Supplementary Information (S1)

Scott-Brown A.S., Rial-Lovera K., Giannitsopoulos M.L., Rickson R.J., Staton, T., Walters K.F.A., Burgess P. J., Farmland trees and integrated pest management: A review of current knowledge and developing strategies for sustainable systems

S1: IPM & Farmland Trees: Survey Analysis & Dissemination

Reporting back to survey participants, May 2021

Evaluating how farmland trees contribute to integrated pest management strategies in agricultural landscapes in England and Wales

Background

This document forms part of the output of a project to understand the extent to which farmland trees can constitute an accepted element of pest management strategies (IPM) applicable to arable and grasslands in England and Wales. The purpose of this preliminary report is to provide a brief summary of the outcome of the initial survey to contributing participants and to enable the opportunity for further engagement.

We are interested to receive feedback on the initial results, particularly in relation to those questions which most closely align with your work interests and encourage you to review or add additional comments you feel are relevant.

Below we list the questions and participants comments, amalgamating comments where necessary and begin to highlight examples of relevant resources and workflows where openly available.

A.1 Is information on the principal farmland tree and shrub species available?

Survey outcome: Availability of knowledge - **Limited** Priority for research – **Moderate**

Participants comments: No specific response

Indication of resources: The National Inventory of Trees in England and Wales describes the tree species composition of wide and narrow linear features. The survey indicates that 93-95% of species in England and Wales are broadleaf, with high tree species including ash (10%) and oak (8-10%) (Forest Commission 2001a; b). Forest Research has more detailed data. Hawthorn (*Crataegus spp.*) and blackthorn (*Prunus spinosa*) are reported to dominate two-thirds of British hedges (Montgomery et al 2020). The National Vegetation Classification scheme has become the standard for describing plant communities in the UK and is widely used in the academic literature (Rodwell 2006).

A.2 What are the main forms of the layout and management of farmland trees and shrubs?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Moderate**

Participants comments: No specific response

Indication of resources: About 20% of tree cover in Great Britain (GB) occurs outside of woodlands and hedgerows occupy about 1% of the land area of England and Wales (Forest Research 2017). The National Inventory of trees in England and Wales (Forestry Commission 2001a, b) describes the relative areas of trees found in wide features, linear features and in

areas between 0.25-2.00 ha. Carey et al (2008) reported the status of boundary and linear features in GB, estimating 700,000 km of lines of trees and hedgerows and a 6% loss in managed hedgerow length in GB between 1998 and 2007, with a large proportion turning into lines of trees and relict hedges. Since 2007, there has been no definitive dataset or approach for monitoring or mapping trees outside of woodlands and hedgerows within Great Britain, although there have been modelling studies (Scholefield *et al*. 2016). Determining the management of farmland trees and shrubs is more complicated.

A.3 Which invertebrate groups are key economic pests on arable farms?

Survey outcome: Availability of knowledge - **Some** Priority for research – **Moderate**

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A.4 Which invertebrate groups are key economic pests on livestock farms?

Survey outcome: Availability of knowledge - **Some** Priority for research - **Low**

Participants comments: Regarding key economic pests, it would be useful to understand both (i) farmer perceptions of the most problematic pest groups, to improve links between research and practice, and (ii) objective measures of key economic pests if possible.

Indication of resources: Open resources include national databases for pests and disease e.g., DEFRA (2021), CABI Invasive Species Compendium CABI (2021) and international databases monitoring existing and emerging risks from plant trade and imports e.g., European and Mediterranean Plant Protection Organization (EPPO 2021). Further information is available through global pest and disease biosecurity platforms and communicated through regional plant health authorities e.g. MPI (2021) and USDA (2021). Further, data compiled by long-term study sites monitoring the distribution and abundance of insect groups across England and Wales (RIS 2021) are relevant here, but also to Questions A.3, B.5, B.7 and C.2.

