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Environmental Evidence

SYSTEMATIC REVIEW PROTOCOL

Open Access

What is the effect of giving the grazers access to additional nutrient sources on biodiversity in semi-natural pastures? A systematic review protocol

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Abstract

Background: Semi-natural pastures are unfertilized grasslands with a long history of traditional low-input grazing management. This kind of pastures are recognized for their high species richness. However, as a consequence of modernization of agriculture, many of the semi-natural pastures have been lost during the last century, leading to a serious threat to farmland biodiversity. Semi-natural pastures are relatively low in productivity. Hence, to increase profitability, farmers may want to give the grazing animals access to additional nutrient sources. This can be done either as supplementary feeding, or by fencing the semi-natural pastures into the same enclosure as improved, more nutrient-rich, pastures. These practices are, however, controversial. It is argued that since semi-natural pastures are species-rich partly because they are nutrient-poor, introducing additional nutrients into the system should be avoided. Accordingly, in Sweden, these interventions are often prohibited while receiving financial subsidies for management of semi-natural pastures. However, since many farmers are dependent on such support to maintain their pastures, these prohibitions often cause problems. The question has been raised whether giving the grazers access to additional nutrient sources really affect the biodiversity in semi-natural pastures, as is assumed. The primary aim of the proposed systematic review is to answer this question.

Method: Peer-reviewed and grey literature will be searched for using bibliographic databases, search engines, specialist websites and stakeholder contacts. The references will be screened for relevance according to a predefined set of eligibility criteria. The criteria will be tested and clarified iteratively, until consistency in interpretations is achieved. Thereafter, the literature will be screened in two stages, first based upon title and abstract and then by examining full texts. Full text screening will be performed with blinded decisions by two independent reviewers. Each relevant study will then be critically appraised, based on a set of predefined validity criteria. A narrative synthesis will be provided, outlining the evidence base in terms of bibliographic information and study metadata. If possible, quantitative syntheses based on meta-analyses will be performed. Identified relevant knowledge gaps will be highlighted and discussed.

Keywords: Grasslands, Grazing management, Supplementary feeding, Creep feeding, Nutrient relocation, Biological diversity, Species diversity, Functional diversity, Cattle, Livestock

Background

Semi-natural pastures, i.e., pastures with a long history of traditional low-input grazing management, are recognized globally for their high species richness at small

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spatial scales [1]. The high species richness is an effect of removal of plant material by grazing, in combination with animal trampling [2, 3]. The removal of plant material creates relatively nutrient-poor environments, and the trampling creates vegetation gaps. This disturbance of vegetation cover makes it possible for less competitive species to co-exist with more competitive species [4], which promotes species richness and prevents succession of the grassland into forest.[1] The mechanism for plant competition in relation to soil nutrients as well as productivity-diversity relationships are complex [6]. However, if these environments become more nutrient-rich, for example in parts of the pasture where the cattle defecate and urinate [7], a few species with larger competitive abilities tend to outcompete the others [8].

Semi-natural pastures have played an important role for millennia, as areas producing fodder for animals [9]. They are, however, declining worldwide, especially in northern Europe, where over 90% have been lost since the 1930s [10, 11]. The main reason for this decline is the shift towards more productive intensive agricultural practices with higher inputs of nutrients and machinery [12, 13]. Especially remote pasture areas are abandoned to a high degree. Consequently, the remaining semi-natural pastures are often small and isolated, resulting in a heavily fragmented grassland landscape [10]. Since many farmland plant and animal species are dependent on the specific environmental conditions offered by semi-natural pastures, the decline of those is a serious threat to overall farmland biodiversity. This has been acknowledged at the EU level through the concept of High Nature Value Farmland, providing means to conserve biodiversity [14].

As traditionally managed semi-natural pastures are relatively low in productivity, economically profitable grazing of those has been identified as a challenge for contemporary farmers and landowners [15]. To increase profitability, farmers may want to offer the animals supplementary feed, alternatively fence the semi-natural pasture into the same enclosure as improved, more nutrient-rich, pastures, such as former arable fields. The latter practice may be economically beneficial also for other reasons than increasing fodder availability, as large pasture areas may be grazed to a lower fence cost per area unit than letting the semi-natural pasture and the more nutrient-rich pasture be grazed separately.

Although these measures might lower the risk of abandonment of more traditional management, they are still controversial. The reasoning behind the opposition is that semi-natural pastures are species-rich because they are nutrient-poor, hence introducing additional nutrients into the system should be avoided. The described practices might lead to transfer of nutrients from the improved pastures, or from the supplementary feed, to the less fertile semi-natural pastures, either in the form of urine and manure [16, 17], or simply as spillage around the feeding site.

