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Environmental Evidence

SYSTEMATIC MAP PROTOCOL

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What evidence exists relating to effectiveness of ecotechnologies in agriculture for the recovery and reuse of carbon and nutrients in the Baltic and boreo-temperate regions? A systematic map protocol

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Abstract

Background: The degradation of the water quality of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. Excessive inputs of nutrients coming from the surrounding land are among the primary causes of the Baltic Sea eutrophication. Diffuse sources, of which most originate from agricultural activities, are two dominant riverine pollution pathways for both nitrogen and phosphorus. Recently, there is growing attention on the reuse of carbon, nitrogen and phosphorus from agricultural waste streams. However, to our knowledge, no comprehensive and systematic assessment of ecotechnologies focusing on recovery or reuse of these substances in the agricultural sector is available.

Methods: This map will examine what evidence exists relating to effectiveness of ecotechnologies (here defined as '*human interventions in social-ecological systems in the form of practices and/or biological, physical, and chemical processes designed to minimise harm to the environment and provide services of value to society*') in agriculture for the reuse of carbon and/or nutrients (nitrogen and phosphorus) in the Baltic Sea region and boreo-temperate systems. We will search for both academic and grey literature: English language searches will be performed in 4 bibliographic databases and search platforms, and Google Scholar, while searches in 38 specialist websites will be performed in English, Finnish, Polish and Swedish. The searches will be restricted to the period 2013 to 2017. Eligibility screening will be conducted at two levels: title and abstract (screened concurrently for efficiency) and full text. Meta-data will be extracted from eligible studies including bibliographic details, study location, ecotechnology name and description, type of outcome (i.e. recovered or reused carbon and/or nutrients), type of ecotechnology in terms of recovery source, and type of reuse (in terms of the end-product). Findings will be presented narratively and in a searchable geographically explicit database, visualised in an evidence atlas (an interactive geographical information system). Knowledge gaps and knowledge clusters in the evidence base will be identified and described.

Keywords: Carbon, Circular economy, Eutrophic, Fertilisers, Manure, Nitrogen, Nutrient reuse, Nutrient recycle, Phosphorus, Pollution

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Background

The degradation of the water quality of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. The Baltic Sea is particularly vulnerable to waterborne nutrient loadings because of its large catchment to sea area ratio, long freshwater renewal time, and limited water exchange with the North Sea.

Excessive inputs of nutrients coming from the surrounding land are among the primary causes of the Baltic Sea eutrophication [1]. A recent indicator-based assessment revealed an increase in the spatial extent of eutrophication [2]. Inorganic, nutrient-induced increase of primary production followed by organic matter load (predominantly organic carbon) have been identified as the two greatest environmental pressures in the Baltic Sea [3]. However, both the magnitude of carbon load from terrestrial sources and the processes driving the aquatic carbon cycle are still poorly understood [1].

As of 2014, diffuse sources in the Baltic Sea were responsible for 46.5% and 35.7% of total riverine loads for total nitrogen and total phosphorus, respectively, as stated by the most recent HELCOM report [4]. These percentages are greater than all other nitrogen and phosphorus source types (point, natural background and transboundary sources). Most of the diffuse sources originate from agricultural activities. Hence, a lot of attention is currently placed on the agricultural sector to solve the problem of Baltic Sea eutrophication. Decision-makers seek cost-efficient solutions towards reducing nitrogen and phosphorus loads from agriculture, and investments in specific measures are being made to reduce external inputs of pollutants and nutrients. However, available technological and management measures to curb eutrophication and pollution are often designed based on single objectives, thereby limiting opportunities for multiple benefits [5].

The need to shift attention from the reduction of carbon and nutrient loads towards their recovery and reuse has several drivers. Rock phosphate is being depleted, while global phosphorus demand is increasing, which, in combination, threatens food security [6, 7]. The European Commission has identified phosphorus as a critical raw material of high economic importance and high supply-risk [8]. Additionally, the global nitrogen cycle has considerably overstepped its planetary boundary, and nitrogen fixation from the atmosphere should be reduced [4, 6]. Recycling resources from waste is a sustainable practice and is central to the idea of a circular economy [9]. Although current environmental and water policies focus on reduction of pollution from different waste streams rather than on recovery and reuse of nutrients, attention of policy and research is shifting towards the latter.

