# What are the impacts of agroforestry on nature recovery in the UK?

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**Abstract**

Agricultural intensification has had negative impacts on rural biodiversity in the United Kingdom. Temperate agroforestry practices can facilitate increases in the abundance or diversity of farmland birds, invertebrates, mammals, and soil microbes, and influence a wide variety of ecosystem services. The impacts of agroforestry are likely to be greatest in intensive arable settings, and more apparent on a catchment or landscape scale than an individual farm basis. Generalist species may benefit more from agroforestry in the short-term, but the biodiversity response is likely to be positively associated to the range and complexity of agroforestry assemblages over time. The potential benefits of agroforestry to rural biodiversity are gaining attention; however, the outcomes of interventions are difficult to predict, owing partially to a lack of long-term controlled experiments and the wide range of confounding factors. Rather than being seen as a new intervention and judged accordingly, agroforestry should be assessed in a historical light; reversing a widespread loss of woody habitat features and associated practices across the English landscape. Agroforestry is a management tool to slow or reverse declines in biodiversity, alongside a suite of other sustainable farming methods. Its full utility may only become apparent across the long-term and with a concerted national effort to reduce the impact of agriculture.

## 1. Introduction

### 1.1. What is Agroforestry?

As noted by the Soil Association's Agroforestry Handbook (Burgess et al. 2019), the simplest definition of agroforestry is 'farming with trees.' A more detailed definition is encapsulated by: 'the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions.' (Burgess et al. 2019). Agroforestry takes many forms globally and across Europe. In the UK, agroforestry practices can be broadly grouped into two overarching categories depending on if farmland trees are placed *within* or *between* fields (Table 1). The components of agroforestry also vary depending on existing land use for forestry or agriculture (Table 1). For trees *within* fields, a further distinction can be made between silvopastoral and silvoarable systems, with some overlap between the two (Table 1). Trees *between* fields comprise a wide variety of farming systems, including hedgerow and shelterbelt networks

(Table 1). Thus, it can be argued that much of the current and historical UK land area exists as an agroforestry landscape (for more detail on agroforestry practices and features, see Burgess et al. 2019).

**Table 1:** Types of Agroforestry in the UK and their common components (adapted after Burgess et al. 2019) (*coppiced species include willow, poplar, alder, and hazel).

| Tree location | Agroforestry system | Land use | |
|---|---|---|---|
| | | Forest Land | Agricultural Land |
| Trees within fields | Silvopastoral | Forest Grazing | Wood pasture<br>Orchard Grazing<br>Individual, clumps or lines of trees |
| | Silvoarable | Forest farming/gardening | Alley cropping<br>Alley coppice*<br>Orchard intercropping<br>Individual trees |
| | Agrosilvopastoral | Mixtures of the above | |
| Trees between fields | Hedgerows, shelterbelts and riparian buffer strips | Forest strips | Wooded hedges<br>Shelterbelts and hedgerow networks<br>Hedgerow coppice*<br>Riparian buffer strips |

**1.2. What are impacts?**

For the purposes of this review, impacts will be defined as:

*A notable or significant change in a response variable (nature recovery) attributable to the intervention (agroforestry)*

No restriction is imposed regarding the scale of impact (ranging from whole landscapes, to habitats, sites, species, and individuals). Positive (with a net biodiversity gain), negative or neutral evidence will also all be reported equally. However, priority is given to impacts that have relevance to the UK policy landscape, such as those concerning the Nature Recovery Network (NRN), the Local Nature Recovery Strategy (LNRS), UK Biodiversity indicators, the GB red list and Keystone species or taxa.

## 2. Methods

This non-systematic literature review was conducted using Collaboration for Conservation Evidence's recommended guidelines and standards for evidence synthesis (CCE, 2018). Evidence was primarily located by interrogating online databases for peer-reviewed reviews and meta-analyses, such as Web of Science, Google Scholar. Individual studies, grey and unpublished literature were also considered, including internal Woodland Trust evidence briefings, PhD chapters and industry resources. Search strings included "agroforestry", "temperate agroforestry review", "agroforestry biodiversity UK", Individual authors were also searched for. To create more complicated search strings, Boolean operators were also used, such as AND, OR and NOT; for example "agroforestry AND birds review" and "agroforestry benefits pasture OR crops". Evidence from England and the UK was prioritised; however, where appropriate, studies from temperate European or other global locations were considered for inclusion. For example, this may include instances where vulnerable UK-native species are investigated in controlled experiments, or where UK data has fed into wider reviews and meta-analyses on the impacts of temperate agroforestry. A full exploration of other aspects of agroforestry - such as regulating ecosystem services and improved crop production - are beyond the scope of this study.

