

What specific plant traits support ecosystem services such as pollination, bio-control and water quality protection in temperate climates? A systematic map protocol

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SYSTEMATIC MAP PROTOCOL

Open Access



What specific plant traits support ecosystem services such as pollination, bio-control and water quality protection in temperate climates? A systematic map protocol

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Abstract

Background: Agricultural intensification has increased diffuse source pollution within water catchments, reduced heterogeneity within the landscape and caused major declines in farmland wildlife, including birds, mammals, invertebrates and wildflowers. This increase in pollution and wildlife decline, has effected three vital ecosystem services, pollination, biological pest control and water quality protection. The morphological traits of plant species, such as floral display size and leaf area, provide support to these services and vegetative strips can be established with plants that have these desirable traits. Vegetative strips are widely used across Europe and integrated into government environmental schemes such as The Common Agricultural Policy and The Water Framework Directive. However, issues of land availability and food security require a sustainable intensification of current agricultural practices. One component of this process is to sow vegetative strips that are designed to support multiple ecosystem services. To do this, combinations of plant species that will support specific ecosystem services, have been designed. However, to enable a fully-informed design process, evidence must be collated on which specific plant traits provide the support to the target ecosystem services. We propose to systematically map all evidence on which specific plant traits provide support for three of the most vital ecosystem services, pollination, bio-control and water quality protection. Information from this map could inform future decisions on which plant species are suitable for inclusion within a multifunctional vegetative strip that aims to provide the target ecosystem services. The aim of this systematic map is to create a searchable database of studies that demonstrate evidence of plant traits and how they support the named ecosystem services.

Methods: Seven bibliographic databases, 25 organisational websites and 2 search engines, will be systematically searched with predefined and tested key search terms. All searches will be undertaken in English and only those undertaken in a temperate climate zone will be considered. Studies found will be screened at title, abstract and full text levels, recording the number of excluded articles. Following full text assessment, the meta-data of included studies will be incorporated into a systematic map database in Microsoft Access. A report will summarise the evidence, highlight any knowledge gaps, and provide recommendations for future research.

Keywords: Pollinator, Beneficial invertebrate, Natural enemy, Buffer strip, Agri-environment scheme, Biodiversity, Multifunctional field margin, Vegetative strip

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Background

Around the globe, farming practices have intensified over the past 60 years, with an increase in the application of pesticides and fertilisers and the removal of off-crop habitat such as hedgerows and vegetative strips [1, 2]. This has increased diffuse pollution within entire water catchments, reduced heterogeneity within the landscape and caused major declines in farmland wildlife, including birds, mammals, invertebrates and wildflowers [3–6]. This increase in pollution and decline in wildlife, directly affects the services that a farmland ecosystem provides to the land-owner. For example, in 2007, 35% of global agricultural crops were animal-pollinated [7], but declines in wild pollinator numbers and their associated plants [8], have led to pollination deficits [9–11]. In contrast, widespread use of pesticides has led to increased resistance in over 500 species of crop pests [12] and this number is still rising. A recent review by Bass et al. [13], collated evidence on the global rise in insect resistance to the widely used neonicotinoid insecticides. Within this review, using data extracted from Michigan University's Arthropod Pesticide Resistance database [14], resistance was shown to be already present in over twenty insect pest species including some significant crop pests such as *Bemisia tabaci*, *Myzus persicae*, *Aphis gossypii* and *Nilaparvata lugens*. This, combined with recent calls for sustainable intensification [15], drives the need to control pests using other means, such as predation by their natural enemies (biological pest control) [16]. However, supportive habitat that provides shelter, overwintering sites, alternate hosts or prey and pollen and nectar [17], has been widely removed [18]. These off-crop habitats within agricultural land offer other benefits too. Riparian buffer strips, for example, provide a valuable barrier to pollution, protecting water quality [19]. Without them, pollutants such as pesticides, nitrates and phosphates start to increase water toxicity and cause eutrophication [20–22].