The chain of thoughts, illustrated by the conceptual model in Fig. 1, is that if grazers are given access to additional nutrient sources, their behaviour will change when it comes to, e.g., grazing habits, dietary choices, movements, defecation and urination. This change in behaviour could lead to eutrophication of the semi-natural pastures, and this eutrophication could impact the biodiversity in the semi-natural pastures negatively.

The question has been raised whether this problem, although reasonable in theory, is relevant in practice. One objection is that atmospheric deposition in general exceeds nitrogen transported by cattle, and that nitrogen transported by cattle seldom exceeds the nitrogen loads that are critical to ground vegetation [18]. Further, although a study by Andree et al. [19] shows that cattle indeed prefer grazing in productive nutrient-rich areas, this does not necessarily mean that grazing animals transfer nutrients from the nutrient-rich areas to the semi-natural pastures, if they are given access to such nutrient-rich areas within the same enclosure. Manure and urine tend to accumulate where the animals spend most of their time, which might not be in the semi-natural part of the pasture. Cattle often create so-called camping areas, where they rest for long periods of time. Badia et al. [7] showed that soil nutrients were higher in camping areas and that from the outskirts to the centre of the camping area, plants with low nutrient demands were progressively replaced by those with medium and high nutrients demands, and by pioneers.

Because of the complexity of the question, it could be that the problem is substantial under certain conditions and not under others. For example, it has been shown that nutrient accumulation and grazing intensity depend on, for example, grassland area, herd size, grazing season [18] and breed [20].

In short, whether giving the grazing animals in semi-natural pastures access to additional nutrient sources impact the biodiversity of the pastures is still under debate and has not been thoroughly reviewed.

[1] The definitions of the terms semi-natural and natural pasture, respectively, vary. However, in this systematic review protocol, as well as in the forthcoming systematic review, we will use the following definitions: Semi-natural pastures as well as natural pastures are grazed by domestic animals. Semi-natural pastures remain open due to the grazing by domestic animals. Natural pastures, on the other hand, remain open due to natural processes such as fire or grazing by wild animals [5].

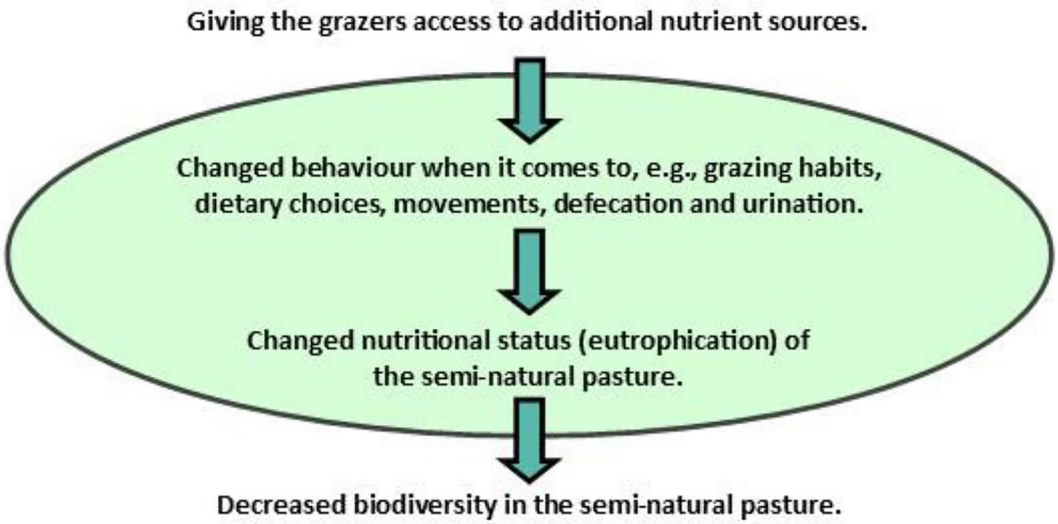

Fig. 1 Conceptual model illustrating how giving the grazers access to additional nutrient sources may lead to decreased biodiversity in the semi-natural pasture

Disputed regulations call for a systematic review

In Sweden, many farmers are dependent on financial subsidies from the Swedish rural development programme[2] to be able to maintain their semi-natural pastures. Each semi-natural pasture funded by the programme is expected to be managed according to a commitment plan, developed for each specific pasture by the local county administration board. The regulations formulated in the commitment plans aim to promote biodiversity. Accordingly, giving the grazing animals access to more nutrient-rich pastures by fencing the semi-natural pasture into the same enclosure as an improved pasture is often prohibited [21], as well as supplementary feeding. These prohibitions are formulated as regulatory possibilities in the Code of Regulations of the Swedish Board of Agriculture [22].