## 3. Results

### 3.1. Agroforestry impacts in the temperate zone

As the biodiversity crisis is a trans-boundary issue, the potential benefits of agroforestry for in the UK must also be considered in the context of global change. There are several large reviews and/or meta-analyses establishing the biodiversity impacts of agroforestry in temperate regions, many of which have included studies from the UK (Table 2). Rather than repeating these works, this report will synthesise their conclusions for the first time and allow some general statements on the impacts of temperate agroforestry to be made. Where possible, the agroforestry system and number of individual studies considered in reviews or meta-analyses are reported (Table 2). As well as reviews, a range of relevant individual studies are also considered.

**Table 2:** Reviews and meta-analyses that have synthesised the evidence for impacts of agroforestry on temperate zone biodiversity. Unless otherwise stated, observations are based on comparisons to conventional open pasture/arable cropping controls.

| **Study** | **Type/region** | **Objective** | **Number of peer-reviewed studies/resources considered** | **Agroforestry systems** | **Main conclusions** |
|---|---|---|---|---|---|
| Burgess, 1999 | Review/UK | General impacts of agroforestry on biodiversity | 16 | Wood pasture, alley cropping | Silvopasture:<br>• Reduced dominance of *Lolium, Trifolium* and *Cirsium* below trees<br>• Increases in invertebrate numbers and richness<br>• Greater number of birds<br>• Trend for greater diversity of birds<br>Silvoarable:<br>• Area beneath trees dominated by arable weeds<br>• Increases in airborne arthropods numbers and richness<br>• Variable impacts on ground beetles<br>• Strong increase in small mammals<br>• Possible increase in thrip crop pests/slugs |
| Jose, 2009 | Review/Global | Overall impacts of agroforestry, including biodiversity | 6 based in temperate regions | Riparian buffers, wood pasture, cover crops, windbreaks | • Swedish wood pastures had increased bird species richness and higher invertebrate abundance/diversity<br>• Temperate American riparian buffer strips higher in bird density and diversity than monocultures<br>• Increased understory arthropod diversity in cover crops/wind-breaks |
| Dauber et al. 2010 | Review/temperate regions globally | Impacts of bioenergy crops on biodiversity | 47 | Short rotation coppice (SRC) in farmland or woodland | • Biomass crops (incl. Poplar and Willow) had positive effects for a broad range of taxa (not for ground and rove beetles)<br>• Species richness of SRC generally lower compared to woodland<br>• Higher bird richness compared to uncultivated land, no effect on mammals<br>• No consistent effect compared to grassland |
| Tsonkova et al. 2012 | Review/temperate Europe | Overall impacts of agroforestry, including biodiversity | 22 | Alley cropping/SRC | • Edge habitats enhance species recruitment<br>• Shade may reduce plant species diversity in understory<br>• Enhanced distribution of ground beetles via shelter provision<br>• Increased arthropod diversity<br>• Greater abundance of hymenoptera/large hemiptera in UK SRC compared to canary grass crops<br>• Shelter for pollinators, possibly moths<br>• Increased small mammal and bird diversity |
| Pumariño et al. 2015 | Meta-analysis/Global | Quantifying effect of agroforestry on pests, disease, and weeds | 2 from temperate regions | Silvoarable | • Agroforestry reduces pest or competitive weed burden<br>• Reduced invertebrate pests in perennial crops but not annuals |

