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Environmental Evidence

SYSTEMATIC MAP PROTOCOL
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What evidence exists on the impact of agricultural practices in fruit orchards on biodiversity indicator species groups? A systematic map protocol

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Abstract

Background: Biodiversity loss, due in part to intensification of agriculture, has become a global issue. In this context, fruit producers are looking for nature-friendly production methods. Their aim is to reduce intensive pesticide use and to enhance orchard management in terms of optimising habitats for beneficial organisms. However, fruit production, especially in low-stem orchards, requires several interventions over the course of the year (tillage, thinning, mowing, disking, spraying, fertilisation, etc.), each of them representing a disturbance. Surprisingly, international journals seem to contain few publications on the impact of most of these practices (except pesticides) on biodiversity in general and beneficial organisms in particular, even though the benefits of predators to control pests have been known for decades. However, an increasing number of studies have been published in the past 10 years, corroborating the importance that biodiversity has gained as a topic in life cycle assessment. In this context, an expert system that considers the impact of individual farming activities on a set of biodiversity indicators (flora of crops and grasslands, birds, mammals, amphibians, slugs and snails, spiders, carabids, butterflies, wild bees, and grasshoppers) is to be extended to practices in low-stem and high-stem orchards. We therefore intend to conduct a systematic map to assess what evidence exists on the impact of agricultural practices in fruit orchards on biodiversity indicator species groups.

Methods and output: By gathering this information, we aim (a) to assess the state of research on discrete indicators and/or practices, (b) to identify literature relevant for assessing production impact and habitat suitability and (c) to provide a wide-ranging overview of existing evidence and its transfer to extension services and public perception. A literature search in scientific journals, agronomy magazines and the internet will therefore be performed in English, German and French. Following article screening, included articles will be recorded and coded (per the results of a limited study quality assessment). The resulting database and maps will be presented along with descriptive statistics of the distribution and abundance of evidence across interventions and outcomes.

Keywords: Arboriculture, Habitat management, Management system, Natural enemies, Obstbau, SALCA-biodiversity, Scoring, Semi-natural habitat, Verger

Background

Biodiversity loss has been recognised as a global issue, and agriculture has been one of the main drivers of global biodiversity change. In recent centuries, traditional low-intensity farming and its interaction with varying climate, topography and soil conditions have created diverse semi-natural habitats, which initially increased biodiversity across much of Europe although natural habitats declined as agriculture spread. However, intensification of agriculture in recent decades has occurred on several scales, from field scale by increased inputs of agrochemicals and mechanical activities, to landscape scale by the reduction, simplification and

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fragmentation of habitats [1]. These processes have led to major and in some cases unpredictable effects on biodiversity, in terms of both conservation and function issues.

Agricultural production relies on interventions that protect agroecosystems and yields from pests but cause unsuitable conditions for most organisms except those capable of adapting. This is particularly true for fruit, vegetable and vine growing. One of the farming activities with the highest impact on wild farmland species is the use of pesticides, the effects of which have long been discussed in many scientific reviews and reports, e.g. [2–5]. These analyses have shown that attempts to control pests using synthetic pesticides have opened a Pandora's box, especially in view of the current debate about pollinator decline [6]. Measures to enhance both pest control and pollination functions have to be implemented to benefit service providers, i.e. natural enemies and pollinators. These organisms interact with others through resource sharing, competition, predation, etc. and are organised into networks in ecosystems.

Public awareness has been growing and some producers nowadays are looking for nature-friendly production methods which would allow reductions in pesticide use [7] and reliance principally on pests' natural enemies. The role of organisms in supporting the fruit grower's fight against pests was recognised early [8, 9] and has led to successfully applied pesticide substitutes such as the release of predators and mating disruption. However, the role of organism communities supported by habitat management has been examined with controversial results in recent decades [10]. In this context, it seems that research into negative or positive impacts on biodiversity of all agricultural practices remains fragmentary and incomplete, especially in fruit orchards. Yet, in the past few years, pest management relying on biodiversity ('functional biodiversity') has become increasingly important and successful in modern agriculture [11]. It is promoted by statutory organisations [12, 13] and—at a more general level—by national and international policies [14–16]. Functional biodiversity is a major pillar of agricultural production [17, 18]. The subject has become important enough to be assessed in transnational research projects [19]. This emphasises that sustainable production strategies require consideration of many factors, especially considering biodiversity at large while looking at functions, which a particular group of species may provide.