As described above, the question has been raised whether the eutrophication problem is substantial enough to be considered. If not, strict regulations in the commitment plans might not be necessary, and possibly even counterproductive. The management of semi-natural pastures must be practicable and attractive to the farmers and landowners, and a prerequisite for this is that the management can be performed without financial loss. Otherwise, there is a risk that proper management will cease, and the semi-natural pastures become either abandoned and overgrown, or transformed to serve other land use purposes. On the other hand, in case the eutrophication problem is substantial enough to be relevant, then tightening the relevant paragraphs in the Code of Regulations of the Swedish Board of Agriculture, now formulated as regulatory possibilities and not as general requirements, might be needed. Accordingly, the Swedish Board of Agriculture has called for a systematic review on the issue. However, although the conclusions of the planned systematic review must be valid for a Swedish context, they should be of interest to stakeholders also in other countries.

Stakeholder engagement

This systematic review is commissioned by the Swedish Board of Agriculture, but the results of the review are expected to be useful also for other stakeholders. These include local county administrative boards, the Swedish Environmental Protection Agency, the Swedish National Heritage Board, the Federation of Swedish Farmers, research institutes, wildlife conservation organizations, and—not the least—farmers and landowners.

During the writing of the protocol, consultations have been held with, primarily, the Swedish Board of Agriculture, local county administration boards and the Swedish National Heritage Board. Stakeholders have been invited to comment on the protocol before submission, and they will also be invited to comment on the forthcoming systematic review before publication.

[2] The Swedish rural development programme is funded by the European Union and Sweden in collaboration.

