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Environmental Evidence

SYSTEMATIC MAP PROTOCOL

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The multifunctional roles of vegetated strips around and within agricultural fields. A systematic map protocol

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Abstract

Background: Agriculture and agricultural intensification can have significant negative impacts on the environment, including nutrient and pesticide leaching, spreading of pathogens, soil erosion and reduction of ecosystem services provided by terrestrial and aquatic biodiversity. The establishment and management of vegetated strips adjacent to farmed fields (including various field margins, buffer strips and hedgerows) are key mitigation measures for these negative environmental impacts and environmental managers and other stakeholders must often make decisions about how best to design and implement vegetated strips for a variety of different outcomes. However, it may be difficult to obtain relevant, accurate and summarised information on the effects of implementation and management of vegetated strips, even though a vast body of evidence exists on multipurpose vegetated strip interventions within and around fields. To improve the situation, we describe a method for assembling a database of relevant research relating to vegetated strips undertaken in boreo-temperate farming systems (arable, pasture, horticulture, orchards and viticulture), according to the primary question: What evidence exists regarding the effects of field margins on nutrients, pollutants, socioeconomics, biodiversity, and soil retention?

Methods: We will search 13 bibliographic databases, one search engine and 37 websites for stakeholder organisations using a predefined and tested search string that focuses on a comprehensive list of vegetated strip synonyms. Non-English language searches in Danish, Finnish, German, Spanish, and Swedish will also be undertaken using a web-based search engine. We will screen search results at title, abstract and full text levels, recording the number of studies deemed non-relevant (with reasons at full text). A systematic map database that displays the meta-data (i.e. descriptive summary information about settings and methods) of relevant studies will be produced following full text assessment. The systematic map database will be displayed as a web-based geographical information system (GIS). The nature and extent of the evidence base will be discussed.

Keywords: Vegetative strip, Buffer strip, Filter strip, Buffer, Agri-environment, Agricultural policy, Mitigation, Agricultural pollution, Agricultural management

Background

The ecological impacts of agricultural intensification and change in Europe since the Second World War are well documented and affect both agricultural areas and their surrounding systems [1]. Biodiversity, air and water quality, soil structure and ecology have all been affected [2]. Well-documented impacts of agricultural development include: widespread negative effects of the application of nutrients in fertilisers (mineral and organic) and agrochemicals on soil, and surface and ground water quality [3], emission of N_2O as a potent greenhouse gas [4], and negative effects of pesticides on non-target invertebrate species [5], birds [6] and biological control potential [7]

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together with the loss of ecological heterogeneity at multiple spatial and temporal scales [8]. The establishment and management of vegetated strips (including field margins, buffer strips and hedgerows) are key mitigation measures for these negative environmental impacts [9].

Definition of vegetated strips

Here, we define vegetative strips as any vegetated area set-aside from the main cropping regime within or around a field, and installed for the purposes of benefiting native biota, water and air quality, socio-economics, and yield. Examples of such interventions include: hedgerows, field margins, buffer strips, beetlebanks and shelterbelts (Fig. 1). For the purposes of this review, we focus on those interventions that are permanent or semi-permanent fixtures in agricultural landscapes, and the interventions must therefore be in place for longer than 12 months (see Inclusion Criteria for further details).

Vegetated strips have a multi-functionality that covers a range of processes, including protection of water quality in surface waters, habitat improvement, biodiversity, shading, carbon sequestration, flow capture, biomass production, landscape diversity, and societal services [10]. These processes are recognised to occur through a suite of pathways that impact socio-economic and environmental outcomes (Fig. 2).

Vegetated strips and water flow

Many of the ecosystem services provided by vegetated strips exist because of a reduction in water flow that occurs due to the presence of aboveground vegetation, roots and soil complexity.

As surface runoff passes across field margins, the velocity of flow tends to decrease in response to the type and density of strip vegetation as well as to any changes in slope. This reduction of flow allows suspended sediment to be deposited, which decreases the transport of sediment and sorbed nutrients and other contaminants beyond the strip. The reduction also provides potential for infiltration of water into the strip, decreasing the total volume of runoff water and the associated load of dissolved contaminants. The effectiveness of vegetated strips in reducing sediment transport off-site is known to vary with the ratio of runoff area to the area of the strip [11] as well as with other factors including soil type, topography, soil–water management (such as drainage pipes), land use, rainfall intensity and antecedent moisture conditions [12]. For instance, nutrients and pollutants may readily flow through vegetated strips from the soil surface and into drainage pipes, particularly in clay soils, through macropores, cracks and root channels. This effect may be prevalent on any soil type where heavy rain follows dry periods. Similarly, the beneficial flow reduction properties of vegetated strips can be negated either where the strips occur on steep ditch banks, or where steep channels allow flow to be diverted around the strips.

