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Systematic Map Protocol

Title
What evidence exists on the impacts of regenerative agriculture practices on greenhouse gas emissions and agricultural yield in temperate farming systems?: A Systematic Map Protocol

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Corresponding author's email address
richard.francksen@cumbria.ac.uk

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Background
Balancing food production and reaching net-zero in agricultural systems is a major societal challenge. Regenerative agriculture (RA) is an approach to farming that focuses (with varying emphasis) on topsoil protection and regeneration, biodiversity recovery, and enhancement of ecosystem services. RA aims to sustainably produce food, increase farm resilience and contribute to the overall health of the environment, and may hold potential to aid progress towards net-zero. Researchers are increasingly interested in RA practices, yet evidence is disparate, difficult to access for non-academics and has not been clearly summarised, creating uncertainty and risk among farmers. Furthermore, measuring the contribution of RA to reaching net-zero is hampered by a lack of readily available, transparent and collated evidence of impacts. Specifically, there is a lack of collated information on how RA can: (i) reduce greenhouse gas (GHG) emissions, thus aiding in reaching net-zero targets; and (ii) affect agricultural yields, which is vital for farm businesses. Here we ask how five practices, representative of regenerative agriculture, affect greenhouse gas emissions and agricultural yield in temperate farming systems. We drew upon the regenerative agriculture philosophy outlined by, among others, the Royal Agricultural Society of England (see: https://www.rase.org.uk/news/the-principles-of-regenerative-agriculture/). This philosophy outlines five principles of regenerative agriculture (minimise soil disturbance; keep soil covered; maintain living roots in the soil; maximise plant diversity; reintroduce livestock). These five principles formed our starting point. To each of these we matched what we deemed to be a representative farming practice, as follows: Minimise soil disturbance - Adopt minimum or zero tillage Keep soil covered - Utilise cover crops Maintain living roots in the soil - Incorporate under-sowing Maximise plant diversity - Incorporate intercropping Reintroduce livestock - (Re-) Integrate livestock Here, we aim to map the evidence for these five representative practices on greenhouse gas emissions and agricultural yield.

Theory of change or causal model
Regenerative Agriculture aims to aid progress towards net-zero targets, in part by reducing greenhouse gas emissions, and increase crop yields through adoption of various management practices. The underlying assumption of this protocol is that regenerative agriculture can have an

impact on greenhouse gas emissions from farming activity, and that its adoption may, in part, be influenced by its impact on agricultural yield and therefore farm economics. This research aims to detail how farming practices, deemed representative of regenerative agriculture, impact greenhouse gas emissions and agricultural yield in temperate farming systems.

Stakeholder engagement

This evidence map was conceived at a two-day workshop hosted by the AgriFood4NetZero Network+ (https://www.agrifood4netzero.net/) in Bristol, UK in June 2023. A team of researchers and food system stakeholders conceived the idea and developed the initial approach. Subsequently, this protocol was developed in collaboration with these food system stakeholders engaged with the AgriFood4NetZero Network+, who helped in forming the research question and co-developed the search terms and inclusion/exclusion criteria.

Objectives and review question

This systematic map aims to describe the current research into five different agricultural practices, deemed representative of the regenerative agriculture philosophy, with reference to their impact on greenhouse gas emissions and agricultural yield. The primary research question is: What evidence exists on the impacts of regenerative agriculture on greenhouse gas emissions and agricultural yield? The aims of this research are to: (i) reveal areas for future research by identifying evidence gaps; (ii) reveal evidence clusters for future evidence reviews; (iii) highlight areas of heterogeneity in the literature; and (iv) provide a searchable resource (database) to inform future policy and practice.

Definitions of the question components

Population: Farms and agricultural systems that are either in the United Kingdom, or are of a farming system similar to those used in the UK, i.e. in regions with a temperate oceanic climate (Köppen–Geiger Cfb) and utilise similar farming methods, crops and/or livestock to those typical of farming systems in the UK. Intervention: Incorporation of one or more of the five representative regenerative agriculture practices outlined above, which match five regenerative agriculture principles, namely minimum or no tillage; use of cover crops; under sowing; intercropping; and (re-) incorporating livestock grazing. Comparator: no regenerative agricultural practice as defined above, or an alternative farming practice. Either spatial comparison or before/after implementation. Outcome(s): must relate to the impact on greenhouse gas emissions (into the air at a plot, field and/or farm scale) and/or agricultural yield (change in farm income, crop or livestock growth/yield or total production).

