Defra Sustainable Intensification Research Platform

SIP Project 1: Integrated Farm Management for Improved Economic, Environmental and Social Performance (LM0201)

Supplementary Study

Exploring the scope for SIP's practice based approach to be boosted through summary, rapid or systematic reviews and/or meta-analysis

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Contents

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The Sustainable Intensification Research Platform (SIP) is a multi-partner research programme comprising farmers, industry experts, academia, environmental organisations, policymakers and other stakeholders. The platform has explored the opportunities and risks of Sustainable Intensification (SI) from a range of perspectives and scales across England and Wales, through three linked and transdisciplinary research projects:

SIP Project 1 Integrated Farm Management for improved economic, environmental and social performance

SIP Project 2 Opportunities and risks for farming and the environment at landscape scales

SIP Project 3 A scoping study on the influence of external drivers and actors on the sustainability and productivity of English and Welsh farming

Projects 1 and 2 have investigated ways to increase farm productivity while reducing environmental impacts and enhancing the ecosystem services that agricultural land provides to society.

Project 1 partners are: NIAB (lead), IBERS (Aberystwyth University), ADAS, Agri-Food and Biosciences Institute (AFBI), Bangor University, Biomathematics and Statistics Scotland (BioSS), University of Bristol, University of Cambridge, Carbon Trust, Centre for Ecology and Hydrology (CEH), Duchy College, University of Exeter, Fera, Game and Wildlife Conservation Trust (GWCT), Glasgow Caledonian University, Harper Adams University, University of Hertfordshire, Linking Environment And Farming (LEAF), University of Leeds, Newcastle University, NIAB EMR, University of Nottingham, Organic Research Centre, University of Reading, Rothamsted Research, Royal Society for the Protection of Birds (RSPB), Scotland's Rural College (SRUC), Soil Association and Velcourt.

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The data used for this publication was created as part of the SIP, and is freely available (subject to data embargo) at the Agricultural and Environmental Data Archive (AEDA) owned by the Freshwater Biological Association (FBA). All data is owned by Defra.

ABBREVIATIONS

CEBC	Centre for Evidence-Based Conservation
CEE	Collaboration for Environmental Evidence
Defra	Department for Environment, Food and Rural Affairs
DSS	Decision Support Systems
GHG	Greenhouse Gas
IFM	Integrated Farm Management
K	Potassium
Mg	Magnesium
N	Nitrogen
P	Phosphorus
PICO	Population, Intervention, Comparator, Outcome
SI	Sustainable Intensification
SIP	Sustainable Intensification Research Platform

1. INTRODUCTION

As part of the Sustainable Intensification Research Platform (SIP), a 4-month supplementary study linked to Project 1 (LM0201, Integrated Farm Management for Improved Economic, Environmental and Social Performance) was carried out with the following objectives:

1. Evaluate whether or not a standardised synopsis, rapid/systematic review and/or meta-analysis would add significant value to SIP, and the feasibility of this; and

2. Propose prioritisation and scope for any such work.

This document comprises a scoping report to assess the potential for undertaking systematic reviews and/or meta-analyses on existing studies examining the effects of five different Interventions on a number of Outcomes as prioritised by the SIP Community. These priority questions have been designed to complement the ongoing field/practice based work by the SIP Community around the UK.

A systematic review is a critical assessment and evaluation of all research studies in order to answer a specific question with clearly defined inclusion criteria. Meta-analysis refers to the statistical analysis of a collection of data from individual primary studies for the purpose of integrating the findings.

If systematic reviews and meta-analyses for a set of questions already exist, there is potential for a higher level of evidence synthesis, into summaries that describe results across a range of possible options [1].

2. METHODS

2.1 Question Setting

Questions scoped within this report were developed following provision of an initial list of Interventions and Outcomes of interest within the SIP Community (Appendix 1). Based on this list CEBC circulated an initial set of 10 questions together with potential search keywords for consultation with the SIP Community. These questions were subsequently updated to the final set scoped within this report (Appendix 2).

Questions were developed according to a Population, Intervention, Comparator, Outcome (PICO) structure. The following questions have been identified for the purpose of this scoping exercise:

1. What are the effects of adopting minimum or no tillage systems on: soil biodiversity; soil quality; yield; and system inputs (water, nitrogen, fertiliser, pesticide) (Appendix 1, broad Intervention 4).

