree present per km of hedgerow.	Evidence is lacking on optimal species richness to support thriving biodiversity
		11.3	45% of trees need to be 20 cm diameter or less	This is the percentage of young trees required for a stable population (Forest Research)
12	Availability of flowers throughout spring/summer and fruit for migrant and overwintering wildlife		Significant amounts of flowers, berries, nuts, etc., present in at least 2 years out of every three	Provision of flowers (for nectar and pollen resources), and berries and nuts, are heavily influenced by the frequency, timing and severity of trimming (Staley et al., 2012)
13	Lack of pesticide (insecticide or herbicide)		Level at which lethal or sub-lethal effects on non-target organisms are observed	Where thresholds for toxic effects are unknown, a precautionary approach should be taken, the assumption being that any detectable levels are harmful
14	Lack of water stress		No hedgerow trees dying through water stress that is preventable through local action	Water stress, resulting from close ploughing, drought or lowered water tables, can lead to increased plant mortality, especially of trees, and increased susceptibility to pests and pathogens
15	Invasive pests and diseases, at hedgerow network level		Level at which a significant impact is observed on relevant biotic communities, at a landscape scale	The impact of pests and diseases may be mitigated by remedial actions—for example encouraging other trees with similar ecological traits to grow in place of ash trees, increasing the diversity of trees for resilience
16	Presence of dead and decaying wood		At least one standard tree developing veteran features c. every 50 m. All veteran trees, stools, and rotting stumps retained unless they pose a significant risk to safety. Substantial amounts of dead and decaying wood retained in situ when hedges are layed or coppiced	No evidence is available for the necessary frequency of veteran trees within hedgerow networks to support key saproxylic species: one per 50 m is indicative

supported by hedgerows (Montgomery et al., 2020), policy documents proposing a substantial increase in the extent of hedgerow in the United Kingdom (Committee on Climate Change, 2019; National Farmers Union, 2019; Staley et al., 2020), and ongoing policies to incentivize sensitive hedgerow management, restoration and planting (Natural England, 2019). There is moderate evidence to support an increase in hedgerow extent in the United Kingdom to an average of 10 km/km^2, to optimize availability of resources and habitat for several wildlife taxa, potential habitat connectivity and also carbon storage. Evidence also supports improving the quality of hedges through appropriate management that would result in denser, larger hedges. A diversity of hedgerow structures and management across the landscape should be retained and extended, giving due consideration to the needs of particular conservation priority species in any local area or region. However, barriers to the implementation of these ambitious policies need to be addressed, and substantive knowledge gaps remain, notably in which landscapes to best plant additional hedges, the role of hedgerows in connectivity as species' ranges change under a future climate, the current quality or condition of hedges across the United Kingdom, and whether an increase in hedgerow extent might increase the spread of invasive species, tree pests or diseases.

AUTHOR CONTRIBUTIONS

Joanna T. Staley drafted this manuscript, and Robert Wolton and Lisa R. Norton contributed to discussions about the manuscript structure and the final version. All three authors wrote different sections of the Definition of Favourable Conservation Status for Hedgerows (Staley et al., 2020), which this manuscript draws upon.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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DATA AVAILABILITY STATEMENT

No new data were collected for this Perspectives article. Where existing data are used the source is referenced, for example, Figure 1 is derived from Brown et al. (2014) dataset.

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