The services that an ecosystem provides are numerous, but the three outlined above, (pollination, biological pest control (bio-control) and water quality protection) are some of the most vital when making agriculture more environmentally sustainable [23]. The morphological traits of different plant species, such as floral display size, nectar content and leaf area, can provide support to these services [24]. For example, Kudo et al. [25] found that *Bombus hypocrita* subsp. *Sapporoensis*, were more attracted to a larger floral display size, Bianchi and Wackers [26] found that a plant with a higher nectar content attracted more parasitoids, and Burylo et al. [27] found that a plant's ability to trap sediment was positively correlated with leaf area. An illustration of how plant traits may support these three different ecosystem services can be seen in Fig. 1.

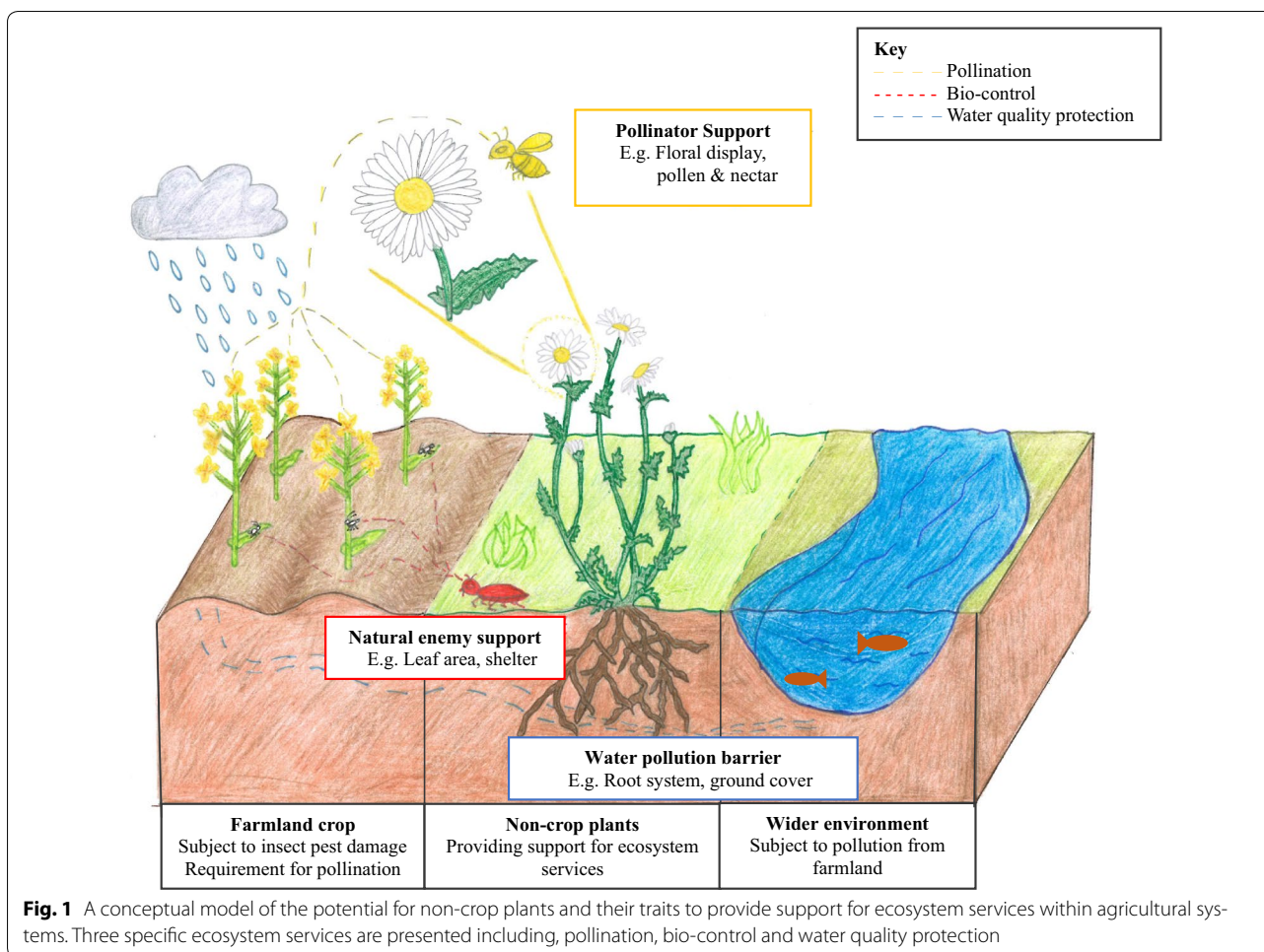
Non-crop habitats, such as vegetative strips, can be established with plant species that have desirable traits, to try and return support for these vital ecosystem services [28], and support may even be made available through legislation and incentives. In Europe, for example, specified habitats, plants and animals are protected through the Habitats Directive [29], and water quality through the Water Framework Directive and the Nitrates Directive. The latter specifically addresses water pollution by leaching of nitrates from agriculture into farmland watercourses [30]. Also, funding for the preservation of habitat biodiversity, water quantity and quality and the protection of soil from erosion is provided via the Common Agricultural Policy (CAP) [31–34].