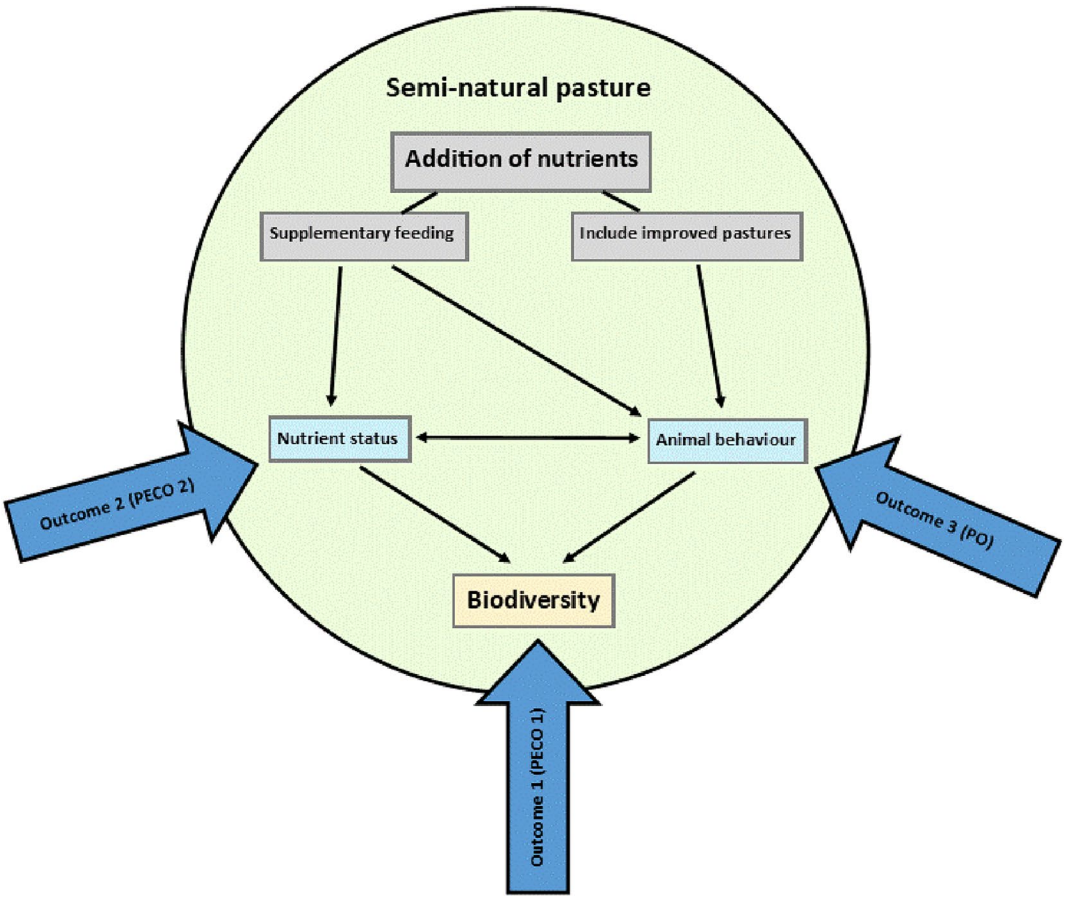

Fig. 2 Conceptual model illustrating how nutrient addition, either by supplementary feeding or by incorporating semi-natural and improved pastures within the same enclosure, might affect biodiversity in semi-natural pastures. Thin arrows indicate possible impact directions. Note that supplementary feeding might impact the nutritional status either directly, via spillage, or indirectly, via manure and urine. The outcomes of the three respective questions are indicated by thick arrows, to elucidate the relations between the P(EC)Os

Objective of the review

The primary question of the planned systematic review is "How does giving the grazers access to additional nutrient sources affect biodiversity in semi-natural pastures?". Relevant grazers are livestock present in Sweden, such as cattle, horses, sheep, goats, mules and donkeys (but not pigs, since pigs are not considered to be grazers). There are two supporting questions to be investigated, each of them aiming to elucidate a specific step in the possible mechanistic event chain (Fig. 1). The first supporting question is "How does giving the grazers access to additional nutrient sources affect the nutrient status of the soils of semi-natural pastures?" and the second one is "How do the grazers of semi-natural pastures behave while having access to additional nutrient sources?". The rationale for the two supporting questions is that in case the evidence base is insufficient to answer the primary question, then answers to the supporting questions could at least increase the general understanding of it. Potential effects on grazing behaviour, or on soil nutrient status, may be indicative of a negative impact on the biodiversity, in accordance with the chain of thoughts presented in Fig. 1. The relation between the three questions is illustrated by the conceptual model in Fig. 2.

The primary question can be defined by the following elements (PECO 1):

Population: Semi-natural pastures
Exposure: Giving the grazers access to (an) additional nutrient source(s)
Comparator: No additional nutrient source(s)
Outcome: Effects on biodiversity

The first supporting question can be defined by the following elements (PECO 2):

Population: Semi-natural pastures

Table 1 Bibliographic databases to be searched

Database/platform	Search field	Language of search terms	Subscription information
Scopus	Title, Abstract, Keywords	English	Swedish Research Council Formas subscription
Web of Science Core Collection	Topic (search the fields: title, abstract and keywords)	English	Swedish Research Council Formas subscription includes: Science Citation Index Expanded; Social Sciences Citation Index; Arts & Humanities Citation Index; Conference Proceedings Citation Index- Science; Conference Proceedings Citation Index- Social Science & Humanities; Emerging Sources Citation Index
CAB Abstracts	Title, Abstract, Heading Words	English	Swedish Research Council Formas subscription on Ovid platform
Directory of Open Access Journals[a]	All fields	English	Free, does not require a subscription
DiVA[a]	All fields	English and Swedish	Free, does not require a subscription
ProQuest Natural Science Collection	Title, Abstract, All subjects and indexing	English	Swedish Research Council Formas subscription includes: AGRICOLA; Agricultural Science database; Aquatic Sciences and Fisheries Abstracts; Biological Science database; Biological Science index; Earth, atmosphere & Aquatic Science database; Environmental Science database; Environmental Science index; Meteorological & Geoastrophysical Abstracts
SwePub[a]	All fields	English and Swedish	Free, does not require a subscription

[a] A simplified search string will be used and published in the final report

Exposure: Giving the grazers access to (an) additional nutrient source(s)
Comparator: No additional nutrient source(s)
Outcome: Changed nutrient status of the soils in the semi-natural pasture

The second supporting question can be defined by the following elements (PO):

Population: Grazers of semi-natural pastures, that also have access to (an) additional nutrient source(s)
Outcome: Behavioural measures related to a possible nutrient relocation, grazing pressure or mechanical disturbance within the pasture

The second supporting question is a PO question since we consider that also observational studies (without a comparator) may contribute to elucidate how grazers of semi-natural pastures behave while having access to (an) additional nutrient source(s).

The elements of the questions are further defined in the section on article screening and study inclusion criteria below.

Methods

This review will follow the Collaboration for Environmental Evidence guidelines [23] and conform to the ROSES reporting standards [24]. The ROSES form is available in Additional file 1.