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|---|---|---|---|---|---|
| Torralba et al. 2016 | Meta-analysis/ Europe wide | Quantifying effect of agroforestry impact on biodiversity | 53 | Silvopasture, silvoarable, agrosilvopasture | • Overall positive effect of agroforestry on European biodiversity<br>• Strong increase in bird biodiversity<br>• Effect size for plants, fungi, and insects were smaller<br>• Stronger effect in arable situations<br>• Wide geographic variation: total benefits of agroforestry for biodiversity and ecosystem service provision are greatest in warmer drier regions<br>• Effects of agroforestry more apparent at catchment or landscape scale |
| Moreno et al. 2017 | Review/Europe wide | Overall impacts of agroforestry, including biodiversity | 4 from temperate countries | Wood pasture | • General enhancement of biodiversity<br>• Wood pasture habitat and ancient trees support wide variety of species |
| Bentrup et al. 2019 | Review/temperate regions globally | Impacts of agroforestry on pollinators | 134 | Shelterbelts, hedgerows, and windbreaks | • Linear agroforestry practices (i.e., windbreaks, hedgerows, riparian buffers, alley cropping) in temperate regions can aid pollinators by providing habitat, including foraging resources, and nesting or egg-laying sites, enhancing site and landscape connectivity, and mitigating pesticide exposure |
| Staton et al. 2019 | Meta-analysis/temperate regions globally | Quantifying impacts of agroforestry on pests and pollinators | 12 | Silvoarable | • General increases in predators and reductions in pests<br>• Increases in molluscs compared to conventional arable<br>• Increases in pollinators |
| Udawatta et al. 2019 | Review/global | General impacts of agroforestry on biodiversity | Unknown, selected from pool of >100 publications | Silvopasture, Silvoarable, riparian buffers | • Significant positive impact of agroforestry for biodiversity globally<br>• Agroforestry impacts on biodiversity induced can be attributed to food, shelter, habitat, protection, refuge, favourable microclimate, improved soil-plant-water relationships, and other resources provided by multi-species vegetation<br>• Relative paucity of studies for agroforestry in temperate regions compared to the tropics |
| Vanbeveren & Ceulemans, 2019 | Review/temperate Europe | Impacts of SRC on biodiversity | 47 | SRC | • Short-rotation coppice offers a spatio-temporally dynamic habitat<br>• Higher fungal species richness and abundance under long-term SRC<br>• Increases in plant and floral richness around SRC stands with ongoing management. Concomitant increases in invertebrates<br>• Diversity related to length of coppice; dense homogenous coppice favours generalist plant species<br>• Species diversity and abundance of birds, mammals, butterflies, soil mites, other arthropods and earthworms all increased in SRC compared to surrounding agriculture but less so compared to natural habitats.<br>• Animal diversity closely related to nearby landscape features |
| Marsden et al. 2020 | Review/global | Effects of agroforestry on soil fauna | 13 studies based in Europe | Silvopasture, Silvoarable | • In temperate Europe, general positive effect of agroforestry for soil fauna compared to conventional arable; overall negative effect on soil fauna when compared to pasture. No difference when compared to forest |
| Mupepele et al. 2021 | Meta-analysis. Europe wide | Quantifying general impacts of agroforestry on biodiversity | 50 | Silvopasture, Silvoarable | • No consistent positive effect of agroforestry on biodiversity as compared to forest or abandoned land<br>• Silvoarable agroforestry had significantly higher diversity than conventional cropland<br>• Silvopasture had no consistent benefit<br>• Agroforestry in general increases bird and arthropod biodiversity but benefits are small |

### 3.1.1. Data coverage, biases, and knowledge gaps

The relative paucity of published studies from temperate climates - and particularly the Atlantic oceanic region - is repeatedly highlighted in reviews and meta-analyses that have investigated the impacts of agroforestry (e.g. Pumariño et al. 2015; Marsden et al. 2019; Staton et al. 2019; Udawatta et al. 2019; Mupepele et al. 2021). This contrasts with the much larger pool of studies focusing on agroforestry in the Mediterranean and tropics. Biodiversity impacts have also often been synthesised in an unsystematic way, discussed as part of a suite of benefits of agroforestry, such as carbon sequestration or productivity (e.g. Jose, 2009; Moreno et al. 2017). Low quality of individual studies, anecdotal evidence or a lack of standardisation also hinders more detailed analysis of agroforestry impacts. The most recent meta-analysis suggests an overall neutral effect on biodiversity (Mupepele et al. 2021), although this was mainly limited to one facet of biodiversity (species richness) and this analysis has been criticised for downplaying the potential benefits of agroforestry (see Boinot et al. 2022)

As well as national or continental-scale impacts, evidence is also lacking for key taxonomic groups or agroforestry systems. Perhaps surprisingly, relatively few studies have considered the effects of agroforestry on ground flora, and effects on mammals, herptiles and microorganisms are also under-reported (Boinot et al. 2022). Conversely, there may be a bias towards studies reporting impacts on birds and invertebrates. Despite being a major component of temperate agroforestry, the benefits of woody landscape features such as hedgerow networks, shelterbelts, and riparian buffers, are also underrepresented compared to alley cropping, short rotation coppice (SRC) or wood pasture (Boinot et al. 2022). This may also reflect differing definitions of agroforestry between authors, and regional variations in agroforestry systems (for example, the preponderance of hedgerow landscape within North-West Europe).