Though these policies are effective, future availability of land is likely to be restricted due to food production requirements, which have increased with consumption growth, and issues of food security such as, competition for land, climate change and other land use pressures, caused by the continued exponential increase of the human population [35, 36]. This has created a need to sustainably intensify agriculture, which involves increasing food production from existing agricultural land whilst minimising pressure on the environment [15].

In order to support this sustainable intensification, it may be necessary to increase the ecosystem service value of off-crop habitats by designing vegetative strips that aim to support multiple ecosystem services [28, 37] rather than prioritising one over the others. Combinations of plant species to support specific ecosystem services, are already utilised in parts of Europe (e.g. [38, 39]). However, to enable the maximum functionality of measures such as vegetative strips, it may be valuable to consider which specific plant traits provide support to the target ecosystem services. Therefore, we propose to systematically map all evidence on specific plant traits that provide support for three of the most vital ecosystem services, pollination, bio-control and water quality protection.

Objective of the systematic map

This systematic map will collate existing research on plant traits and how they may support pollinators, natural enemies and water quality protection. It will focus on studies undertaken in temperate climate zones, applied to any type of habitat. The study will focus on specific plant traits that provide support for the target ecosystem services. Whole plant community traits will not be included in this map. The outputs will consist of a searchable database for all the named ecosystem services and a report summarising the nature and character of the evidence.



Primary question

Which plant traits provide the following ecosystem services, within temperate climates:

- Pollinator support
- Crop pest natural enemy support
- Water quality protection

Elements of the primary question

Population

Water quality, pollinator species and natural enemies of insect crop pests, within temperate climates. A temperate zone has a temperature range of -3 to +18 °C, shown as 'C' in the Köppen-Geiger world map on climate classification Kottek et al. [40].

Exposure

Specific plant traits, for example floral display size, leaf area etc.

Comparator

Lack of traits or alternative traits, for example no floral display.

Outcome

Outcomes of each study will be stated as they are found within the relevant articles included and details will be coded into the map accordingly.

Methods

The methods used in the development of the systematic map database will be adapted from the Collaboration for Environmental Evidence (CEE) Systematic Review Guidelines [41] and from an existing systematic map report, Randall and James [42].

Searches

A comprehensive search will be undertaken using multiple information sources to capture an un-biased sample

of literature. The search strategy was developed to identify both published and grey literature.

Key search terms

An initial scoping search was performed to validate the methodology and used to provide a preliminary indication of the volume of relevant literature. Search terms were tested between November 2014 and March 2015 for specificity and sensitivity using the Harper Adams University library electronic database, 'Findit@Harper', and used to indicate the volume of relevant literature. The search terms, number of articles found and general quality of the search results were recorded in Microsoft Excel (Additional file 1).