Searching for articles

We will search for peer-reviewed articles and grey literature using bibliographic databases, search engines, websites of relevant organizations and stakeholder contacts. The reference management software EndNote will be used to collect all search results and to remove duplicates. In case the review is still uncompleted two years after the initial literature searches, a search update will be performed.

Bibliographic database search

Searches will be made in the 7 bibliographic databases and platforms listed in Table 1. The search strings will be adapted to the specific syntax in respective database.

Since the objective of this systematic review is defined by three P(EC)Os, we have developed three different search strings, one for each P(EC)O.

The search strings for PECO 1 and PECO 2 consist of three search blocks, one with population terms, one with exposure terms and a final search block with outcome terms. The search block with population terms (semi-natural pastures) and the search block with exposure terms (giving the grazers access to additional nutrient sources) are the same in both PECO 1 and PECO 2, but the search block with outcome terms differs between the two search strings.

Since the second supporting question is restricted to a population and an outcome (PO), the search string for this question consists of only two search blocks, one with population terms and the other one with outcome terms. In the PO search string, the search block with population terms is broader than for PECO 1 and PECO 2, since the population of this question is grazing domestic animals in semi-natural pastures, that also have access to one or more additional nutrient sources. The broad population search block incorporates both the population terms (semi-natural pastures) and the exposure terms (giving the grazers access to additional nutrient sources) from PECO 1 and PECO 2. A search block with outcome terms (behavioural measures) was also added to the PO search string.

The three search strings, adapted to each bibliographic database, can be found in Additional file 2. We will use English search terms in all databases and Swedish search terms in two of the databases, that contain publications from Swedish universities and authorities. We expect that the use of English search terms also will identify articles in other languages than English, since non-English articles often have a title and abstract in English. We will limit the search to include articles in English, Danish, French, German, Norwegian, Spanish and Swedish. The searches will not be limited by publication date or document type.

The search terms were derived from a combination of different approaches. One approach was brainstorming within the review team. Many of the biodiversity terms were retrieved from previous systematic reviews [25, 26]. More relevant terms were found in an international terminology for grazing lands and grazing animals [27]. A list of benchmark studies (see Additional file 3) was used to test the comprehensiveness of the search. The bibliographic database Scopus was used when developing the search strings and testing whether the benchmark studies were found. If any of the benchmark studies had been missed, the search strings were adapted to include the missed studies. One of the benchmark studies is not indexed in Scopus and could therefore not be found during the comprehensiveness test.

Search engines

We will search the academic search engine Google Scholar for peer-reviewed and grey literature. We will use simple search strings in English, Danish, Norwegian and Swedish. The search strings for Google Scholar can be found in Additional file 2. The search results will be sorted by relevance and the first 50 results from each search string will be exported from Google Scholar using Publish or Perish software [28].

Websites of relevant organizations

In order to find grey literature, we will search the websites of relevant organizations, listed in Table 2. Simple search strings will be used, such as "semi-natural pastures" and "semi-natural grasslands". The search strings will be adapted to the language and the search capabilities of each website. The grey literature search will not include records in French, German or Spanish, as the bibliographic database search will do. We expect to find a large amount of literature (since we will perform three different, broad searches), and therefore we find it reasonable to limit the grey literature search to English, Danish, Norwegian and Swedish, to make the material more manageable. All search strings and matching results will be published in the final review.

Supplementary searches

We will contact stakeholders and experts in the field to request studies and reports. If we identify relevant reviews during the article screening process, we will examine the bibliographies of these reviews and include relevant literature not already identified.

Article screening and study eligibility criteria

Screening process

Before the conclusive screening process starts, a subset of articles (at least 250) will be screened by several of the reviewers, based upon title and abstract. Any disagreement will be used to evaluate, and—if found necessary—more clearly define the eligibility criteria. This process will be repeated until the criteria are interpreted and applied in a consistent way.

Then the articles will be screened for relevance in two stages. In the first stage, after removal of duplicates, the references will be single screened based upon title and abstract. The reviewer will have three options during the screening process: (1) include, (2) exclude, or (3) maybe include. Option 2 (exclusion) will be applied only if it is completely obvious that the topic is out of scope. Articles coded with option 3 will