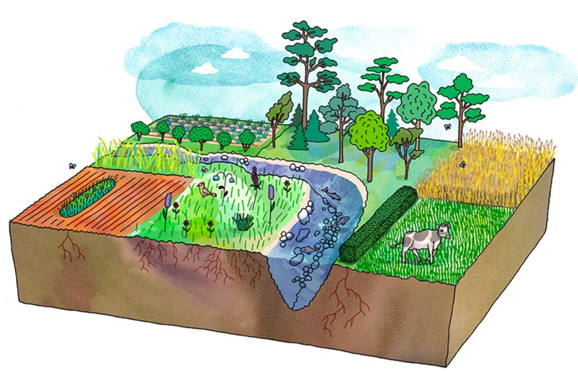
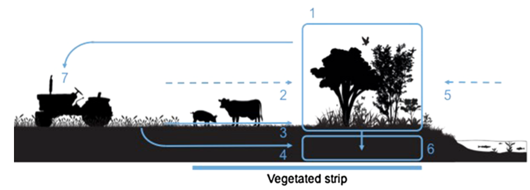


Fig. 1 Illustration of the variety of vegetated strips used within and around fields. Interventions include: in-field strips such as beetlebanks, hedgerows, forested shelterbelts, shrubs, grassy strips, and wildflower margins. Illustration: Gunilla Hagström/Form Nation



Pathways to impact:
1. Presence of habitat
2. Interception of chemical drift
3. Overland flow/surface unoff
4. Subterranean flow (sublateral flow, artificial drainflow, shallow groundwater flow)
5. Interception of wind
6. Interaction with the soil
7. Agronomic

Fig. 2 Conceptual model of pathways to impact for vegetated strips within or around fields. Illustration: Neal Haddaway

Effects on nutrients and other contaminants

Nutrients and pesticides are amongst the most important pressures on aquatic ecosystems, where excess inputs may deteriorate ecosystem integrity and/or threaten drinking water resources [13, 14]. Even strongly-sorbed compounds, including faecal pathogens from livestock or slurry fertiliser applications, can harm surface water quality through long-distance erosive runoff. Management of these pollutant losses takes place both through baseline regulations, and by introducing cross compliance or general binding rules for protection of receiving water bodies [15]: both for control at source and locally targeted regulations using incentives at high risk contaminant pathways. Buffer strips are one of the most commonly applied management measures, and are mainly designed and implemented to control sediment, phosphorus, nitrogen and pesticide losses to off-site surface waters [16, 17]. They have been shown to be highly efficient for reducing nutrient runoff from farmed fields in a wide range of climate regions across the world [18, 19]. Similarly, vegetated strips in riparian zones are also effective at removing nitrogen in proximity to watercourses, particularly subsurface nitrogen, although their efficacy appears to be variable [20]. Generally, the effectiveness of vegetated strips in controlling transport of more soluble contaminants is less than for strongly-sorbed chemicals. There is also potential that dissolved contaminants infiltrating into the margin may subsequently reach surface water via subsurface drains and/or shallow groundwater.

Where contaminants may be emitted to the air, as for pesticide spraying, vegetated strips have a dual functionality in increasing the distance between the emission source and vulnerable habitats such as surface waters or non-crop habitats, but also through the potential for interception of spray drift. Finally, it is known that pharmaceuticals used in animal husbandry may also be important contaminants of terrestrial environments adjacent to agricultural fields [e.g. 21]. In such cases, vegetated strips can provide a physical barrier where operations such as spreading of manure and biosolids are not allowed.

Effects on biodiversity

The widespread loss of spatial landscape heterogeneity, associated with the use of a few high yielding crop types across large uniform fields [8], is often viewed as a key driver of biodiversity loss on arable land across Europe [22–24]. Hence, the creation and management of various field margin habitats has the potential to restore habitat diversity for the benefit of associated farmland biodiversity [25]. Hedgerows and other field margin vegetation types have been shown to affect the richness and abundance of flora, invertebrates and birds [26–28]. For instance, grassy field margins have been shown to provide important refuge and food for invertebrates, mammals and birds [29, 30]. Yet, these effects may depend on landscape structure and regional levels of agricultural intensification [31]. As a result measures are sometimes implemented in landscapes where their effects are small or even negative [32].