The following Boolean search operators will be used. A wildcard (*) will be used where accepted by a database or search engine to pick up multiple word endings, for example plant* would pick up plant, plants, etc. A keyword may be made more restrictive by the addition of a qualifier e.g. (plant*) AND (trait*) AND (beneficial) AND (invertebrate*). The combination of qualifiers and keywords will vary for each ecosystem service, based on the results of the scoping search. The exact keyword and qualifier combinations to be used are listed in Table 1 in Additional file 2.

Plant traits identified by the systematic map will then be used as keywords for further searches linking them with the specific target ecosystem services, e.g. (floral display*) AND (pollinat*). This will ensure that the searches are as comprehensive as possible.

Sources of publications

Several online sources will be searched in the English language to identify relevant literature and a record of each search will be made to enable a re-run of the search if needed. Data that will be recorded include: date search conducted, database name, search term, number of hits and any other notes.

The following online sources will be searched:

1. Bibliographic electronic databases:

- 1.1. Harper Adams University Library Database ('Findit@Harper') which includes the following relevant sources (all other sources included in this database can be found in Additional file 3):
- 1.2. ISI Web of Science involving the following products: ISI Web of Science; ISI Proceedings
- 1.3. Index to Theses Online
- 1.4. Agricola (United States department of Agriculture National Agricultural Library) NAL catalogue
- 1.5. Copac
- 1.6. Directory of Open Access Journals (DOAJ)

2. Grey literature for specialist searching

2.1 Organisational websites

Where possible, Boolean search terms will be used in these databases. However if the technical infrastructure of a database does not support this search method, simplified subsets of the key search terms will be used.

- 2.1.1. Defra (<https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs>)
- 2.1.2. UK Environment Agency (<https://www.gov.uk/government/organisations/environment-agency>)
- 2.1.3. UK Forestry Commission/Forestry Research (<http://www.forestry.gov.uk/>)
- 2.1.4. The Woodland Trust, UK (<https://www.woodlandtrust.org.uk/>)
- 2.1.5. Natural England (<https://www.gov.uk/government/organisations/natural-england>)
- 2.1.6. Natural Resources Wales (<https://naturalresources.wales/>)
- 2.1.7. Scottish Natural Heritage (<http://www.snh.gov.uk/>)
- 2.1.8. Scottish Environment Protection Agency (<https://www.sepa.org.uk/>)
- 2.1.9. Northern Ireland Environment Agency (<https://www.doeni.gov.uk/>)
- 2.1.10. European Environment Agency (<http://www.eea.europa.eu/>)
- 2.1.11. European Commission Joint Research Centre (<https://ec.europa.eu/jrc/en>)
- 2.1.12. Ministry of Agriculture and Forestry (Finland) (<http://mmm.fi/en/frontpage>)
- 2.1.13. Swedish Environmental Protection Agency (<http://www.swedishepa.se/>)
- 2.1.14. Danish Environmental Protection Agency (<http://eng.mst.dk/>)
- 2.1.15. Ministry of Environment and Food of Denmark (<http://en.mfvm.dk/the-ministry/>)
- 2.1.16. Government Norway Portal (<https://www.regjeringen.no/en/>)
- 2.1.17. Flemish Environment Agency (<http://en.vmm.be/>)
- 2.1.18. Federal Environment Agency (Germany) (<http://www.bmub.bund.de/en>)
- 2.1.19. Federal Ministry of Food, Agriculture (Germany) (<http://www.bmel.de>)
- 2.1.20. Netherlands Environmental Assessment Agency (<http://www.pbl.nl/en>)
- 2.1.21. Federal Department for the Environment,