There are a number of sources for nutrient or carbon recovery and reuse in agriculture. These sources can be animal manure (including wastewater from animal husbandry) and different types of plant-based agricultural waste such as crop residues, brown waste (e.g. hay, sawdust) and wastewater from, for example, greenhouses. Animal and plant waste can also be combined together, sometimes with additions of sewage sludge and/or food waste for example, as feedstock for anaerobic digestion or composting.

Nitrogen, phosphorus and carbon are also ubiquitous in agricultural runoff (surface runoff, tile flow, groundwater flow), but also in natural water bodies (e.g. rivers and lakes) [10, 11]. However, the implementation of recovery technologies for non-reactive P, is much lower for natural water bodies than for manure [10], due to several reasons: (1) the presence of other constituents such as organics; (2) a lower per unit conversion efficacy; and, (3) the technical ease of implementation. Another important consideration is that, to date, pollutants in agricultural runoff or environmental waters were mainly treated as the source for removal, as in the case of constructed or restored wetlands [12, 13], or the source for retention, as in the case of river restoration projects [14], but not the source for recovery. To our knowledge, no comprehensive and systematic assessment of modern technologies or practices concerning the reuse of carbon and nutrients in agricultural sector has been conducted.

In the present study, we deal with ecotechnologies for the recovery and reuse of carbon and nutrients in agricultural sector. The term 'ecotechnology' is a buzzword [9], with very few explicit definitions. This term has been used since the early 1970s to describe combinations of practices relating to the environment and technological interventions. Despite its common usage, there seems to be little consensus on its practical meaning. We based our definition on a recent systematic review and thematic synthesis of the research literature [15], which identified several key domains, including the type of technology, how it works, for whom and with what synergies across human and ecological domains. The definition is as follows:

> *"Eco-technologies are human interventions in social-ecological systems in the form of practices and/or biological, physical, and chemical processes designed to minimise harm to the environment and provide services of value to society"*

This definition encompasses both hard (e.g. mechanical or chemical) and soft (e.g. behaviours and practices) technologies and is hence very broad. We use a broad definition in this review to remain conservative and broadly relevant to society.

Stakeholder engagement
The topic for this review was initially proposed by the research funder BONUS (https://www.bonusportal.org/). The scope of the project was then refined through expert discussions as part of the process of drafting an application in response to the call by the research funder. The scope and the search strategy were further refined by the stakeholder group, consisting of the broader BONUS RETURN project consortium members (see https://www.bonusreturn.com/), which explains the Baltic Sea basin focus.

Objective of the review
The primary question for this systematic map is:

> *What evidence exists relating to effectiveness of ecotechnologies in agriculture for the recovery and reuse of carbon and nutrients in the Baltic and boreo-temperate regions?*

This review will identify a comprehensive list of studies that focus on the effectiveness of ecotechnologies for recovery and reuse of carbon and/or nitrogen and phosphorus compounds in the Baltic and boreo-temperate regions. We will then describe these studies in terms of the PIO elements [population(s), intervention(s), and outcome(s)]. The key outputs will be as follows:

1. A comprehensive list of studied ecotechnologies in the Baltic and boreo-temperate regions.
2. A detailed database of studies and their descriptive information (meta-data).
3. An evidence atlas (i.e. a geographical information system that maps included studies by their locations).
4. A series of heat maps (cross tabulations of key descriptors, e.g. interventions and outcomes, interventions and populations/settings) that will be used to systematically identify knowledge clusters (subtopics that are well-represented by research studies) and knowledge gaps (subtopics that are un- or under-represented by research studies).
5. A list of knowledge clusters that would be suitable for full systematic review.
6. A list of knowledge gaps that warrant further primary research effort.

Definitions of the question components
Population(s) The boreo-temperate regions (with a focus on the Baltic Sea region).

Intervention(s) Any practice undertaken for the purposes of (intention to) recovering and/or reusing carbon and/or nutrients from agricultural waste, manure, soil or waters within the boreo-temperate regions.

Comparator(s) None, before ecotechnology use, a control site without an ecotechnology, a comparison between different ecotechnologies, different intensities of the same ecotechnology, time series after ecotechnology implementation.