Table 2 Websites to be searched

Organization	URL	Language of search terms
bioRxiv (online archive for unpublished preprints in biology)	https://www.biorxiv.org	English
Conservation Evidence	http://www.conservationevidence.com	English
European chapter of the Society for Ecological Restoration (SER)	http://chapter.ser.org/europe	English
European Commission Joint Research Centre	http://ec.europa.eu/jrc	English
European Environment Agency	http://www.eea.europa.eu	English
Danmarks Miljøportal (Environmental Portal of Denmark)	https://miljoeportal.dk	Danish
Landbrugsstyrelsen (Danish Agricultural Agency)	https://lbst.dk	Danish
Miljøstyrelsen (Danish Environmental Protection Agency)	https://mst.dk	Danish
Ministry of the Environment in Denmark	https://mim.dk	Danish
Ministry of Food, Agriculture and Fisheries of Denmark	https://fvm.dk	Danish
Luke (Natural Resources Institute of Finland)	https://www.luke.fi	English and Swedish
Metsähallitus (Steward of state-owned land and water areas in Finland)	https://www.metsa.fi	English and Swedish
Ministry of Agriculture and Forestry in Finland	https://mmm.fi	English and Swedish
Ministry of the Environment in Finland	https://ym.fi	English and Swedish
SYKE (Finnish Environment Institute)	https://www.syke.fi	English and Swedish
BioFokus (Norway)	https://biofokus.no	Norwegian
Landbruksdirektoratet (Norwegian Agricultural Agency)	https://www.landbruksdirektoratet.no	Norwegian
Miljødirektoratet (Norwegian Environment Agency)	https://www.miljodirektoratet.no	Norwegian
Ministry of Agriculture and Food in Norway	https://www.regjeringen.no/no/dep/lmd/id627	Norwegian
NIBIO (Norwegian Institute of Bioeconomy Research)	https://www.nibio.no	English and Norwegian
NINA (Norwegian Institute for Nature Research)	https://www.nina.no	English and Norwegian
Jordbruksverket (Swedish Board of Agriculture)	https://jordbruksverket.se	Swedish
Länsstyrelser i Sverige (County Administrative Boards in Sweden)	https://www.lansstyrelsen.se	Swedish
Naturvårdsverket (Swedish Environmental Protection Agency)	http://www.naturvardsverket.se	Swedish
SLU (Swedish University of Agricultural Sciences)	https://www.slu.se	English and Swedish
DEFRA (Department for Environment, Food & Rural Affairs)	http://randd.defra.gov.uk	English
Natural England	http://publications.naturalengland.org.uk	English
Natural Resources Wales	http://libcat.naturalresources.wales	English
NatureScot (Scotland's Nature Agency)	https://www.nature.scot	English
NORA (Research publications from British Antarctic Survey, British Geological Survey, National Oceanography Centre, and UK Centre for Ecology & Hydrology)	http://nora.nerc.ac.uk	English
UK Environment Agency	https://www.gov.uk/government/publications?departments%5B%5D=environment-agency	English

be screened by two other reviewers, with blinded decisions. Any disagreements will be reconciled through discussion.

In the second stage, all articles included in the first step will be screened in full text. This will be done by two reviewers, with blinded decisions. Any disagreements will be reconciled through discussion.

Articles excluded in the first stage will not be coded with a reason for exclusion. However, a list of articles excluded in the second stage (full text), will be provided, including reasons for exclusion.

Authors of the review will not be allowed to assess the relevance of studies authored by themselves.

Eligibility criteria

PECO 1

Eligible population: Fenced, uncultivated, semi-natural or natural pastures. Focus will be on semi-natural pastures, i.e., grasslands that are the result of human management, and that require grazing by domestic animals to maintain their grass/forb domination and avoid being encroached by shrubs and trees. Studies on natural pastures, i.e., grasslands grazed by domestic animals but mainly created and maintained by natural processes (such as fire or wildlife grazing) are also eligible. There are no limitations as to geographic location of the pastures.

Eligible exposure: Giving the domestic grazing animals access to one or more additional nutrient source(s). The grazing animals must be livestock present in Sweden, such as cattle, horses, sheep, goats, mules and donkeys (not pigs, since pigs are not considered to be grazers). The additional nutrient source(s) may be in the form of supplementary feeding (the feeding site may be located outside, in the semi-natural or natural pasture, or inside, in a byre), or by fencing the semi-natural or natural pasture into the same enclosure as an improved pasture. The additional nutrient may not be added as fertilizers directly to the semi-natural or natural pasture as, e.g., inorganic or organic manure.

Eligible comparators: Eligible studies must include a control. The control site(s) must be semi-natural or natural pasture(s) not being the subject of the above-described exposure.

Eligible outcomes: Any outcome indicating biodiversity level or change in the focal pasture, including measures of functional or taxonomic diversity, abundance of indicator species, or vegetation structure.