Search strategy

Our methods are based on James, L., Randall, N. and Haddaway, N. (2016) (1) and the Collaboration for Environmental Evidence guidelines (2). We adhered to ROSES reporting standards (3) and these are documented in the attached additional files. Our search terms were identified from discussion with food system stakeholders and the PICO analysis. These were developed using a scoping study, outlined in the additional files, alongside a list of benchmarking articles, also outlined in the attached files. We did not restrict our search terms by publication date of articles, but we restricted the publication language to English. Searches will be conducted in bibliographic databases, with the details of each search recorded (date, time, number of results and search string used). A database will be produced of our results, with our data coding strategy outlined in the attached additional files. The initial search string, developed from discussions with our food system stakeholders and refined in discussions with the author team using our PICO analysis, is detailed in the attached scoping study file.

Bibliographic databases

The search for relevant literature will be conducted using Web of Science (WoS) and Scopus databases available through host institution subscriptions. Following the scoping study (see attached file), conducted in WoS, the refined search string was as follows (where 'TS' refers to Topic Search in WoS): TS=(“cover crop*” OR “under sow*” OR undersow* OR under-sow* OR “no till*” OR no-till* OR “zero till*” OR “low till*” OR “min* till*” OR “conservation till*” OR “reduced till*” OR "direct drill*" OR ((graz* OR sheep OR ewe* OR cattle OR cow* OR ruminant* OR livestock) AND *integrat*) OR intercrop* OR “multi crop*”) AND TS=(“greenhouse gas*” OR emissions OR methane OR CH4 OR “nitrous oxide” OR NOx* OR CO2 OR yield* OR harvest* OR return* OR productivity OR production) NOT (desert OR savannah OR arid OR tropical OR dryland OR Mediterranean OR Africa* OR China OR India* OR Kenya* OR Tanzania* OR Canad* OR America* OR USA OR U.S.A. OR Brazil* OR cotton OR rice OR paddy OR coffee OR weed* OR soy*)

Web-based search engines
N/A

Organisational websites
We will search the websites of CORDIS (EU research); the knowledge library of the Agriculture and Horticulture Development Board (AHDB); and UK government pages (.gov.uk) to search for evidence using the search string defined following a scoping study exercise.

Comprehensiveness of the search
A scoping exercise was carried out to test the specificity and sensitivity of terms used, with terms adjusted accordingly. The process and details of this can be found in the attached additional file. In summary, the principal decisions made in adjusting the original search term were as follows: (i) stipulating that livestock are (re-)integrated into an agricultural system; (ii) excluding some of the major countries/regions and ecosystems appearing in the results without a temperate oceanic climate (i.e. Köppen–Geiger climate classification Cfb); (iii) excluding results relating to some major crops grown outside Köppen–Geiger climate classification Cfb regions, e.g. coffee, rice and cotton

Search update
N/A

Screening strategy
The articles returned by the searches will be stored and managed for screening in EPPI Reviewer (https://eppi.ioe.ac.uk/cms/Default.aspx?tabid=2914). Primary screening will be conducted on titles to remove duplicates. Remaining articles will be screened against inclusion criteria by title, then abstract, then full texts. Studies must have been conducted in a region with a temperate oceanic climate (Köppen–Geiger Cfb), and reported in the English language. Eligible outcomes include a measurable or observable effect on greenhouse gas emissions and/or agricultural yield from one of the five regenerative agriculture practices. Only field studies will be eligible (i.e. not laboratory studies). Field studies can be of any design with spatial comparators or before-and-after studies. Owing to the restricted time frame of this project, a decision was made to not restrict search results too strictly to minimise loss of relevant studies, but instead to consider priority screening by relevance in EPPI Reviewer, and to consider ceasing screening when inclusion rate drops below 1% of screened articles (4), although this would be reviewed at the later screening stage.