Outcome(s) Described recovery and/or reuse of carbon and/or following nutrients: nitrogen compounds (nitrogen, nitrate, nitrite, ammonium) and phosphorus compounds (phosphorus, phosphate).

As requested by the stakeholders, this review is expected to be particularly relevant to the Baltic Sea region, but we will also include studies from other comparable boreo-temperate regions in both hemispheres (see '*Eligible population(s)*' below).

Methods
The review will follow the Collaboration for Environmental Evidence Guidelines and Standards for Evidence Synthesis in Environmental Management [16] and it conforms to ROSES reporting standards [17] (see Additional file 1).

Searching for articles
Bibliographic databases
We will search for evidence in following databases and platforms:

1. Scopus
2. Web of Science Core Collections (consisting of the following indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, and ESCI)
3. Electronic Theses Online Service (eThOS)
4. Digital Access to Research Theses (DART)
5. Directory of Open Access Journals (DOAJ).

Searches will be performed using subscriptions of Warsaw University of Life Sciences and Stockholm University. These searches will be conducted using English language search terms. The following search string will be used in bibliographic databases:

> (recycl* OR reus* OR circul* OR conver* OR recover* OR return*) AND (agr* OR farm* OR crop* OR livestock OR "live stock" OR manure OR animal OR cultivat*) AND ("organic carbon" OR DOC OR "organic C" OR "organic matter" OR nutrient* OR nitrogen OR nitrate OR nitrite OR ammoni* OR phosphorus OR phosphate) [shown as formatted for Web of Science search].

See Additional file 2 for details of Scopus and Web of Science searches. We intend to concentrate on technological innovations not yet in industrial use, so we will restrict our searches to the period of 2013–2017. We will conduct searches until 2017 as this year marked the start of the BONUS RETURN project.

Search engines Searches will also be performed in Google Scholar, which is an effective tool for grey literature searches [18]. These searches will make use of terms related both to synonyms for ecotechnologies (e.g. 'ecotechnology'), and combinations of outcome terms and reuse terms (e.g. 'carbon reuse'). Searches will be performed in English (see Additional file 2 for Google Scholar search details). Google Scholar searches will be restricted to articles published between 2013 and 2017, as above. The first 1000 search results will be extracted as citations using Publish or Perish software [19] and introduced into the duplication removal and screening workflow alongside records from bibliographic databases.

Organisational websites Searches will be performed across a suite of relevant organisational websites for ecotechnologies for the reuse of carbon and/or nutrients (see Table 1). These searches will be especially important to capture grey literature. Each website will also be hand-searched for relevant publications. These searches will also use terms related both to synonyms for ecotechnologies and combinations of outcome terms and reuse terms. Searches will be performed in English, Swedish, Finnish and Polish corresponding to the case-study countries within the BONUS RETURN project as well as many of the Baltic languages (see Table 1, and Additional file 2 for search terms). Literature from organisational websites will be screened separately before being combined with other records.

Testing comprehensiveness of the search

Twenty articles of known relevance to the review were screened against scoping search results to examine whether searches are able to locate relevant evidence (see a list of benchmark studies in Additional file 3). If articles were not found during scoping, search terms were examined to identify the reasons why articles were missed, and search terms were modified accordingly.

Assembling library of search results

Results of the searches in bibliographic databases and Google Scholar will be combined, and duplicates will be removed prior to screening. A library of search results will be assembled in a review management software (i.e. EPPI reviewer [20]). These search results will be randomly divided into 5 equal sets (each containing 20% of all searches from bibliographic databases and Google Scholar), and then each set will be screened and coded sequentially to facilitate rapid identification of knowledge gaps and knowledge clusters. Thus, at any one point, we will have a representative (due to randomization and high sample size) assessment of the nature of the evidence base prior to completion of the screening. This approach is needed to allow the evidence synthesis work to inform other work packages of the BONUS RETURN project under which this map will be conducted. This approach will not affect the final systematic map outputs, since the entire evidence base will be screened in a random manner. However, it represents a novel means of reducing risk of incompletion relative to external, fixed deliverable deadlines.

Article screening and study eligibility criteria

Screening process

Screening will be conducted at two levels: at title and abstract level together, and at full text level. Title and abstract screening will be conducted together for efficiency. The full texts of potentially relevant abstracts will be retrieved, tracking those that cannot be located or accessed and reporting this in the final review. Retrieved records will then be screened at full text, with each record being assessed by one experienced reviewer.