2. What are the effects of adopting minimum or no tillage systems and planting over-winter cover crops on yield? (Appendix 1, combination of broad Intervention 4 and 14);

3. What are the effects of implementing grazing management plans on: yield; greenhouse gas (GHG) emissions; and animal welfare (Appendix 1, broad Intervention 19);

4. What are the effects of planting legumes on: soil quality; yield; and system inputs (water, nitrogen, pesticide, fertiliser) (Appendix 1, broad Intervention 14); and

5. What are the effects of improved animal nutrition on: yield; GHG emissions; and veterinary medicine inputs (Appendix 1, broad Intervention 6)?

2.2 Methodology

Taking elements of systematic review methodology [2], the defined questions were scoped according to their potential for systematic reviews and/or meta-analysis.

2.2.1 Scoping Strategy

The purpose of this report is to scope Interventions identified by the SIP Community not to undertake a full systematic review or meta-analysis on each Intervention. As such the following rules have been followed in order to add efficiencies into the scoping process:

1. Searches for existing meta-analyses relevant to the Intervention being assessed were initially undertaken using the journal Environmental Evidence and Web of Science. Where meta-analyses were identified that covered elements of the PICO for each question being scoped, screening of search results was not undertaken as it was assumed that the potential for further meta-analyses exists;

2. Searches were limited by location to restrict the total number of hits retrieved to a manageable number. Screening was undertaken for all searches for which existing meta-analyses have not been identified.

3. Once the potential for a meta-analysis is indicated (5 suitable papers identified), additional screening was not undertaken.

We selected 5 papers as the minimum number of studies required to indicate the potential for meta-analyses. This is an arbitrary cut-off that was chosen under the assumption that if five papers were identified within our limited sample using basic search strings, more data would likely be identified through a systematic review with more comprehensive search strings. In addition, we chose this cut-off in order to enable scoping of a greater number of Intervention/Outcomes within the time resources available.

Should full systematic reviews or meta-analyses be undertaken at a later date it is expected that Collaboration for Environmental Evidence (CEE) compliant methodology [2] would be applied to identify the relevant evidence base.

2.2.2 Search Strategy

Searches were undertaken between April and May 2015. For the purposes of this Scoping Report only articles published in English have been considered. The following bibliographic databases, covering material from the natural and social sciences and from both peer-reviewed and grey literature, were searched:

1. Thomson Reuter's (formally ISI) Web of Science, New York, USA;
2. CAB Direct, published by CAB International, Wallingford, United Kingdom; and
3. AGRICOLA Agricultural Research Database.

No supplementary searches were undertaken to identify relevant grey literature.

For each search, citation results were exported directly into Endnote for screening.

Search strings are identified for each Intervention/Outcome scoped in the relevant sections below. Inclusion of the search term 'temperate' may have meant that otherwise relevant studies were missed.

2.2.3 Screening

Articles identified from each search were screened for relevance following the removal of any duplicates in Endnote. Articles were screened until 5 relevant articles were identified in order to enable a wider range of Intervention/Outcomes to be screened. Intervention specific inclusion and exclusion criteria are detailed within Section 3.

2.2.4 Assumptions

The methodology used was applied in order to obtain representative samples of the available literature based on keywords identified by CEBC in consultation with the SIP Community. It is unlikely that the full range of articles available has been captured within this report. Consequently, we consider it likely that if the potential for meta-analyses has been identified, further evidence will exist than that described.

The following assumptions have been made while undertaking this report in order to comply with necessary resource restrictions:

1. Searches of grey literature through the websites of relevant organisations would have little effect on the outcomes of this report; and
2. Search strings are appropriate for the Intervention/Outcome considered.

3. RESULTS AND DISCUSSION

3.1 Broad Overview of the Evidence-base

A broad overview of the evidence base available on the topics covered in this report is provided in Figure 1 overleaf. We did not undertake screening for those Intervention/Outcomes where existing meta-analyses have been identified that answer part, or all, of the question asked by SIP, as there are clearly potential data available to address aspects of the question. There may be additional relevant meta-analyses available but, once recent syntheses were identified, searching was discontinued. The relevant meta-analyses for those Intervention/Outcomes that we did not screen are summarised below.

Reduce tillage to minimum or no till

Two recent meta-analyses were identified that looked at the effects of reduced, minimum or no till on **yield** when compared to conventional tillage [3, 4]. One meta-analysis looking at the effects of reduced tillage on **soil quality**, specifically soil organic matter, was detected [5], as was one on **biodiversity**, focusing on earthworms and fungi [6].