A.5 Which invertebrate groups are natural enemies of pests?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **High**

Participants comments: We require a better understanding of which arthropod groups provide pest control benefits / What constitutes 'economically viable' in terms of natural enemies? / Different stakeholders may consider different pest species (and therefore natural enemies) to be of priority concern, for example, Defra Plant Health and Quarantine and industry levy boards will have different perspectives. All such perspectives need to be taken to account in this work.

Indication of resources: Natural solutions pest control tool, supported by a formal alliance between CABI and the International Biocontrol Manufacturers Association (IBMA) and in collaboration with a growing network of globally-operating commercial partners, is currently being developed and applied (CABI bioprotection portal 2021). An equivalent database focussed on encouraging populations of relevant natural enemies in farmland ecosystems, which included those species/groups associated with trees, would be a valuable resource. Key gaps in our knowledge of the potential impact of trees in the farmed environment will need to be filled to produce a comprehensive database. For example, limited research appears to

have been carried out in the UK or similar temperate conditions on the effects of natural enemies or pests associated with hedges on crop yields, particularly their impact on farm profitability: this is a major gap in the evidence base.

B.1 Which species of trees and shrubs directly affect the diversity and abundance of pests?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Moderate**

Participants comments: Participants noted that tree species are capable of harbouring arthropod groups that can cause damage to crop (e.g., aphids) but from an ecological perspective, their status as a pest (in terms of abundance, dispersal) is influenced by the crop. Thus, to address tree management for IPM, research should first focus on the tree-natural enemies associations.

Indication of resources: Trees may provide resources for pest arthropods that threaten a broad range of economically important crop species (e.g., Spotted Wing Drosophila) or have the capability to vector livestock pathogens (e.g., *Culicoides*), increasing competition between all groups (harmful, benign, or beneficial) for the limited resources that farmland trees offer. Insects from all groups form food chain components and therefore provide alternative food sources for beneficial arthropods. Understanding trade-offs are imperative to maintaining communities or species mix with stability or potential to provide pest-control services beyond tree lines (in field) and available evidence appears limited.

B.2 Which species of trees and shrubs directly affect the diversity and abundance of beneficial invertebrates?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **High**

Participants comments: A suggested order of research priority i) categorise and consolidate list of key arthropods in each group (B.1 & B.2), ii) arthropod (species) distribution at landscape scale, iii) arthropod-tree association.

Indication of resources: Several open resources such as those listed above (A.3) make it possible to identify plant-hosts of important existing or potential threats from invasive arthropods if pest species is known. For indigenous natural enemies and pests, obtaining regional, compiled information on tree-arthropod associations requires a moderate level of knowledge of potential arthropod-host plants associations and multiple searches using a range of databases including those listed in A.3. Collated, comprehensive and openly accessible, on-line information on species of trees associated with beneficial arthropods is currently unavailable, beyond undertaking searches for published research and general literature held in bibliography databases.

B.3 How does layout and management affect diversity and abundance of pests?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Moderate**

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B.4 How does layout and management affect diversity and abundance of beneficial invertebrates?

Survey outcome: Availability of knowledge - **Negligible** Priority for research - **High**

Participants comments: Breakdown (B.3 & B.4) required to address diversity and abundance i) harboured within tree line and/or ii) migration and distribution in-field / How does tree management interact with other environmental management in IPM programmes (e.g., field margins)? / How does tree management impact yield/management of crops in proximity (particularly in low pest pressure years)?