As field margins comprise a variety of different vegetation types that are managed for different purposes, their effects on biodiversity and associated ecosystem services may vary. For instance, pollinator habitat enhancement in the form of hedgerows and flower-rich buffer strips may contribute to yield on adjacent fields [33] but also overall biodiversity and biological control potential in the surrounding landscape [34]. Buffer strips established using densely planted perennial grasses may primarily benefit invertebrates for pest suppression [35] but also increase the availability of suitable nesting sites for ground-foraging farmland birds on adjacent crop fields [36]. However, the access to foraging opportunities for insectivorous birds in these strips may be substantially lower compared to margins planted with wildflower mixes [37] or naturally regenerating margins on poor soils with a diverse seed bank (19). At the regional scale these benefits may be particularly valuable in resource-poor landscapes [38]. In addition, both at local and regional scales, vegetated strips provide valuable linear habitats that may promote connectivity between areas of non-agricultural land or semi-natural landscapes [39]. Finally, it is important to mention that vegetated strips around and within fields may also negatively impact on crop production and biodiversity. This is because field margins harbour weeds, pests and diseases (e.g. viruses), which could potentially create a conflict between crop production and biodiversity conservation [9, 40]. Increased habitat heterogeneity may also have negative impacts on some species that require or prefer large, homogeneous environments, such as farmland and migratory birds [41, 42]. Some of these homogeneous environments, commonly considered to be the result of agricultural development and intensification, may represent natural systems, particularly those in central and eastern Europe [43].

Other effects

Depending on the nature of their management, vegetated strips can provide various other services. For example, strips with perennial grasses or trees and/or shrubs, can counter soil erosion via filtration of larger sediment particles [44, 45], and by increasing soil stability through increased root density [46]. Some resources from vegetated strips can be harvested periodically, such as wood and fodder [16], and strips are also used to provide nesting and foraging habitat for game bird populations [e.g. 47] although elevated mortality and nest predation can occur in these habitats [48, 49]. A less well-studied aspect of vegetated strips is their potential to enhance aesthetic values and perceived "naturalness" of agricultural landscapes, especially when vegetated with trees and/or shrubs and employed in areas where such features are absent [16]. Similarly, other values may be investigated, including provision of game habitat, refugia for crop pest predators, and amenity use of agricultural land, for example by horse riders.

Multipurpose vegetated strips and conflicting objectives

One key question relating to vegetated strips as an environmental intervention on farmland is how to evaluate multifunctional effects; that is, impacts of single strips on multiple outcomes. True evaluation for areas larger than the plot-scale is difficult to undertake due to difficulties in having representative controls. One possibility to overcome large-scale evaluation problems is therefore upscaling of plot results and/or modelling, and in both cases collection of data from experimental studies conducted around the world will be invaluable as a baseline. In their review of the multifunctional role of vegetated strips on arable farms, Hackett and Lawrence [50] concluded that although different strip types can produce multiple benefits, none can wholly provide for all environmental outcomes. One way to optimise multiple benefits from field margins at the field and landscapes scale could therefore be to adjust management practices locally according to purpose.

In reality, however, many vegetated strips vary in their purpose, method of establishment and ongoing management. Common forms of field margins include those that are naturally regenerated from unused farmland, those sown with grass or wildflower mixes, those sown specifically for target organisms such as pollinators (nectar and pollen mixes) or for wild birds (seed mixes), those that are annually cultivated and those that are unmanaged [50]. The specific design and management of a vegetated strip may depend on the main reason for the intervention, and the resultant efficacy for the different outcomes described above may vary accordingly. Wildflower strips, for example, are designed to benefit pollinators such as bees [29], whereas densely vegetated strips typically established by sowing a mixture of perennial grass species adjacent to water courses, are primarily used to mitigate soil erosion [51] and reduce leaching of nutrients and agro-chemicals [52]. The access to foraging opportunities for insectivorous birds in strips designed for water protection may be substantially lower compared to strips planted with wildflower mixes [37] or naturally regenerating strips on poor soils with a diverse seed bank [30]. Accordingly, managing vegetated strips for biodiversity or for diffuse pollution purposes may entail very different management practices, since retained dissolved or particulate matter eventually accumulates within the strip, which in turn may reduce the potential for biodiversity benefits. However, removal of plant material from vegetated strips could help maintain long-term retaining capacity, avoiding their transformation into nutrient sources, and with simultaneous benefits of lower nutrient levels and/or sparser vegetation for wild flora and visual foragers such as birds [53]. An additional consideration in this context relates to pollution swapping [54], where mitigation measures for one pollutant cause an increase in another pollutant. In this way, vegetated strips for controlling nitrogen leaching could lead to simultaneous transformation of sediment-bound phosphorus into soluble reactive phosphorus.