### 3.1.2. The relative impacts of agroforestry depend on land-use and climate

Where comparisons of effect, size or direction have been made, agroforestry is often reported as having stronger impacts in arable situations compared to pasture (Torralba et al. 2016; Marsden et al. 2019; Mupepele et al. 2021). Aside from any bias in study number or quality, this may reflect the often-lower baseline diversity of intensive monocultures compared to grassland habitats, which can therefore experience greater relative improvements in diversity. Forest or naturally-regenerating vegetation may also exhibit comparative or greater biodiversity gains than can be obtained by agroforestry (e.g. Marsden et al. 2019; Vanbeveren & Ceulemans, 2019; Mupepele et al. 2021). Where climate has been considered as a factor, the potential biodiversity gains obtained in drier and more productive climate zones, such as the Mediterranean basin, may also be greater than in temperate regions (Torralba et al. 2016). The quantifiable impacts of agroforestry are also likely to be greater at a catchment or landscape scale for mobile taxa, rather than an individual farm basis (Torralba et al. 2016).

### 3.1.3. Agroforestry increases landscape heterogeneity and functional diversity

Agroforestry features such as SRC alleys and hedgerows can improve connectivity within and between sites and buffer sharp edges between habitats (Bentrup et al. 2019;

Vanbeveren & Ceulemans, 2019). Hedgerows contiguous to ancient woodland remnants act as refuges for woodland specialist plants (Lenoir et al. 2019). Small mammal density, including bats, is negatively associated with distance from woody features, which act as habitat corridors (e.g. Gelling et al. 2007; Giordano & Meriggi, 2009; Toffoli et al. 2016), and continuous hedgerows with complex understories are important for the dispersal of arboreal species such as hazel dormice (*Muscardinus avellanarius*) (Bright, 1998; Dondina et al. 2016). Bird numbers are similarly related to the height of trees and the availability of woody edge habitat amongst other factors (e.g. Göransson, 1994; Sanderson et al. 2009). Woody features also promote movement of pollinators and other insects; including bees, moths, flies, and butterflies (Bentrup et al. 2019). However, in some circumstances, dense agroforestry can also act as a barrier and impede insect pollinator or predator movement (e.g. Wratten et al. 2003). This effect can isolate plant populations and potentially reduce pollen collection (Klaus et al. 2015; Bentrup et al. 2019). Agroforestry expands the range of available niches in farmland settings; trees can modify microclimates via windbreaks or temperature regulation and create an abundance of new opportunities for high-quality forage, cavity-nesting, ground-nesting or overwintering sites (Bentrup et al. 2019; Vanbeveren & Ceulemans, 2019).

### 3.1.4. Farmland birds and invertebrates consistently benefit

The diversity and/or abundance of birds is consistently suggested as benefitting from agroforestry compared to conventional agriculture (e.g. Burgess, 1999; Jose, 2009; Dauber et al. 2010; Tsonkova et al. 2012; Torralba et al. 2016; Vanbeveren & Ceulemans, 2019). Most often, this has been attributed to improved food availability, nesting or egg-laying sites, or shelter provision. In the UK, a broad range of bird species have been recorded utilising developing agroforestry sites, and this has included several of increasing conservation concern, such as wood pigeon (*Columba palumbus*), starling (*Sturnus vulgaris*), mistle thrush (*Turdus viscivorus*), merlin (*Falco columbarius*), fieldfare (*T. pilaris*), skylark (*Alauda arvensis*) and hen harrier (*Circus cyaneus*) (Toal & McAdam, 1995; Agnew and Sibbald, 1996; McAdam, 2000; Sage et al. 2006; Stanbury et al. 2021). Alley cropping or SRC can support greater bird diversity and abundances than control arable or grassland sites and introduce shrub or woodland species to lowland agriculture (e.g. Wilson, 1978; Thevathasan & Gordon, 2004; Sage et al. 2006; Sanderson et al. 2009; Tsonkova et al. 2012; Vanbeveren & Ceulemans, 2019). Amongst other factors, the number or diversity of generalist farmland birds may be positively associated to the length and complexity of coppicing (Sage & Robertson, 1996). While a broad range of species may benefit from an expansion in agroforestry, sensitive ground-nesting or farmland specialists such as yellow wagtail (*Motacilla flava*) and lapwing (*Vanellus vanellus*) may experience some displacement with a large increase in tree cover (Sage et al. 2006).