Prior to commencing screening, consistency checking will be performed with all reviewers (3 in total) on a subset of articles at both title and abstract level and full text level screening. A subset of 700 title and abstract records and 40 full text records will be independently screened by all reviewers. These numbers represent approximately 10% of each set of results at each level for both searches (estimated based on the scoping exercise). The results of the consistency checking will then be compared between reviewers and all disagreements discussed in detail. Where the level of agreement is low (below c. 0.8 agreement), further consistency checking will be performed on an additional set of articles and then discussed.

Eligibility criteria

The following criteria will be applied at all levels of screening:

Eligible population(s) Relevant studies will be located in the Baltic and comparable boreal and temperate regions in both hemispheres, with fully humid temperate (Cfa, Cfb, Cfc) and fully humid boreal (Dfa, Dfb, Dfc, Dfd) climates according to the Köppen-Geiger climate classification [15].

Eligible intervention(s) Any eco-technology (see the definition of 'ecotechnology' above) undertaken for the purposes of (intention to) recovery and/or reuse of carbon and/or nutrients in agriculture. Recovery affects

Table 1 A list of specialist websites and search languages

Website	Search language
1. Foundation for Applied Water Research (STOWA) (http://www.stowa.nl)	English
2. Ekologgruppen i Landskrona AB (http://www.ekologgruppen.com/)	English
3. Danish Centre for Environment and Energy (DCE) (http://dce.au.dk)	English
4. European Environment Agency (EEA) (https://www.eea.europa.eu/)	English
5. Finnish Environment Institute (SYKE) (http://www.syke.fi)	English
6. Federal Environment Agency (UmweltBundesAmt, Germany) (https://www.umweltbundesamt.de)	English
7. Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB) (http://www.igb-berlin.de)	English
8. EAWAG Aquatic Research (https://www.eawag.ch/en/)	English
9. Netherlands National Institute for Public Health and the Environment (RIVM) (https://www.rivm.nl/en)	English
10. United States Environmental Protection Agency (US EPA) (https://www.epa.gov/)	English
11. Swedish Environmental Protection Agency (SEPA) (http://www.naturvardsverket.se)	English, Swedish
12. Swedish Board of Agriculture (http://www.jordbruksverket.se)	English, Swedish
13. The Swedish Agency for Marine and Water Management (https://www.havochvatten.se)	English, Swedish
14. Swedish directory of Master thesis (DiVA) (http://www.diva-portal.org)	English, Swedish
15. The Swedish Water & Wastewater Association (SWWA) (http://www.svensktvatten.se)	Swedish
16. Federation of Swedish Farmers (http://www.lrf.se)	Swedish
17. The Swedish Environmental Institute (http://www.IVL.se)	Swedish
18. Agro base (http://agro.icm.edu.pl/agro)	Polish
19. Tech Base (http://baztech.icm.edu.pl)	Polish
20. Catalog of the WULS diploma and doctoral dissertations (https://sgw0.bg.sggw.pl)	Polish
21. Archive of Diploma Theses of the University of Agriculture Hugo Kołłątaj, Krakow (https://apd.ur.krakow.pl/catalogue)	Polish
22. Archive of Diploma Papers of the University of Technology and Life Sciences in Bydgoszcz (https://apd.utp.edu.pl/catalogue)	Polish
23. Central Catalog of Polish Journals (http://mak.bn.org.pl/cgi-bin/makwww.exe?BM=7)	Polish
24. NUKat (http://katalog.nukat.edu.pl)	Polish
25. Portal of Scientific Journals (http://www.ejournals.eu)	Polish
26. Journal repository of the Nicolaus Copernicus University (http://wydawnictwoumk.pl/czasopisma)	Polish
27. Repository of the Open Science Center (http://depot.ceon.pl)	Polish
28. SYMPOnet (https://gate.bg.pw.edu.pl/)	Polish
29. Melinda (https://melinda.kansalliskirjasto.fi)	Finnish
30. ARTO (https://arto.linneanet.fi/vwebv/searchBasic?sk=fi_FI)	Finnish
31. HELDA Institutional repository (https://helda.helsinki.fi)	Finnish
32. DORIA Institutional repository (https://www.doria.fi)	Finnish
33. JUKURI (http://jukuri.luke.fi)	Finnish
34. TAMPUB (http://tampub.uta.fi)	Finnish
35. THESEUS (http://www.theseus.fi)	Finnish
36. University of Lapland (http://lauda.ulapland.fi)	Finnish
37. Aalto University (https://aaltodoc.aalto.fi)	Finnish
38. SYKE library collection (http://kirjasto.ymparisto.fi/syke/fi/search_yha.htm)	Finnish