Indication of resources: Different tree species and arrangements are known to promote different ecosystem services, but information on contribution in terms of IPM is limited (O'Grady & Mitchell 2018). Evidence suggests that in-field trees and tree-lines can alter natural enemy and pest communities, rather than being universally beneficial or detrimental in terms of pest incidence (Burgess *et al*. 2003; Staton *et al*. 2021). Arrangements (sentinel trees, woodland-edge, hedges/tree lines) and structure (composition, age and tree size) are all factors which will influence apparency of tree resources to arthropods (natural enemies or pests), with imposed management strategies further influencing spatio-temporal resource availability across agricultural landscapes. In this context, trees and shrubs as components of hedges (placement, management, and structure) have been more widely investigated and information has been made openly available through commissioned reports and published literature addressing favourable conditions to enhance populations of the natural enemies (Wolton *et al.* 2014, Staley *et al.* 2016). At landscape scale, numerous research studies have explored the impact of fractured habitats on wildlife (corridors, mosaic arrangements), without emphasis specifically on IPM benefits received in field crops.

B.5 How does the distribution of beneficial invertebrate groups affect the importance (relevance) of farmland trees for IPM?

Survey outcome: Availability of knowledge - **Negligible** Priority for research - **Moderate**

Participants comments: No specific response

Indication of resources: i) Regional distribution/habitat range overlap of natural enemies and tree-host across UK, ii) significance of individual pest-prey species in different regions, iii) distribution of natural enemies at the field-scale (movement from field-boundary tree-hosts into cropping areas). Overlaying these three factors may result in the significance of specific natural enemy/tree associations varying between UK regions, with consequences for the relative contribution of different tree species as components of IPM between those regions. Much research on the biology, predator-prey interactions and dispersal capability is available for many species of natural enemies, with the UK distribution well studied for a sub-set. For example, amongst other groups, distribution and phenology of predatory hoverflies is recorded by the UK Hoverfly Recording Scheme (Biological Records Centre: Ball and Morris, 2012; Stubbs, 1990; Stubbs & Falk, 2002). The importance of farmland plants (particularly hedge plants) of value to invertebrate wildlife is also well researched and has been reviewed in several reports during the last 25 years (e.g., Breeze *et al.*, (1998); Wolton *et al*., 2014). However, significant gaps in our knowledge still occur and further work

is required. In addition, in many cases the work is published as scientific reports and accessibility to agronomists/farmers is limited.

B.6 What local factors affect the association between farmland trees and economically important invertebrates?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Moderate**

Participants comments: No specific response

Indication of resources: The question scope aimed to address environmental factors beyond those imposed directly through farm management measures (see B.4 & B.7), although we accept these are not mutually exclusive. From a research perspective current debates focus on a range of interacting factors such as soil properties, hydrology, elevation, microclimatic buffering and influence of composition and structure of surrounding vegetation. Direct and indirect anthropogenic drivers highlighted to impact pollinators (IPBES, 2016) are applicable in most cases to other beneficial insects including natural enemies of agricultural pests and vectors of disease. The influence of context-dependent factors, such as local environmental factors and farm management, are key research needs, because they could explain the observed heterogeneity in the effects of in-field farmland trees on economically important invertebrates (see section 4.2 of Staton *et al.* 2019).

B.7 What key farm management actions affect invertebrate-tree relationships?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Moderate**

Participants comments: Responses received highlighted knowledge gaps: How are trees and shrubs (and subsequent impacts on IPM for invertebrates) impacted by the use of plant protection products? / Pesticide risks from drift are well known, we require a better understanding of impact on conservation biology. / Important to understand how management actions interact, with increasing dependency on natural enemies due to pesticide withdrawals. / Understanding farm and local environmental effects are key research needs because they could explain the observed heterogeneity in the effects of in-field farmland trees on invertebrates. / Organic management could be a key factor in influencing the tree-invertebrate relationship.