Identification of the topic

The topic was suggested at a general stakeholder meeting arranged by MISTRA EviEM on September 24th, 2012. Suggestions for the topic were made by the Swedish Board of Agriculture, the Swedish Environmental Protection Agency, the Swedish Ministry of the Environment, Svensk Sigill, Hushållningssällskapet, WWF, and researchers from the Centre for Biodiversity and the Department of Ecology at the Swedish University of Agricultural Sciences. The focus and scope of the review was narrowed and better defined during a specific stakeholder event on September 1st, 2015.

Objective of the review

The aims of this review are to identify, collate, and describe relevant published research relating to the effectiveness of vegetated strips in and around farmland for a wide variety of purposes, including but not limited to: the enhancement of biodiversity; the reduction of pesticide and nutrient drift/runoff/leaching; the mitigation of soil loss; the reduction of pathogens and toxins; and, socioeconomic values, such as provision of game habitat and reduction of crop pests. The map will be restricted in geographical scope to boreal and temperate systems (see Inclusion Criteria below) and will consist of a report describing the review process, a searchable database describing the identified relevant studies, and an interactive, web-based geographical information system (GIS) displaying the contents of the database.

Primary question	What evidence exists regarding the effects of field margins on nutrients, pollutants, socioeconomics, biodiversity, and soil retention?
Secondary question	To what extent has this research focused on multi-use vegetated strips?
Population	Boreo-temperate regions as defined by the following Köppen-Geiger climate classification zones [55]: Cfa, Cfb, Cfc, Csb, Csc, Dfa, Dfb, Dfc.
Intervention	Vegetated strip interventions around and within fields used for arable, grazing and horticulture, orchards and vineyards, where presence of a vegetated strip or management of the strip is investigated.
Comparator	Before vegetated strip establishment, before a change in vegetated strip management

	(temporal comparisons); no vegetated strip, different vegetated strip management, including strip width (spatial comparisons); outside a vegetated strip.
Outcome	Outcomes will be included iteratively as they are identified within the relevant literature and will be coded accordingly

Methods

Searches

Bibliographic databases

The following academic citation databases will be searched for studies using English search terms (non-English articles, where present, are typically catalogued with English titles, abstracts and/or keywords):

1. Academic Search Premier (http://www.ebscohost.com/academic/academic-search-premier)
2. Agricola (http://www.agricola.nal.usda.gov/)
3. AGRIS: agricultural database (FAO) (http://www.agris.fao.org/agris-search/index.do)
4. Biosis Citations Index (http://www.wok.mimas.ac.uk/)
5. Directory of Open Access Journals (http://www.doaj.org/)
6. PubMed/MEDLINE (http://www.ncbi.nlm.nih.gov/pubmed)
7. Scopus (http://www.scopus.com/)
8. Web of Science Core Collections (http://www.wok.mimas.ac.uk/)
9. Zoological Record (http://www.thomsonreuters.com/products_services/science/science_products/a-z/zoological_record)
10. JSTOR (http://www.jstor.org/)
11. DART-Europe E thesis (http://www.dart-europe.eu/basic-search.php)
12. EThOS (British Library) (http://www.ethos.bl.uk/Home.do)
13. Index to Theses Online (http://www.theses.com/)

Search string

The following search string will be used as a basis for searches within each of the above databases:

> *("agroforestry buffer*" OR "barrier strip*" OR "beetle bank*" OR beetlebank* OR "bird cover barrier*" OR "bird cover border*" OR "bird cover boundar*" OR "bird cover buffer*" OR "bird cover filter*" OR "bird cover margin*" OR "bird cover strip*" OR "bird cover zone*" OR "border strip*" OR "boundary buffer*" OR "boundary management*" OR "boundary margin*" OR "boundary strip*" OR "buffer management*" OR "buffer strip*" OR bufferstrip* OR "buffer zone*" OR bufferzone* OR "conservation buffer*" OR "conservation head land*" OR "conservation headland*" OR "countour strip*" OR "cropland buffer*" OR "cultivated barrier*" OR "cultivated border*" OR "cultivated boundar*" OR "cultivated buffer*" OR "cultivated filter*" OR "cultivated margin*" OR "cultivated strip*" OR "cultivated zone*" OR "ditch bank*" OR "farm buffer*" OR "farm edge*" OR "farm interface*" OR "farmland buffer*" OR "farmland margin*" OR "field bank*" OR "field border*" OR "field boundary*" OR "field buffer*" OR "field edge*" OR "field interface*" OR "field margin*" OR "filter margin*" OR "filter strip*" OR "filter strip*" OR filterstrip* OR "filter zone*" OR "filter zone*" OR filterzone* OR "*flower barrier*" OR "*flower border*" OR "*flower boundar*" OR "*flower buffer*" OR "*flower filter*" OR "*flower margin*" OR "*flower strip*" OR "*flower zone*" OR "forest barrier*" OR "forest border*" OR "forest boundar*" OR "forest buffer*" OR "forest filter*" OR "forest margin*" OR "forest strip*" OR "forest zone*" OR "forested barrier*" OR "forested border*" OR "forested boundar*" OR "forested buffer*" OR "forested filter*" OR "forested margin*" OR "forested strip*" OR "forested zone*" OR "grass water way*" OR "grass waterway*" OR "*grass barrier*" OR "*grass border*" OR "*grass boundar*" OR "*grass buffer*" OR "*grass filter*" OR "*grass margin*" OR "*grass strip*" OR "*grass zone*" OR "grassed barrier*" OR "grassed border*" OR "grassed boundar*" OR "grassed buffer*" OR "grassed filter*" OR "grassed margin*" OR "grassed strip*" OR "grassed water way*" OR "grassed waterway*" OR "grassed zone*" OR "grassy barrier*" OR "grassy border*" OR "grassy boundar*" OR "grassy buffer*" OR "grassy filter*" OR "grassy margin*" OR "grassy strip*" OR "grassy water way*" OR "grassy waterway*" OR "grassy zone*" OR "grazed barrier*" OR "grazed border*" OR "grazed boundar*" OR "grazed buffer*" OR "grazed filter*" OR "grazed margin*" OR "grazed strip*" OR "grazed zone*" OR "hedge row*" OR hedgerow* OR "herbacious barrier*" OR "herbacious border*" OR "herbacious boundar*" OR "herbacious buffer*" OR "herbacious filter*" OR "herbacious margin*" OR "herbacious strip*" OR "herbacious zone*" OR "managed barrier*" OR "managed border*" OR "managed boundar*" OR "managed buffer*" OR "managed edge*" OR "managed filter*" OR "managed margin*" OR "managed strip*" OR "managed zone*" OR "margin strip*" OR "nectar barrier*" OR "nectar border*" OR "nectar boundar*" OR "nectar buffer*" OR "nectar filter*"*