The positive effect of agroforestry on birds (and small mammals) can be partially attributed to increased abundance or diversity of invertebrates. In UK-based studies, agroforestry interventions have had positive effects on the abundance or diversity of spiders, bumble bees, butterflies, moths, springtails, true flies, aphids and shield bugs, parasitoids, gallers, leafbeetles, rove beetles, ground beetles and slugs (Peng et al. 1993; Sage et al. 1999; Griffiths et al. 2002; McAdam et al. 2007; Broome et al. 2011; Rowe et al.

2011; 2013; Varah et al. 2013). Temperate agroforestry settings can also experience greater biomass or richness of earthworms and nematodes (e.g. Schrama et al. 2014; Stauffer et al. 2016; Cardinael et al. 2018). However, under some circumstances, agroforestry may also increase populations of crop or foliar pests and associated damage, and pest management priorities may be altered (e.g. Sage et al. 1999; Peacock et al. 2001; Griffiths et al. 2002; Sage & Tucker, 2007). Via its effects on invertebrates, agroforestry is likely to enhance key ecosystem services such as pollination and decomposition (Rowe et al. 2013; Bentrup et al. 2019; Staton et al. 2019; Varah et al. 2020; Staton et al. 2021a, b). Agroforestry can also reduce pesticide drift or run-off from agricultural sites and could help to protect sensitive species or habitats (see Pavlidis & Tsihrintiz, 2017). However, the ability to absorb pollutants could also cause an accumulation of long-lasting pesticides such as neonicotinoids in nearby vegetation and inadvertently increase exposure to pollinators (Bentrup et al. 2019). Where long-lasting residual pesticides are a concern, species that are less attractive to pollinators should be considered in field margins or crop alleys (Bentrup et al. 2019). Concomitantly, the benefits to invertebrates may be greatest in organic farming systems (Boitot et al. 2020). It is clear agroforestry can support pollinator conservation, and evidence for its use as a crop pollination service in temperate regions is beginning to accumulate (Bentrup et al. 2019; Varah et al. 2020; Staton et al. 2021a).

**3.1.5. Small mammals benefit more clearly than large mammals**

Large and medium-sized mammals (e.g. deer, rabbit) may transit or shelter in coppice but exhibit no clear preference to dense plantations opposed to forest or open land (Christian, 1997). Small mammals more clearly benefit from agroforestry interventions (Wright, 1994; Burgess, 1999; Tsonkova et al. 2012; Vanbeveren & Ceulemans, 2019). For example, in a complex farming landscape in Northern England, Klaa et al. 2005 tested the effect of alley cropping on mammal distribution over a two-year period. Compared to control arable blocks, tree row understories or their adjacent arable alleys had greater small mammal numbers, and a significantly increased capture density (Klaa et al. 2005). Generalist wood mice (*Apodemus sylvaticus*), benefitted especially from the increased complexity of agroforestry plots, whilst bank vole (*Myodes glareolus*) and common shrew (*Sorex araneus*) exhibited a preference for nearby mature hedgerows (Klaa et al. 2005). The increased plant diversity afforded by agroforestry practices may be closely associated to the range of niches available for small mammals, which in turn provide a food source for predator species. Widespread losses in traditionally-managed woodland and hedgerow during the 20$^{th}$ century are implicated in the decline of threatened BAP species such as hazel dormouse (*M. avellanarius)* and hedgehogs (*Erinaceus europaeus*) (Bright & Morris, 1996; Goodwin et al. 2017; Pettet et al. 2017). Expanding and maintaining the area of these habitats is considered essential in helping to reverse these declines (Bright et al. 2006; BHPS, 2018).