Eligible types of study design: Studies that quantify how giving the grazers of semi-natural or natural pastures access to (an) additional nutrient source(s) affect the biodiversity values of the focal pastures. Comparisons can be made temporally and/or spatially, that is, 'BA' (Before/After), 'CI' (Control/Impact) as well as 'BACI' (Before/After/Control/Impact) and 'RCT' (Randomized Controlled Trial) designs will be accepted.

PECO 2

Eligible population: Fenced, uncultivated, semi-natural or natural pastures. Focus will be on semi-natural pastures, i.e., grasslands that are the result of human management, and that require grazing by domestic animals to maintain their grass/forb domination and avoid being encroached by shrubs and trees. Studies on natural pastures, i.e., grasslands grazed by domestic animals but mainly created and maintained by natural processes (such as fire or wildlife grazing) are also eligible. There are no limitations as to geographic location of the pastures.

Eligible exposure: Giving the domestic grazing animals access to one or more additional nutrient source(s). The gazing animals must be livestock present in Sweden, such as cattle, horses, sheep, goats, mules and donkeys (not pigs, since pigs are not considered to be grazers). The additional nutrient source(s) may be in the form of supplementary feeding (the feeding site may be located outside, in the semi-natural or natural pasture, or inside, in a byre), or by fencing the semi-natural or natural pasture into the same enclosure as an improved pasture. The additional nutrient may not be added as fertilizers directly to the semi-natural or natural pasture as, e.g., inorganic or organic manure.

Eligible comparators: Eligible studies must include a control. The control site(s) must be semi-natural or natural pasture(s) not being the subject of the above-described exposure.

Eligible outcomes: Any outcome indicative of the nutritional status of the soils of the focal pastures, including measures of nutrients in the soil, plant indicators (like Ellenberg values[3]) or biomass production.

Eligible types of study design: Studies that quantify how giving the grazers of semi-natural or natural pastures access to (an) additional nutrient source(s) affect the nutritional status of the soils of the focal pastures. Comparisons can be made temporally and/or spatially, that is, 'BA' (Before/After), 'CI' (Control/Impact) as well as 'BACI' (Before/After/Control/Impact) and 'RCT' (Randomized Controlled Trial) designs will be accepted.

PO

Eligible population: Grazing domestic animals in semi-natural or natural pastures, that also have access to (an) additional nutrient source(s). The grazing animals must be livestock present in Sweden, such as cattle, horses, sheep, goats, mules and donkeys (not pigs, since pigs are not considered to be grazers). The additional nutrient source(s) may be in the form of supplementary feeding (the feeding site may be located outside, in the semi-natural or natural pasture, or inside, in a byre), or an improved pasture within the same enclosure as the semi-natural or natural pasture. There are no limitations as to geographic location of the pastures.

Eligible outcomes: Measures of animal behaviour related to (1) possible nutrient relocation within the pasture (for example, grazing habits, dietary choices, movements, and distribution of feces and urine), or (2) grazing pressure, or (3) mechanical disturbance (for example heavy trampling).

Eligible types of study design: Studies that relate the focal behavioural measure to the access to (1) supplementary feeding, or (2) an improved pasture within the same enclosure as the semi-natural or natural pasture. There must not be a comparator, although this would be preferable. That is, observational case studies will be accepted, as well as studies of any kind of comparative design ('BA' [Before/After], 'CI' [Control/Impact], 'BACI' [Before/After/Control/Impact] or 'RCT' [Randomized Controlled Trial]).

[3] Ellenberg values classify species' position along environmental gradients in their realized ecological niche into ordinal values [29, 30].

In addition to the P(EC)O-specific eligibility criteria described above, the following general criteria will be applied: As regards languages, English, Danish, French, German, Norwegian, Spanish and Swedish will be eligible for peer-reviewed articles, and English, Danish, Norwegian and Swedish for grey literature. As regards time frame, any publication date will be eligible.

Study validity assessment

Studies that fulfill the relevance criteria described above will be subject to critical appraisal. The purpose of the critical appraisal is to reduce the risk of misleading conclusions of the review.

We will use CEECAT: Collaboration for Environmental Evidence Critical Appraisal Tool Version 0.2 (prototype) [31] to formalise our assessments and make them more transparent and replicable. In accordance with CEECAT, the studies will be categorized as having low risk of bias, medium risk of bias or high risk of bias.

Authors of the review will not be allowed to perform critical appraisal of their own work. All validity decisions will be performed by two authors independently, to ensure consistency. Any disagreement will first go to discussion between the two reviewers to reach consensus. If consensus is not reached, disagreements will be reconciled through discussions with the entire review team. If no agreement can be reached, the most conservative judgement (the highest risk of bias category) will be selected.