OR "nectar margin" OR "nectar strip*" OR "nectar strip*" OR "nectar zone*" OR "noncropped barrier*" OR "non-cropped barrier*" OR "noncropped border*" OR "non-cropped border*" OR "noncropped boundar*" OR "non-cropped boundar*" OR "noncropped buffer*" OR "non-cropped buffer*" OR "noncropped filter*" OR "non-cropped filter*" OR "noncropped margin*" OR "non-cropped margin*" OR "noncropped strip*" OR "non-cropped strip*" OR "noncropped zone*" OR "non-cropped zone*" OR "perennial barrier*" OR "perennial border*" OR "perennial boundar*" OR "perennial buffer*" OR "perennial filter*" OR "perennial margin*" OR "perennial strip*" OR "perennial zone*" OR "permanent border*" OR "permanent buffer*" OR "permanent margin*" OR "permanent strip*" OR "plant barrier*" OR "plant border*" OR "plant boundar*" OR "plant buffer*" OR "plant filter*" OR "plant margin*" OR "plant strip*" OR "plant zone*" OR "planted barrier*" OR "planted border*" OR "planted boundar*" OR "planted buffer*" OR "planted filter*" OR "planted margin*" OR "planted strip*" OR "planted zone*" OR "pollen barrier*" OR "pollen border*" OR "pollen boundar*" OR "pollen buffer*" OR "pollen filter*" OR "pollen margin*" OR "pollen strip*" OR "pollen zone*" OR "riparian barrier*" OR "riparian border*" OR "riparian boundar*" OR "riparian buffer*" OR "riparian filter*" OR "riparian margin*" OR "riparian strip*" OR "riparian zone*" OR "river barrier*" OR "river border*" OR "river buffer*" OR "river margin*" OR "setaside border*" OR "set-aside border*" OR "setaside buffer*" OR "set-aside buffer*" OR "setaside margin*" OR "set-aside margin*" OR "shelter belt*" OR shelterbelt* OR "sown barrier*" OR "sown border*" OR "sown boundar*" OR "sown buffer*" OR "sown filter*" OR "sown margin*" OR "sown strip*" OR "sown zone*" OR "sterile strip*" OR "stream barrier*" OR "stream border*" OR "stream buffer*" OR "stream margin*" OR "strip management" OR "strip vegetation" OR "strip-management" OR "uncropped barrier*" OR "un-cropped barrier*" OR "uncropped border*" OR "un-cropped border*" OR "uncropped boundar*" OR "un-cropped boundar*" OR "uncropped buffer*" OR "un-cropped buffer*" OR "uncropped filter*" OR "un-cropped filter*" OR "uncropped margin*" OR "un-cropped margin*" OR "uncropped strip*" OR "un-cropped strip*" OR "uncropped zone*" OR "un-cropped zone*" OR "uncultivated barrier*" OR "uncultivated border*" OR "uncultivated boundar*" OR "uncultivated buffer*" OR "uncultivated filter*" OR "uncultivated margin*" OR "uncultivated strip*" OR "uncultivated zone*" OR "unmanaged barrier*" OR "unmanaged border*" OR "unmanaged boundar*" OR "unmanaged buffer*" OR "unmanaged filter*" OR "unmanaged margin*" OR "unmanaged strip*" OR "unmanaged zone*" OR "unploughed barrier*" OR "un-ploughed barrier*" OR "unploughed border*" OR "un-ploughed border*" OR "unploughed boundar*" OR "un-ploughed boundar*" OR "unploughed buffer*" OR "un-ploughed buffer*" OR "unploughed filter*" OR "un-ploughed filter*" OR "unploughed margin*" OR "un-ploughed margin*" OR "unploughed strip*" OR "un-ploughed strip*" OR "unploughed zone*" OR "un-ploughed zone*" OR "vegetated barrier*" OR "vegetated border*" OR "vegetated boundar*" OR "vegetated buffer*" OR "vegetated filter*" OR "vegetated margin*" OR "vegetated strip*" OR "vegetated water way*" OR "vegetated waterway*" OR "vegetated zone*" OR "vegetation barrier*" OR "vegetation border*" OR "vegetation boundar*" OR "vegetation buffer*" OR "vegetation filter*" OR "vegetation margin*" OR "vegetation strip*" OR "vegetation zone*" OR "vegetative barrier*" OR "vegetative border*" OR "vegetative boundar*" OR "vegetative buffer*" OR "vegetative filter*" OR "vegetative margin*" OR "vegetative strip*" OR "vegetative water way*" OR "vegetative waterway*" OR "vegetative zone*" OR "water way border*" OR "water way buffer*" OR "water way maring*" OR "waterway border*" OR "waterway buffer*" OR "waterway margin*" OR "weed strip" OR "weeded barrier*" OR "weeded border*" OR "weeded boundar*" OR "weeded buffer*" OR "weeded filter*" OR "weeded margin*" OR "weeded strip*" OR "weeded zone*" OR "weedy barrier*" OR "weedy border*" OR "weedy boundar*" OR "weedy buffer*" OR "weedy filter*" OR "weedy margin*" OR "weedy strip*" OR "weedy zone*" OR "widlife strip*" OR "wildlife corridor*" OR "wind buffer*" OR "wood barrier*" OR "wood border*" OR "wood boundar*" OR "wood buffer*" OR "wood filter*" OR "wood margin*" OR "wood strip*" OR "wood zone*" OR "wooded barrier*" OR "wooded border*" OR "wooded boundar*" OR "wooded buffer*" OR "wooded filter*" OR "wooded margin*" OR "wooded strip*" OR "wooded zone*" OR "woody barrier*" OR "woody border*" OR "woody boundar*" OR "woody buffer*" OR "woody filter*" OR "woody margin*" OR "woody strip*" OR "woody zone*") AND ("agro-ecosystem*" OR agroecosystem* OR agricult* OR agronom* OR arable* OR crop* OR cultivat* OR farm* OR field* OR grassland* OR "grass land*" OR hotricult* OR meadow* OR orchard* OR plantation* OR ranch* OR vineyard* OR pasture* OR cattle* OR graz*) OR "riparian buffer"*

Search terms were identified through a scoping process. Firstly, we generated a list of 120 articles known by the review authors to be relevant to the topic. The titles, keywords and abstracts were then subjected to textual analysis to identify the most frequently occurring words. Key terms were then selected from this list and added to a pre-existing list generated by the review authors. Key terms were then used to probe the titles and keywords of articles in the above list to identify common *co-locators* (i.e. words located next to key terms in the text). *Common pairs* (i.e. any pair of words that frequently occur together in the corpus) were also identified. All key terms were then assembled and tested both individually and in combination. Terms that resulted in very large numbers of results but that were also subjectively assessed as having low relevance (i.e. the terms 'vfs', 'bz', 'bzs', 'fbz') were excluded from the final search string. See Additional file 1 for details of search string development.