Decision-making for nature-friendly land use in farming landscapes needs methods and indicators for assessing effects on biodiversity. Measuring impact of farming activities has a high importance with respect to both biodiversity conservation and function. Over the last decade, biodiversity has become an important topic as an impact category in life cycle assessment (LCA) [20]. Several approaches have been developed, focusing on various aspects of biodiversity at different scales. Here, we contribute to improving an expert system that considers the impact of individual farming activities on a set of biodiversity indicators [21]. This expert system was developed to include biodiversity (i.e. organismal diversity) as an LCA impact category in agricultural production (SALCA Biodiversity for Swiss Agricultural LCA [22]). Eleven indicator species groups or ISGs (flora of crops and grasslands, birds, mammals, amphibians, slugs and snails, spiders, carabids, butterflies, wild bees, and grasshoppers) were selected on the basis of ecological and lifecycle assessment criteria. Inventory data on arable crops, grasslands and SNHs and agricultural practices with detailed management options were specified. A scoring system was developed, estimating the suitability of farmland crops and SNHs as habitats as well as the reaction of each indicator species group to the management options. In this way, production systems can be compared in terms of their potential impact on biodiversity, which may in turn enable us to make recommendations for good practice.

We now aim to extend the expert system to fruit growing orchards. Examples of contrasting orchard habitats include highly equipped crops with, e.g. protection against hail, stakes and wire support, or freestanding trees and perches for raptors (Additional file 1: Figures 1, 2). Examples of important agricultural practices in orchards (APO) are pesticide application, fertilisation, thinning of flowers and foliage, training system and architecture of the canopy, green cover in the inter-row and use of flowering mixtures, direct or indirect utilisation of natural enemies, and tillage in the row and the inter-row.

The development of expert systems s.l. relies strongly on available information from the scientific literature and thus requires a strong and clear extraction strategy. In order to improve the classification and ease the use of the information, we decided to develop a systematic map (Additional file 1: Figure 3). This procedure has high potential to be beneficial for similar processes and future extensions of the expert system considered here. We therefore aim here to describe our approach in detail.

Objectives of the map

Looking for best practice methods in agriculture requires close cooperation between research and practical knowledge. This map will therefore contain articles published in scientific journals, information delivered by extension services for farmers, as well as information material from popular science.

The primary intention is to show the extent and distribution of research into the impact of agricultural practices in fruit orchards on biodiversity indicator species groups. This will allow the evaluation of the current depth and degree to which the relationship has been examined for specific practices and species groups. It will thus allow the detection of possible needs for further research or deeper review. The main question is therefore (PICO key elements):

> *What evidence exists on the impact of agricultural practices in fruit orchards on biodiversity indicator species groups?*

Population: Selected biodiversity indicator species groups (ISG; flora of crops and grasslands, birds, mammals, amphibians, slugs and snails, spiders, carabids, butterflies, wild bees, and grasshoppers).

Intervention: All identified agricultural practices in fruit orchards (APO).

Comparator: Comparison of pre- and post-intervention and/or comparison of impacts of practices with each other or to an untreated, abandoned or semi-natural site.

Outcome: Measures of change in diversity, dispersal and abundance of the biodiversity indicator species groups.

Potential uses of the map are (A) to show, for each ISG and APO, whether existing research is ample enough to answer impact questions regarding, e.g. production and management systems, methodologies, geographic distribution, (B) to help in determining priorities for future research on the impact of discrete practices on discrete indicators, and (C) to provide agricultural extension services and public science with a wide-ranging overview of existing evidence aligning with major priorities in biodiversity research, in order to improve knowledge transfer from science to agricultural practice.

Methods

Searches

The search will include the eleven selected ISGs (flora of crops and grasslands, birds, mammals, amphibians, slugs and snails, spiders, carabids, butterflies, wild bees, and grasshoppers) and agricultural practices in orchards (Table 1).

Based on the inventory data of the expert system developed for crops [21, 23], an inventory of orchard-specific practices has been established. We identified 48 main practices including a total of 219 options. Examples of practices are pruning, tillage, insecticide application, machines, installation of hail protection nets; examples of options are type of fertiliser, type of pesticide, type of machine, date and/or duration of the intervention, type of tillage, etc. Out of these, we defined nine generic search terms, which are likely to be used in most articles dealing with the subject.