**3.1.6. Plant communities are transitional**

The semi-open nature of coppiced woods or strips and a mosaic of differently-aged vegetation patches can simulate early successional woodland and can support a greater species richness than agricultural land or high forest; however colonising species are likely to be generalist and reflect local seed sources (Műllerova et al. 2015; Kirby et al. 2017;

Vanbeveren & Ceulemans, 2019). This may include important forage species such as couch grass (*Elymus repens*) and nettle (*Urtica dioica*) (Rowe et al. 2011). As in unmanaged woodland habitats, dense mature coppice can produce homogenous understories, and declines in richness may occur as plantations age (e.g. Fry & Slater, 2008; Archaux et al. 2010; Wright & Bartel, 2017). Early or frequent harvesting is likely to maintain a higher proportion of grassland or meadow species, which are outcompeted by shade-tolerant forest species as canopies close (Archaux et al. 2010, Wright & Bartel, 2017; Vanbeveren, 2019).

Within fields, tree understories or vegetation strips may also be colonised by species such as sterile brome (*Bromus sterilis*), blackgrass (*Aloprecurus myosuroides*), ryegrass (*Lolium* spp.) and annual meadow grass (*Poa annua*), and depend substantially on management practices (Peng et al. 1993; Burgess, 1999). In silvoarable contexts, this may be viewed as an undesirable outcome requiring intervention. However, the presence of weed species in tree rows does not necessarily translate into increased recruitment into adjacent crop alleys (Boinot et al. 2019a). Agroforestry may also favour perennial creeping weeds as opposed to disturbance-adapted seed-spreading weeds (Staton et al. 2021b). Sown wildflower strips in agroforestry systems can significantly enhance predator activity and pollinator visits, leading to 'win-win' outcomes for diversity, ecosystem services and farm income (e.g. Staton et al. 2021a). On priority or sensitive habitats such as calcareous grasslands or blanket bogs, tree planting is an ecologically disruptive intervention, and may cause a decline in characteristic or target diversity (e.g. Gustafsson, 1988). Overall, agroforestry produces vegetation communities situated between agricultural land and deciduous forest, and outcomes are influenced by a broad range of factors, including seed banks or sources, former land use, soil nutrient status, cultivation, and management. Aside from the impact of new trees, the exceptional levels of diversity hosted by veteran or ancient trees in wood pasture or hedgerows are well established, and such individuals represent a valuable genetic, ecological, and cultural resource (Moreno et al. 2017). Diversifying or buffering existing woodlands with native species has been suggested to support the ecological persistence of threatened keystone species such as oak (*Quercus* spp.) and ash (*Fraxinus excelsior*) (Mitchell et al. 2014; 2019)

#### 3.1.7. Agroforestry introduces a tree-associated microbial community

Temperate agroforestry can introduce (or enhance) a tree or understory-associated microbiome to depleted agricultural settings, increasing fungal or bacterial biomass, and affecting change in soil enzymic diversity and activity, respiration rates, and substrate use (e.g. Udawatta et al. 2008; Chifflot et al. 2009; Hrynkiewicz et al. 2010; Kremer & Hezel, 2012; Schrama et al. 2014; Vanbeveren & Ceulemans, 2019; Beule et al. 2020; Beule & Karlovsky, 2021). Agroforestry can enhance soil organic carbon stocks compared to conventional agriculture (De Stefano & Jacobson, 2018), and may allow for increased control of nutrient cycling and pollutant abatement (Pavlidis & Tsihrintzis, 2017; Pavlidis et al. 2020; Beule & Karlovsky, 2021). Facilitation effects by trees or associated communities may enhance crop growth or resilience to stressors (e.g. Rivest et al. 2013). Increases in the prevalence of denitrification genes in soil microorganisms could potentially reduce nitrate leaching from soils (Beule et al. 2020). The promotion of alpha-rhizobial genera, such as Bradyrhizobium and Mesorhizobium, may also enhance the likelihood of nodulation and Nfixation in nearby plants, which may be an additional benefit passively accrued in agroforestry systems (Beule & Karlovsky, 2021).