Indication of resources: An increasing body of primary research and quantitative data syntheses provide evidence which highlights some of the negative and positive impacts of farm practices on surrounding agroecology, including peripheral-tree communities. This includes but is not limited to, crop fertilisation and crop protection product applications, degraded field-margins (soil quality) or addition of treatments such as diverse/targeted flower

mixes and investment in agrobiodiversity (e.g., Albrecht *et al.* 2020). Notably the European Commission has pledged to support the Member states in the development of methodologies to assess compliance with the eight IPM principles, including crop rotation, cultivation techniques, use of balanced fertiliser, liming and irrigation/drainage, adequate use of PPEs and/or utilisation of ecological infrastructures inside and outside production areas EPA (2021)

C.1 Does a standard typology for IPM exist across research disciplines and industrial sectors?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Low**

Participants comments: No specific response

Indication of resources: All definitions identify with a holistic concept approach to managing pests while decreasing reliance (and/or maximising efficient use of) conventional chemical pesticides, yet 'IPM' often has different meaning depending on the context and the objectives of the user. This calls for a standard typology that can be used across disciplines, acceptable to all those who apply its concept, for example, Directive 2009/128/EC of the European Parliament which establishes a framework for community action to achieve the sustainable use of pesticides (European Union, 2009).

C.2 Do we know how to measure IPM benefits?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **High**

Participants comments: How does tree management impact yield/management of crops in proximity (particularly in low-pest pressure years)? / Measuring the benefits needs to form part of a wider piece that takes into account a whole-system approach to IPM / What constitutes 'economically viable' in terms of natural enemies? / A practitioner toolkit could be used to predict the effect of tree integration on pest management, based on the traits of key pests as defined by the user. This could improve the predictability of the effects of trees, and their arrangement, on pest management, based on the traits of key pests at the local level.

Indication of resources: Multiple interacting dynamic factors and intrinsic variations between populations clearly add to the complexity of accounting for quality and quantity of the benefits that trees can contribute to IPM strategies applied in different cropping systems. A cross-disciplinary approach using local knowledge with objective metrics and land management expertise can provide the best means to address multiple factors, particularly where data is limited. Stakeholder input is essential to support the use of analytical tools used to measure services and evaluate consequences associated with landscape changes and management decisions (summarised in Franco *et al.* 2020). An example of a platform using this kind of approach is being developed and applied by Agrimetrics in collaboration with Natural England and other DEFRA-group agencies (Agrimetrics 2021) to enable the valuation of the natural

environment and specific land uses, facilitating informed decision-making and dialogue between stakeholders. At the national level, accurate assessment of the benefits of IPM relies not only on the impact of the systems introduced but also on the level of uptake within the farming community (Puente *et al.*, 2011). At the farm level, uptake is affected by commercial viability (cost-benefit, reliability, etc.) and financial impact can be difficult to calculate. A practitioner toolkit would potentially define the required activities required to obtain the IPM benefits of farmland trees, thus providing a more reliable baseline from which objective/quantifiable assessments of costs can be estimated (see also comments under Q. C.3).

C.3 Do we know the best ways to promote farmland tree species and arrangements that provide IPM benefits?

Survey outcome: Availability of knowledge - **Negligible** Priority for research - **High**

Participants comments: Tree-management should link with other environmental management practices in IPM programmes (e.g., field margins). Industry levy boards (e.g., AHDB) may be able to promote farmland tree management for IPM.

Indication of resources: Participatory approaches remain the single most relevant consideration when developing tools to value benefits received from nature. Stakeholder engagement is an essential means to gain buy-in from all stakeholder groups at an early stage of initiatives and provides a mechanism to direct research towards farmers needs and translate research outputs into practice. Commercial viability and reliability of an IPM system is essential for uptake and thus must be a core feature of promotion of the use of tree species, as indicated under Q C.2. A proposed approach for monitoring uptake of IPM on UK farms may provide information on success of tree use in IPM (Creissen *et al*., 2019). The approach benchmarks/monitors a national IPM programme relying on (i) identifying key activities contributing to IPM (e.g., use of species and alignments of trees on farmland); (ii) weighting their relative importance to achievement of IPM using expert stakeholder panels to create the metric; (iii) surveying farmer IPM practices; and (iv) measuring level of farmer adoption of IPM using the metric. The practitioner toolkit suggested in participant comments above (Q C.2) may also provide important cost-benefit information for potential end users, enabling more comprehensive consideration of the commercial viability of the approach if adopted by their own businesses, thus supporting decision making on uptake.