- Transport, Energy and Communication (Switzerland) (<http://www.uvek.admin.ch/>)
- 2.1.22. Federal Office for Agriculture (Switzerland) (<http://www.blw.admin.ch>)
- 2.1.23. Food and Agriculture Organization of the United Nations (<http://www.fao.org>)
- 2.1.24. Ecologic Institute (<http://www.ecologic.eu>)
- 2.1.25. EU Cost (European Cooperation in Science and Technology) (<http://www.cost.eu>)
- 3. Search engines
 - Scirus (www.Scirus) and Google Scholar (scholar.google.com). The first 25 hits (.doc,.txt,.xls and.pdf documents where this can be separated) from each data source will be examined for appropriate data. No further links from the captured website will be followed unless to a document/pdf file
- 4. Other literature searches
 - Other specific/specialised databases will be searched where identified or recommended by experts within the field.
- 5. Key studies through stakeholder consultation
 - Bibliographies of articles viewed at full text will be searched for relevant articles missed by previous searches. Recognised experts, practitioners and authors will be contacted for further recommendations and to provide relevant unpublished material or missing data.

Article screening and study inclusion criteria

Screening process

The results of each search term on each database will be imported into a separate EndNote X7 library file. All the database libraries will be incorporated into one library, recording the number of references captured. Using the automatic function in the EndNote X7 software, any duplicates will be removed.

The inclusion criteria will be applied by one reviewer to all potential articles at the title and abstract level. Where there is insufficient information to make an informed decision regarding an article’s inclusion, relevance to full text assessment will be assumed. A second reviewer will examine a random subset of at least 10% of the reference list to assess repeatability of the selection criteria. A

kappa analysis will be performed to determine agreement between reviewers, with a score of 0.6 or above indicating substantial agreement. Disagreement between reviewers will be discussed and resolved by consensus. This same method will be used to assess the quality assessment and data extraction methods.

A full list of articles excluded at full text with reasons for exclusion will be provided.

Inclusion criteria

All retrieved studies will be assessed for relevance using the following inclusion criteria:

Relevant subject(s) Studies that investigate some aspect of plant traits and how they provide support for the target ecosystem services will be considered for inclusion into the systematic map.

Relevant climate zone Studies that have been undertaken in a region with a temperate climate, i.e. those classified as ‘C’ in Kottek et al. [40].

Language All languages will be included in initial searches. Only studies published in English will be included in full text assessment. This is due to limited resources and the languages known by the study reviewers.

Date No date restrictions will be applied.

Relevant ecosystem service provided The following support for ecosystem services provided by plant traits will be included: support for pollinators and crop pest natural enemies and water quality protection.

Relevant Population Water quality, pollinator species and natural enemies of insect crop pests.

Relevant exposure Specific plant traits, for example floral display size, leaf area, root length, plant height.

Relevant comparator Lack of traits or alternative traits, for example no floral display.

Relevant outcome Outcomes of each study will be stated as they are found within the relevant articles included and details will be coded into the map accordingly.

Examples of outcomes may include:

- Effects on pollinator abundance and diversity, visitation rates and attractiveness.
- Effects on natural enemy abundance and diversity or predation rates

Table 1 Study quality assessment categories. Modified from Haddaway et al. [45]

Quality assessment term applied	Replication	Sample selection	Other sources of bias
Yes	Well-replicated (>10 samples per group)	Random or blocked or exhaustive	None evident
Partially	Moderate level of replication (4–10 samples per group)	Not stated but clearly random or blocked	Potential confounder
Not at all	Poorly-replicated or not stated (1–3 samples per group)	Purposive or not stated	Clear confounder

- Effects on water quality protection including inhibiting pollution from nitrogen, phosphorus, pesticides and sediment levels.

Relevant study design: Any primary research study that collects experimental or quasi-experimental data to investigate the effect of specific plant traits on provision of the named ecosystem services.

Potential sources of bias

Due to limitations on resources, only English language articles will be included in full text assessment. This does limit the number of articles discovered. Further funding to translate relevant articles or employ a reviewer that can understand multiple languages, could help increase the geographical scale of this systematic map.