Table 1 ISG and APO terms chosen to compose the search strings

Orchard* AND	
ISG term	**APO term**
Main	*Main*
Amphibian*, bee, bees, bird*, butterfl*, carabid*, flora, grasshopper*, mammal*, slug*, snail*, spider*	Fertili*, hail*, irrigation, mow*, mulch*, pesticide*, insecticide*, fungicide*, pruning, thinning, tillage
Secondary (wildcards not shown)	*Secondary (wildcards not shown)*
Bat, blossom, flower, frog, mouse, mice, toad, weed	Canopy, cover, crop, disking, defoliation, extirpator, field cultivator, grazing, grid, grubber, habitat, harvest, high stem, lumber, management, meadow, nesting, plough, plow, ripper, sawnwood, timber

An *asterisk* will be used as a wildcard to obtain suffixed and plural forms if necessary

Because search functionalities vary across most databases, the search strings shown below may be subject to slight modifications. The full list of strings effectively used on each website will be published in the finalised map. As far as possible, the search will be restricted to title and abstract. A search on full text will be performed if necessary, e.g. on specialist websites. As a basic rule, the nominative singular completed by a wildcard will be used during the search.

The search strings will always be "orchard*" combined with one or more ISG and/or APO terms. Secondary terms will be used in amendments if necessary.

In a first step, the search string composition will be "orchard" AND "ISG term". This string may need to be narrowed in the event of an excessive number of hits. However, a first scoping exercise has shown that an explicit narrowing of the search string will be necessary only on a few websites.

Example step 1: orchard* **AND** carabid*
Example step 2: orchard* **AND** carabid* **AND** (fertilis* OR hail* OR irrigation OR mow* OR mulch* OR pesticide OR pruning OR thinning OR tillage)
Example step 3: orchard* **AND** carabid* **AND** tillage

Searches will be performed in English on the following publication databases: Wiley Online Library; Science Direct; IngentaConnect; Oxford Journals; Web of Science; Taylor Francis Online; Springer Link.

With a view to gathering further scientific, agronomic and grey literature, an internet search using Google Scholar and the search engine Bing will be performed in English, German and French. Finally, specialist sites will be checked for their publications and further leading links. All information obtained from these sites and the internet search will be considered. Because the list depends on the search findings, it cannot be shown exhaustively here but will include the following:

http://www.agroscope.admin.ch/agrarlandschaft-biodiversitaet/index.html?lang=en
http://www.agroscope.admin.ch/publikationen/suche/index.html?lang=en
http://www.bafu.admin.ch/biodiversitaet/15201/index.html?lang=en
www.fibl.org
http://prodinra.inra.fr
http://orgprints.org/
http://www.naturwissenschaften.ch/organisations/biodiversity
http://www.vogelwarte.ch/en/home/
http://www.ctifl.fr/Pages/Kiosque.aspx?idTypePublication=0
http://www.jki.bund.de/de/startseite/veroeffentlichungen/vitis.html

Article screening and study inclusion criteria

Screening process

The article screening will be achieved with speed reading techniques [24] supported by electronic scanning. The inclusion/exclusion process takes place in three successive steps (see schematic view, Additional file 1: Figure 4), always applying the criteria mentioned in the "Inclusion/exclusion criteria" below: (1) at title (online search), (2) at abstract (downloaded reference), and (3) at full-text (downloaded *.pdf) level. Articles excluded after step (2) or (3) will be assigned an exclusion reason and shown on a separate spreadsheet in the additional files of the finalised map.

The team has developed a step-by-step inclusion/exclusion-scheme from the online search to the full-text assessment which is explained in the Additional file 1: Figure 4. This scheme shall serve the replicability of the exclusion process and allow the single reviewer in charge of screening the titles and abstracts to comply with the inclusion/exclusion criteria and, in case of doubt, to tend towards inclusion at these steps. The conformance of the inclusion/exclusion decision among reviewers will be validated by a Kappa-Test: To control for consistency, two reviewers will check one literature database independently, compare their results, and improve the scheme. If required, a similar check will be done on a subset of articles at full-text assessment.

Due to the high number of ISG and APO included in the map, the full-text assessment will first be performed by an electronic scan of the *.pdf within the reference manager software to identify relevant terms. These terms will be recorded on a spreadsheet that will serve as a meta-guiding when reading the "Methods" part of the full-text and thus allow to easily decide upon the final inclusion/exclusion before mapping the relevant articles in details.

Inclusion/exclusion criteria

We will include all publications fulfilling three conditions:

1. They cover an orchard culture type: pip fruits, stone fruits, olives, nuts, kiwi and citrus fruits located within temperate and Mediterranean climates.
2. They cover an indicator species group (flora of crops and grasslands, birds, mammals, amphibians, slugs and snails, spiders, carabids, butterflies, wild bees, and grasshoppers).
3. They cover an agricultural practice [fertilisation, netting (hail, insects, birds), harvest, irrigation, mowing, mulching, pest control (biological, fungicide, insecticide, mechanical, pesticide), pruning, thinning, tillage, training system, vegetation management].