C.4 Do usable resources exist to guide the use of trees to promote IPM?

Survey outcome: Availability of knowledge - **Negligible** Priority for research - H**igh**

Participants comments: In terms of future resources that could be made available, we refer again to the participant suggestion that a tool kit could be developed for practitioners, that would predict the effect of tree integration on pest management, based on the traits of key pests as defined by the user.

Indication of resources: Existing platform formats could be applicable for highlighting regional use e.g., CABIs BioProtection Portal (2021) (free for use for farmers in many countries, more recently including EU countries).

LEAF (2020) has produced a booklet, which considers field margins and hedges for IPM but, there is no explicit mention of the use of trees to promote IPM uptake. The Agricology website provides links to a number of resources that address IPM (Agricology 2021), but again, only a few of these resources mention trees / hedges specifically. The Woodland Trust produce a research briefing based on a PhD study: "Examining the impacts of integrating trees into arable fields on pest control and pollination" (Staton 2019). The Soil Association produce a downloadable handbook, which includes sections on reduced incidence of pests and diseases (Soil Association 2019).

C.5 Do farmer-led research or demonstration sites exist to test and explain the implications of farmland trees for IPM?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **High**

Participants comments: Demonstration sites are extremely valuable in knowledge exchange, particularly if fully costed.

Indication of resources: To our knowledge no specific demonstration sites are currently operating in the UK. Similar examples are found operating nationally (AHDB 2021). As a possible means to disseminate and demonstrate research evidence and increase likelihood of implementation sites should be designed and instrumented to:

- demonstrate how trees management impacts on yields/management of crops in proximity (particularly in low-pest pressure years)
- How trees and shrubs (and subsequent effects on IPM for invertebrates) are impacted by the use/extent of use of plant protection products
- Show the benefits (of trees) as part of a wider piece that takes into account a whole-system approach to IPM.
- capture farmer perceptions of the most problematic pest groups
- improve links between research and practice
- Use objective measures of key economic pests

C.6 Do we understand how voluntary initiatives and government regulation can best be used to promote the use of trees to provide IPM on farms?

Survey outcome: Availability of knowledge - **Limited** Priority for research - **Moderate**

Participants comments: It would be helpful to map out how tree management schemes might interact with other environmental management in IPM programmes (e.g., field margins).; More important to understand the details before working out how to incentivise them.; Current transition to ELMs means that this is unclear at the moment.

Indication of resources: Current Cross Compliance and Greening rules help protect hedgerows and woodlands (Woolford and Jarvis, 2017). The Basic Payment Scheme includes agroforestry (Forestry Commission 2017), but with no direct mention of the role of agroforestry in IPM. A 7-year transition to a system in which farmers are paid to improve the environment, animal health and welfare, and reduce carbon emissions commences in 2021 (DEFRA et al., 2019). The BPS and existing agri-environment schemes will be replaced by

the Environmental Land Management scheme (ELMs), made up of 3 components: Sustainable Farming Incentive (SFI); Local Nature Recovery; and Landscape Recovery.

Currently, a national pilot of ELMs (Sustainable Farming Incentive) is underway, which rewards farmers for meeting a number of standards, including a 'hedgerow standard' and an 'On farm woodland standard'. However, this considers only a sub-set of the ecological services provided and hedgerows/trees specifically for IPM is not mentioned specifically, although provision of a biodiverse habitat for woodland and farmland species is identified (DEFRA 2019).

Monitoring uptake of IPM on UK farms referred to under Question C.3, may also support effective use of ELMs to promote farmland trees for IPM.

Supplementary Information (S1)

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Further Resources

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We thank you for taking an interest and participating in the project survey and dissemination process.