Study quality assessment

This quality assessment method has been informed by the systematic review guidelines' hierarchy of evidence used in medicine and public health [43] and conservation [44]. A generic list of variables used for quality assessment developed by Haddaway et al. [45] will be modified and combined with topic-specific quality measures. These may include an assessment of the sampling methodology used (e.g. number, frequency and period of sampling, quality of measure, standards adhered to etc.). An example of a good quality of measure could refer to the sampling technique, such as ensuring the ground is flush with a pitfall when setting the trap. Standards adhered to refers to any known standards for that method of sampling, for example, observations of pollinators such as bees should be undertaken between 10 a.m. and 4 p.m. Terms including 'yes', 'partially' or 'not at all' will be applied to each study for these methodological factors during the creation of the systematic map database. Studies will be assessed on three categories, degree of replication, sample selection methods and other sources of bias, as shown in Table 1.

For example, a replicated, randomised control trial with no obvious bias would be categorised with the term 'yes' in all cases. No articles will be excluded from the database based on study quality.

Data coding strategy

Studies that pass the inclusion criteria will be imported into a database. Generic and topic specific keywords were discussed with experts to assess their suitability. Each article will be coded and categorised according to these terms, which are as follows:

- Author
- Title
- Publication date
- Reference type
- Target system (e.g. a specific plant species)
- Plant trait
- Target organism (e.g. specific pollinator species)
- Outcome
- Target Ecosystem service
- Study country
- Study region/state
- Study site (e.g. greenhouse, pine forest etc.)
- Study timing (specific date(s) that the study took place)
- Study length
- Study type
- Linked study (ID numbers from the article(s) in which the linked study took place will be cross-referenced here)

The following potential effect modifiers have been compiled following discussion with subject experts and will also be coded in the map:

- Country of origin
- Climate (e.g. annual average rainfall values), only studies undertaken in temperate regions are to be included
- Soil properties (e.g. free or poor draining/nutrient levels)
- Time of planting
- Sampling method
- Species of crop pest natural enemy
- Species of pollinator

Data regarding the study characteristics, quality of design and results will be recorded. A notes section will identify any other interesting results such as other ecosystem services provided (e.g. nutrient or carbon cycling or carbon sequestration), but will not be included in further analysis. Where there is more than one article found for a study, each article will be recorded and cross referenced in the database. Also, where there is more than one study within an article, information about each study will be included in the database.

The systematic map database will describe the extent of the research in the field. It will be searchable by topic and can be arranged according to topic areas, publication date, type of ecosystem service, plant species, plant trait, country of study etc. Simple numerical accounts of the frequencies in each category will be able to be obtained

from the systematic map. Pivot tables will be generated in order to identify trends in the research.

Where information regarding the reasons for heterogeneity is presented in the studies, it will be recorded e.g. species of pollinator, time of sampling etc. Where necessary and feasible, authors will be contacted for missing/suitable data.

Subject experts will review the completed systematic map database to ensure that all relevant categories have been defined.

Study mapping and presentation

The systematic map will be presented in an Access database, accompanied by a report describing the nature and character of the evidence. Summary graphs and tables of the study characteristics and quality will be presented. Possible knowledge gaps will also be identified, and recommendations will be made for future research based on the findings of the map.

Additional files

Additional file 1. Scoping search for plant traits and ecosystem services.

Additional file 2. Keywords and qualifiers to be used in the literature search.

Additional file 3. Sources searched by Harper Adams University Library Database.

Authors' contributions

CJB: Design, drafting and revision of protocol. NPR: Conception of project and design of protocol, involved in drafting and revision of protocol, final approval of version. HMC: Participated in the drafting and revision of the manuscript. AW: Participated in the drafting and revision of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests. Any reviewers involved in this review that are also authors of relevant articles will not be included in the decisions connected to the inclusion and critical appraisal of the articles.

Availability of data and materials

All data generated or analysed during this study are included in this published article and information files.

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