We will exclude all articles not accessible at full-text and those which only address:

1. Berries, arable crops, vegetables, vineyards, forests or grasslands.
2. Tropical fruit and nut crops.
3. Citrus fruits grown in tropical climates.
4. Agronomic aspects of an APO without impact description on an ISG.
5. Life trait aspects of an ISG without impact description of an APO.
6. Organisms other than the chosen ISG.

Study quality assessment

As the main intent of the map, a quality assessment of individual articles will be implemented. Following the general aim of systematic mapping, assessment of individual articles will not be as thorough as that of a review, but shall rather be sufficient to allow for a swift preselection of literature. Several mapped parameters of scientific and thematic relevance will be assigned a value between 0 and 5 to assess the study quality:

1. Scientific relevance: study design, number of sites, duration of the experiment/observation, geographical extent, statistical processing, data visualisation;
2. Thematic relevance: precision level of the description of the ISG and the APO (see data coding beneath), availability of species lists, precision of the shown treatment plan.

Each parameter will be weighted by the project team, each member of the team evaluating the parameters first on their own. The evaluation will then be compared, major differences discussed and adjusted. The detailed study quality assessment will be shown in the finalised map.

Data coding strategy

Several spreadsheet fields will contain code sets (draft shown in Additional file 1: Table 1), which will be developed during the full-text assessment. An overview of the planned information records is given below. The definitive list of code sets will be available in the final map. To do so, articles will be examined for their contents. As a first step, some information required for the coding will be extracted with an electronic screening of the full-text in the reference manager and transferred to the spreadsheets. These records will then serve as indicators, leading the reviewer's attention when reading the full-text. This will be especially helpful when coding the description level.

Reference manager fields: Reference ID, Type, Author, Title, Year, Journal, URL (and/or DOI), Authors Keywords, Abstract.

Map fields: Continent, Country, Region, Language, No of Sites, Duration in Years/growing seasons, Comparator, Study design, Management System-Organic/Integrated/Conventional, Comments, Tables and/or figures Y/N, Statistics Y/N, Species-Lists Y/N, Treatment-plan what Y/N, Treatment-plan when Y/N, Surroundings-Influence, Culture type, Production, Other beneficials, Other pests, Aspects—functional biodiversity/conservation biodiversity/habitat suitability.

Description level of ISG and APO: in four classes according to the importance attached to each ISG and APO: 1: only marginally mentioned; 2: addressed but not deepened; 3: discussed; 4: main focus.

In order to facilitate the handling of the map, a central common keyword list will be elaborated and provided with the finalised map (draft shown in the Additional file 1: Table 2). Articles' own keywords will be kept in the database in a separate spreadsheet.

Study mapping and presentation

All articles will be recorded in a reference manager software (EndNote X7®). For data processing and preparation of the map, records will be transferred to Excel® spreadsheets via an *.xml-file.

In the spreadsheets, tables will be generated with the aim of (a) producing a preliminary evaluation and (b) creating the evaluation spreadsheet for the primary intention. New spreadsheets will then be shaped to gather further information. The reference ID serves as a link between the spreadsheets.

Finally, the individual spreadsheets will be imported into an Access® database. There, spreadsheets will be interlinked (Additional file 1: Figure 5). Mapping, data coding and data extraction will enable an evaluation of the state-of-the-art in current research and discussion. A glossary and a list of terminology will be added to facilitate the handling of three languages and synonyms (Additional file 1: Tables 3, 4). The combination of keywords, quality assessment and additional data (e.g. language, localisation, time frame, etc.) will allow fine-tuned database requests to be done easily on single spreadsheets or among several spreadsheets (Additional file 1: Figures 6, 7).

Additional file

Additional file 1. Pictures, figures and tables cited in the text.

Authors' contributions

MvdM will carry out the literature search and will draft the coding, the keywording and the systematic map's contents as well as editing this manuscript. He will also execute the main part of the mapping and the study quality assessment. GL and SK will regularly check subsets of the literature references, help to develop the data coding rules, and contribute to the consistency checks and to the final version of the manuscript. PJ is responsible for the expert system development and initialising the literature search to complete the scoring for the impact of fruit orchard practices on biodiversity. He will attend and supervise the whole mapping process and contribute substantially to the editing of the manuscript. The whole team will discuss and develop the work in progress in regular meetings. All authors read and approved the final manuscript.

Authors' information

Philippe Jeanneret Ph.D. is an ecologist and senior scientist at Agroscope. His research interests cover terrestrial invertebrate ecology and the effects of agriculture and land use on biodiversity and its functions.

Markus van der Meer M.Sc. is a geographer and has worked in projects focusing on agronomic questions related to food safety or quality and environmental concerns.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The literature references will be published in the form of an Access® database.

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