## 4. Discussion

### 4.1. What benefits to nature and biodiversity could accrue from a significant increase in agroforestry in the UK?

The potential benefit of agroforestry to farmland biodiversity is self-evident; a plethora of evidence suggests agroforestry assemblages can help increase the range and provision of habitats and niches, microclimates, food quality and abundance, shelter, egg-laying sites, increase landscape-scale connectivity and buffer habitats. Nevertheless, the impacts of agroforestry are complex and site-specific, and outcomes of a given intervention are difficult to predict. However, based on the available evidence, some general predictions could be made from a more widespread adoption of agroforestry across the UK. Based on the respective volume of evidence, a suggested level of strength in these conclusions is also indicated:

- Agroforestry can deliver increases in the abundance or richness of farmland species across major taxonomic groups (*strong evidence*). Birds and invertebrates are particularly likely to benefit (*strong evidence*).
- Relative increases in species richness are likely to be greatest in intensive arable settings (*strong evidence*).
- The impacts of agroforestry are likely to be greater on a catchment or landscape scale than on an individual farm basis (*medium evidence*). However individual sites can experience significant local improvements in diversity from tree-planting (*strong evidence*).
- Generalist species will benefit more from agroforestry in the short term (*strong evidence*).
- Farmland diversity will be strongly associated to the range of habitats available over time, and complex landscapes with a variety of agroforestry assemblages and appropriate management (e.g. phased planting or regeneration, maximising area to edge ratios, traditional hedgerow creation and having mixtures of tree species and sexes) can support greater diversity (*strong evidence*).
- The benefits of agroforestry are likely to be enhanced by other sustainable farming practices such as pond creation, organic farming, fallowing, cover cropping, wildflower strips, zero-tillage, and restoration of hay-meadows (*strong evidence*).
- In some circumstances, an expansion of tree cover may favour cereal weeds, arable pest species or displace open-ground specialists (*medium evidence*).
- Accumulation of pesticides in agroforestry vegetation may impact pollinators (*medium evidence*)
- On a site-by-site basis, agroforestry could facilitate the persistence of threatened species across a range of taxa (*medium evidence*). This could include important keystone or charismatic species such as raptors, oak, and dormice (*medium evidence*).

- Agroforestry may enhance key ecosystems services including pollination, predation, and decomposition (*medium evidence*)
- Improvements in soil microbial diversity or abundance, with positive effects on C sequestration, nutrient turnover, and pollutant control (*strong evidence*).
- Improvements in biodiversity may be highest in more productive climate regions of England (*low evidence*) or in areas closest to biodiversity hotspots (*medium evidence*)

In degraded agricultural environments, agroforestry is an intervention that can assist ecological recovery and, in general terms, be said to represent a 'stepping-stone' between managed and natural habitats (i.e. offering less benefit to biodiversity than native forest, wetland or semi-natural grasslands, but more so than intensive croplands or pasture). However, agroforestry is a diverse term and generalisations should be made with caution.

Rather than being seen as a new and radical intervention – and focusing on the short-term outcomes of planting experiments – perhaps the most persuasive argument for agroforestry is a historical one. Indeed, agroforestry represents the return to something that has been *lost* from the English landscape. Since 1945, nearly 1 million km of hedgerows have been lost in England and Wales (O'Connell et al. 2004; Carey et al. 2008). Of the ~140,000 ha of coppiced woodland in Great Britain in 1947, perhaps fewer than 40,000 ha remained by 2002 (Hopkins and Kirby, 2007). Once widespread medieval practices, such as pollarding and woodland grazing have declined precipitously, and there has been extensive but often undocumented loss of rural trees-outside-woods and traditional orchards (Petit & Watkins, 2003; Natural England, 2011; Read & Bengtsson, 2019). These environmental (and societal) transformations have all been widely associated with declines in rural biodiversity, and it is in this context that the potential of agroforestry must be considered. The main role of agroforestry, then, may be as a tool to help arrest or reverse more declines in biodiversity across the English countryside, alongside other sustainable farming practices. Its full utility for this purpose may only become apparent after decades of concerted effort to restore the agroecosystem on a national scale.

### 4.2. Suggested further research

There are numerous knowledge gaps on agroforestry and its impacts, including:

- Potential impacts of agroforestry on herptiles and bats
- Long-term consequences on understory diversity and how to maintain floristic diversity over time
- Maximising the benefit of agroforestry in silvopasture
- Factors limiting the uptake and survival of traditional rural skills such as coppicing and hedgerow laying
- Long term studies tracking changes in biodiversity over time from establishment through to maturity

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