The search yielded a total of 10,263 results in Web of Science Core Collection using a 'topic word' search on 22/12/2015. Abstract and title level screening demonstrated that a subsample of the search results had a proportional relevance of 31 % (n = 100).

Specialist searches

Searches for grey literature will be performed in two key ways (in addition to the searches as part of the citation database searches above; i.e. thesis databases and Scopus). Firstly, searches will be performed using an extensive (i.e. downloading and assessing the first 1000 results) title-only search of Google Scholar (http://www.scholar.google.ca/intl/en/scholar/about.html) (see Web-based Search Engine Searches, below), which has been proven to return a high percentage of grey literature (c. 37 %; [56]).

Secondly, the websites of the following organisations will be queried and downloaded using web crawling software [56]:

1. Aarhus University, Department of Agroecology (http://www.au.dk/en/, http://www.agro.au.dk/en/).
2. Columbia Basin Agricultural Research Center (http://www.cbarc.aes.oregonstate.edu/long_term_pubs).
3. European Environment Agency (http://www.eea.europa.eu/).
4. European Soil Portal (http://www.eusoils.jrc.ec.europa.eu).
5. GRACEnet, USDA Agricultural Research Service (http://www.ars.usda.gov/research/programs/programs.htm?np_code=212&docid=21223).
6. Rothamsted Research (http://www.rothamsted.ac.uk/).
7. Soilservice (http://www4.lu.se/o.o.i.s/26761).
8. Swedish Board of Agriculture (http://www.jordbruksverket.se).
9. Swedish Environmental Protection Agency (http://www.naturvardsverket.se).
10. Swedish University of Agricultural Sciences (http://www.slu.se).
11. UC Davis, Agricultural Sustainability Institute (http://www.ltras.ucdavis.edu/).
12. University of Copenhagen (http://www.ku.dk/english).
13. University of Illinois, Department of Crop Sciences (http://www.cropsci.illinois.edu/research/morrow).
14. USDA Agricultural Research Service (http://www.ars.usda.gov/research/programs/programs.htm?np_code=211&docid=22480).
15. World Bank (http://www.worldbank.org/reference/).
16. Adas (http://www.adas.uk/).
17. INIA (http://www.inia.es/IniaPortal/verPresentacion.action).
18. INRA (http://www.inra.fr/).
19. Arvalis (http://www.arvalisinstitutduvegetal.fr/index.html).
20. IRSTEA (http://www.irstea.fr/accueil).
21. OPERA (http://www.operaresearch.eu/).
22. SERA-17 (http://sera17.org/).
23. Hydrotekniska Sällskapet (http://www.hydrotekniskasallskapet.se/).
24. Wageningen University (http://www.wageningenur.nl/en/wageningen-university.htm).
25. Alterra (Wageningen University) (http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/alterra.htm).
26. Greppa Näringen (http://www.greppa.nu).
27. National Farmers Union (http://www.nfuonline.com/home/).
28. RSPB (http://www.rspb.org.uk/).
29. NABU (https://www.nabu.de/).
30. European Crop Protection Association (http://www.ecpa.eu/).
31. LUKE (http://www.jukuri.luke.fi/).
32. SYKE (http://www.syke.fi/fi-FI/Julkaisut).
33. Aalto University (http://www.otalib.fi/tkk/julkaisee/).
34. Theseus (https://www.theseus.fi/).
35. ARTO (https://www.arto.linneanet.fi/vwebv/searchBasic?sk=fi_FI).
36. VIIKKI (http://www.eviikki.hulib.helsinki.fi/).
37. Hankehaavi (http://www.hankehaavi.fi/).

Internet searches

Title-only searches in Google Scholar will be performed for a range of key intervention search terms that individually returned more than 100 search results in Web of Science during scoping. Details of these searches are provided in Additional file 1. Searches will be performed in English, French, Spanish, Swedish, German, Finnish and Danish. Only the first 1000 results are viewable within Google Scholar, but these records will be downloaded into a database for later screening using the method outlined in Haddaway et al. [56].

Supplementary searches

The results of the above searches will be tested for comprehensiveness by comparing a predefined test list of 114 studies against the combined results to ensure all of these relevant studies are found. This checking will be performed iteratively at the start of the searching process and the strategy will be adapted should additional terms be identified for inclusion in the search string. In addition, the bibliographies of all relevant reviews identified through searching will be screened to retrieve any potentially relevant studies missed by the search strategy.