Eligibility criteria
Eligibility criteria, used to identify relevant studies, are based on the PICO elements outlined above, as well as stakeholder interests and time limitations. Eligible studies: those conducted in an oceanic temperate climatic zone (Köppen-Geiger Cfb), such that they are relevant to UK agricultural systems. The unit of study must include a farming, agricultural or food production system, and

therefore we will exclude studies on non-food production systems (e.g. woodland, forestry, amenity grassland etc.). We will include only studies conducted in the English language. Eligible interventions: involving one or more of the five representative regenerative agriculture practices: minimum/low/no tillage; cover crops; under sowing; intercropping; and (re-) integration of livestock grazing. Eligible comparators: studies comparing an eligible intervention with either no regenerative agricultural practice as defined above, or an alternative farming practice. Spatial comparison or before/after implementation studies will be included. Eligible outcomes: a measurable or observable effect on either greenhouse gas emissions (emissions of carbon dioxide, methane and nitrous oxide into the air at a plot, field and/or farm scale) and/or agricultural yield (change in farm income, yield or total production). We will not include outcomes that measure carbon sequestration, storage, soil organic carbon or carbon balance. We will not include outcomes relating to agricultural quality indices e.g. protein or energy content, instead focussing on economic output, yield or total production. Eligible study designs: field studies can be of any design with spatial comparators or before-and-after studies. Laboratories, greenhouses, pots, and exclusively modelling studies will be excluded.

Consistency checking
A random subset of 5% of articles will be selected from the search results and will be used to check consistency of the screening. The size of this subset may decrease if the quantity of articles is too great for the timeframe. All authors will screen the articles to abstract against the inclusion criteria, however, only the first author will conduct the full screening. Cohen’s Kappa coefficient will be used to determine the consistency of decision making and a value of greater than 0.6 will indicate acceptable agreement. Where authors have differed, the inclusion criteria will be reviewed and adjusted accordingly.

Reporting screening outcomes
A ROSES flow diagram will be produced to report the outcome of the screening. Articles excluded at title and abstract will be detailed in one file, while another separate file will record articles excluded at full text with explanations of their exclusion.

Study validity assessment
Contradictions and discrepancies in the publications will be highlighted as evidence for the need for further research. However, a detailed critical appraisal will not be conducted. While systematic maps do not necessitate a critical appraisal, details such as study type and design will be documented to support any future systematic reviews. Additionally, the final report will acknowledge that the absence of a critical appraisal is a limitation of this study.

Consistency checking
N/A

Data coding strategy
Following the full-text screening, meta-data will be extracted from relevant studies. Details of the information that will be extracted can be found in the data coding document attached in the additional files. This information will be recorded in an Excel dataset.

Meta-data to be coded
The full data coding strategy can be found in the additional files.

Consistency checking
Coding will be performed by the first author, with a subset of 5% of studies checked for coding consistency by the full author team. In case of substantial disagreement, the coding criteria will be

reviewed and a further subset of 5% of studies will be rechecked for consistency, repeating until the consistency reaches at least 90% similarity. Missing relevant information will be coded as “Not specified”, due to insufficient timeframes for contacting authors for information. Information that does not apply to a specific study will be coded as “NA”.

Type of mapping
A full written report will be produced to document the methods and results of the research and will accompany the systematic map database. The searchable database will be produced using Microsoft Excel and will contain a data dictionary, all included studies and all available details from the coding strategy. This will be published as a supporting file with the systematic map report. The results of the searches are likely to be highly heterogeneous. As such, synthesis of the studies will be purely narrative, in line with systematic map protocol.

Narrative synthesis methods
Descriptive statistics will be used to characterise the systematic map.

Knowledge gap identification strategy
The systematic map database will enable regenerative agriculture research clusters and/or gaps to be identified. We will create cross-tabulated heatmaps to identify clusters and gaps in interventions and outcomes, and we will discuss relevant recommendations.

Demonstrating procedural independence
RF will be the primary person conducting the research. None of RFs prior publications appear in the full set of articles following the scoping study. The random subsets of articles checked for consistency will not include papers published by any member of the review team.

Competing interests
The authors declare that they have no competing interests.

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Author’s contributions
The primary question and research objectives were conceptualised by all authors listed here. NR, as the subject expert, proposed the systematic map approach. RF drafted the protocol and performed the scoping study, with guidance from NR and comments from all other authors. All authors read and approved the protocol and associated documents.

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Authors and Affiliations

Name	Country	Affiliation
Richard Francksen	***United Kingdom***	***Institute of Science and Environment; University of Cumbria***
Samuel Eze	United Kingdom	Department of Agriculture and Environment; Harper Adams University
Fiona Fraser	United Kingdom	Department of Rural Land Use, Scotland's Rural College
Jennifer Hodbod	United Kingdom	School of Earth and Environment; University of Leeds
Leonidas Rempelos	United Kingdom	Lincoln Institute for Agri-Food Technology; University of Lincoln
Payton T. O. Yau	United Kingdom	School of Science and Technology; Nottingham Trent University
Nicola Randall	United Kingdom	Department of Agriculture and Environment; Harper Adams University

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