Studies considered to be of high risk of bias may still be included in the review. If such studies are included, they will be given a lower weight in the analysis compared to higher validity studies. This will also be taken account of during the overall grading of evidence, i.e., while assessing the strength of evidence of the research base as a whole in relation to the respective review questions. That is, study validity is one of the aspects that will form the basis for this assessment (the other aspects are described below, under Data synthesis and presentation).

All studies excluded at this stage will be listed, together with a reason for exclusion.

Data coding and extraction strategy

A data coding and extraction sheet will be designed, tested and approved by all reviewers before the data coding and extraction step is initiated. The datasheet will preliminarily include the following information and parameters:

- Article citation
- Study area details (country/state, location, coordinates, climate zone, landscape type)
- Details about the pasture(s) (area, habitat structure, vegetation type, nutritional status, adjacent habitats, landscape context, time since inclusion of improved pasture, management history)
- Supplementary feeding details (kind of feed, amount of feed, feeding frequency, location of feeding site)
- Grazer details (species, breed, age, sex, number of individuals or livestock units)
- Study design details (study type, replication, controls, study duration)
- Outcome details (measured outcomes, unit used for outcome)
- Study results (mean outcomes; variance/standard deviation/standard error/confidence intervals; qualitative results may be recorded for behavioural studies)
- Funding body and author affiliations

The articles included for data extraction will be allocated between several reviewers. At least 25% of the articles allocated to each reviewer will be double checked by another reviewer, to ensure consistency.

Data will be recorded as reported in the primary studies. Transformations and calculations will be performed at the analysis stage, if necessary. Authors of included articles may be contacted to get complementary information or unpublished data, if those data are needed for the analyses. The extracted data records will be made available as Additional files 1, 2, 3.

Potential effect modifiers/reasons for heterogeneity

The parameters listed below may all be regarded as potential effect modifiers, and should, accordingly, be taken into consideration if the data are available in the studies. The list has been compiled through discussions by the experts in the review team; some of them were suggested by stakeholders.

- Climate zone
- Landscape type
- Pasture type (semi-natural or natural)
- Soil type
- Area of semi-natural or natural pasture
- Area of improved pasture
- Habitat structure
- Vegetation/Habitat type
- Nutritional status
- Adjacent habitats
- Landscape context
- Time since inclusion of improved pasture
- Management history
- Kind of supplementary feed
- Amount of supplementary feed

- Feeding frequency
- Location of feeding site
- Species of grazers
- Breed of grazers
- Age of grazers
- Sex of grazers
- Number of individuals per unit of area

Data synthesis and presentation

A narrative synthesis of data from all the included studies will be produced. Tables and figures will be used to describe the evidence base. A narrative synthesis table in the form of an Excel spreadsheet will be provided.

For data synthesis, studies evaluating the effect of supplementary feeding will be treated separately from those evaluating the effect of inclusion of improved pastures. At this stage it is unclear whether there will be enough quantitative data to calculate effect sizes and perform meta-analyses. In case a sufficient number of studies for one or both of these exposures report similar and appropriate outcome measures, meta-analyses will be performed. Random-effects models will then be applied, with standardised mean differences used as effect size. Sensitivity analyses, comparing results with and without exclusion of low-validity studies, will be performed if feasible. Risk of publication bias will be assessed through funnel plots if possible. If no meta-analysis can be conducted using the available data, we will first explore relevant imputation methods (cf. [32]), and lastly consider alternative approaches to data synthesis (e.g. [33]).

Included studies will be grouped according to studied outcome measure, and each group will be discussed separately. The strength of evidence will be assessed based on the following aspects: (1) number of studies, (2) study validity (internal and external), (3) consistency of observed effects across studies, and (4) size and significance of observed effects.

We will search for knowledge gaps by visually inspecting heat maps created by cross-tabulating different key descriptors (e.g., type of nutrient addition and type of outcome). In case we identify any knowledge gaps that warrant further primary research effort, we will present those.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13750-021-00230-2.

Additional file 1: ROSES form. Our adherence to the ROSES standards for systematic review protocols.

Additional file 2: Search strings. Search strings that will be used to find articles to include in the systematic review.

Additional file 3: Benchmark studies. List of benchmark studies used to test the comprehensiveness of the search.

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Authors' contributions

This systematic review protocol is based on a draft written by IE. RL is the main author of the Background section. CÅ is the main author of the section about the literature search strategy. All authors discussed, edited and added text to the draft. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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