Screening

All articles identified through searching will be screened at title, abstract and then full text levels for relevance using predefined inclusion criteria (detailed below). Consistency in the application of the inclusion criteria will be tested by comparing agreement between two reviewers at abstract level screening, using a subset of 200 abstracts. Disagreements will be discussed and the inclusion criteria refined where necessary. Agreement will be tested formally using a kappa test [57], and if agreement score falls below 0.6, indicating moderate agreement, a third reviewer will be consulted and a further 200 abstracts screened following discussion of disagreements. Following abstract screening, potentially relevant studies will be retrieved in full text. Unobtainable articles will be listed in the final report. All screened full texts that are excluded from the review will be listed along with exclusion reasons in the final report.

Inclusion criteria

Relevant subjects	Boreo-temperate regions as defined by the following Köppen-Geiger climate classification zones [55]: Cfa [warm temperate]; Cfb and Cfc [maritime temperate or oceanic]; Csb [dry summer or Mediterranean]; Csc [dry summer maritime subalpine]; Dfa [hot summer continental]; Dfb [warm summer continental or hemiboreal]; and, Dfc [continental subarctic or boreal (taiga)].
Relevant interventions	Vegetated strip interventions in or around fields used for arable, grazing and horticulture, orchards and vineyards, where presence of a vegetated strip or management of the strip is investigated.
Relevant comparators	Before vegetated strip establishment, before a change in vegetated strip management (temporal comparisons); no vegetated strip, different vegetated strip management, including strip width (spatial comparisons); outside a vegetated strip.
Relevant outcomes	Outcomes will be included iteratively as they are identified within the relevant literature and will be coded accordingly. Outcomes will include but are not restricted to: terrestrial and aquatic biodiversity (including connectivity); nutrient runoff or leaching; pesticide runoff, leaching or drift; soil retention; socioeconomics.
Relevant types of study design	Primary research studies involving field-based experimental manipulations and observations. Interventions must have been in place for 12 months or more. Management interventions within fields that are effected upon existing crops (such as cover crops, intercropping, etc.)

	will not be considered. Furthermore, only direct evidence of the impacts of vegetated strips will be included in the map: i.e. not indirect evidence, such as the ability of a border species grown elsewhere to alter an outcome. Modelling studies will be included where they provide primary data. Laboratory studies will not be included. Relevant reviews and meta-analyses will be recorded in a separate database.
Relevant languages	All languages included where possible. Studies in languages not able to be translated will be included in a separate supplementary database.

Critical appraisal

Critical appraisal will not be undertaken within this map, since the measurement methods will vary substantially across different outcomes. A very basic quality assessment will be undertaken in the form of a 'free text' metadata variable where a brief description of the study quality will be made, flagging up clearly unreliable research that should be excluded, or serious deficiencies that should be pointed out in those studies that remain in the map.

Data coding strategy

Meta-data (i.e. descriptive data regarding the methods and setting of each study) will be extracted from included, relevant studies and entered into a searchable database. In addition, the database will be populated with a number of variables, each given a category according to a predetermined strategy (also known as coding). This database will form one of the main outputs of the review and will be supplied as a supplementary file along with a help file. Consistency of data extraction across team members will be conducted using a subset of 100 studies to ensure complex data are extracted reliably.

The following information will be entered into the systematic map database for all included studies that are available and deemed as relevant at full text. The following types of information will be recorded (see Additional file 2 for further details): author email address, study location, soil management practices, soil description, farm management practices, vegetated strip description, vegetated strip management, study design, experimental design, sampling design, measured outcome, data location, and critical appraisal comments.

Study mapping and presentation

The database will be accompanied by a report that describes the review process and the evidence base, identifying possible knowledge gaps (i.e. subtopics requiring further primary research), knowledge gluts (i.e. subtopics with enough evidence and interest to warrant a systematic review), and best practices in research methodology. Particular attention will be paid to studies that describe vegetated strips established for multiple purposes (e.g. biodiversity and nutrient retention). In addition, the database will be displayed visually in the form of a geographical information system (GIS) that maps studies by their location across a cartographical map. This GIS will be made available via the EviEM website (http://www.eviem.se).

Additional files

Additional file 1. Search strategy development.

Additional file 2. Coding tool.

Abbreviation

N_2O: nitrous oxide.

Authors' contributions

This review protocol is based on a draft written by NRH. All authors assisted in editing and revising the draft. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests. Authors of research studies included in this review will not be involved in any decisions regarding their own work.

Availability of data and materials

A list of excluded studies at full text, a list of unobtainable and un-translated articles, a list of relevant reviews and meta-analyses, the systematic map database, and the GIS will be included as supplementary files with the final review report.

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