either agricultural waste (animal- or plant-based) or agricultural runoff (e.g. surface runoff, tile drain flow or groundwater flow). A study will be excluded if a given recovery source was not directly related to agriculture (e.g. industrial/municipal wastewater, agro-industrial wastewater, an inland or sea water body whose pollution level could not be directly attributed to an agricultural activity).

Eligible comparator(s) none, before ecotechnology use, a control site without an ecotechnology, a comparison between different ecotechnologies, different intensities of the same ecotechnology, time series after ecotechnology implementation.

Eligible outcome(s) Described recovery and/or reuse of carbon and/or nutrients from e.g. agricultural waste (e.g. crop residues, manure, agricultural runoff, etc.)

within the Baltic and boreo-temperate systems. Carbon outcomes include: soil carbon, soil organic carbon, total carbon, dissolved organic carbon, and organic matter, but also chemical oxygen demand and biological oxygen demand, which are proxies for carbon. Nutrient outcomes include: nitrogen compounds (nitrogen, nitrate, nitrite, ammonium) and phosphorus compounds (phosphorus, phosphate). Studies describing agricultural reuse of products, such as fertilisers or soil amendments, recovered for example from wastewater or sludge are not included in this map (but they will be catalogued in a separate systematic map (see [21]).

We will provide a list of articles excluded at title and abstract level, and at full text level, with reasons for exclusion provided for all excluded articles.

Study validity assessment

The validity of articles will not be appraised as part of this systematic map in accordance with accepted systematic mapping methodological guidance [16].

Data coding strategy

The following meta-data extraction and coding will be performed for all relevant studies:

- Ecotechnology name
- Short description
- Type of outcome (recovered or reused carbon and/or nutrients)
    - Carbon
    - Nutrients N
    - Nutrients P
- Type of ecotechnology in terms of recovery source
    - Manure-based
    - Crop-based
    - Mixed (manure and crops)
    - Other types
- Type of reuse in terms of end-product (e.g. fertilizer, soil amendment, energy source)
- Study country
- Study location
- Latitude
- Longitude.

Meta-data extraction and coding will be performed by multiple reviewers (3 in total) following consistency checking on a parallel coding of subset of 10% of full texts, discussing all disagreements. The remaining full texts will then be screened in full. If resources allow, we may contact authors by email with requests for missing information.

Study mapping and presentation

The evidence base identified within this systematic map will be described narratively, in the form of descriptive statistics and within a systematic map database; a searchable database with columns containing codes and meta-data related to the variables described in the meta-data extraction and coding schema, above. In addition, we will produce heat maps that cross-tabulate two variables and detail the extent of evidence (number of studies) within each cell of the table. Various combinations of variables will be used for these heat maps, including: the types of ecotechnology and the outcome(s) that can be targeted; the types of ecotechnology and the study setting; the types of ecotechnology and the study country. We will also produce an evidence atlas using study latitude and longitude meta-data, where studies are plotted on an interactive cartographic map. Groups of studies, knowledge gaps and knowledge clusters will be described and listed.

Knowledge gap and cluster identification strategy

Heat maps will be used to identify knowledge clusters. Knowledge gaps will be highlighted by identifying un- or underrepresented subtopics using heat maps. Subtopics with zero studies will be listed together with those that feature a smaller than would be expected number of studies. In practice this will be performed by visual inspection by a methodology expert of the review team (i.e. not a subject expert to avoid preconception bias). This list of knowledge gaps will then be prioritised in the same way as knowledge clusters described above.

Additional files

Additional file 1. ROSES form for systematic map protocols.

Additional file 2. Search strategy.

Additional file 3. Benchmark list.

Authors' contributions

NRH drafted initial version of the manuscript. MP and BM edited, commented on and finalised the manuscript. All authors read and approved the final manuscript.

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