Improve animal nutrition

Five recent meta-analyses were detected that investigated aspects of animal nutrition on **yield** [7-11]. A further three were detected that investigated aspects of diet and nutrition on **GHG emissions** from ruminants [12-14].

Plant legumes, including peas, beans and clover

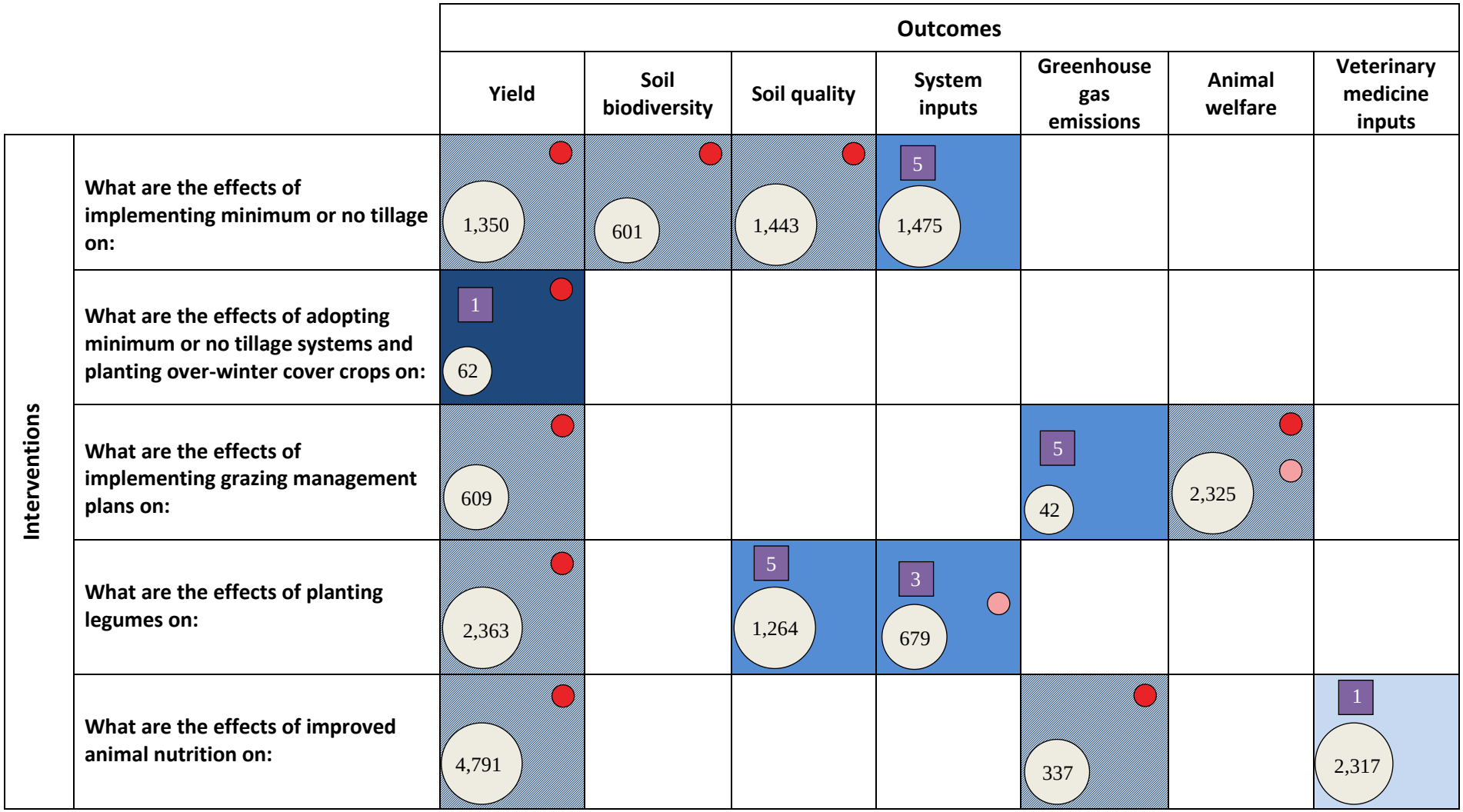
Two recent meta-analyses were identified that investigated the effects of planting legumes on **yield** [15, 16].

Optimise grazing management

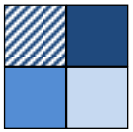
Two meta-analyses were detected that looked at aspects of grazing management (stocking rates and pre-grazing pasture mass) on **yield** in dairy cows [17, 18].

Appendix 3 provides a list of identified meta-analyses for each Intervention/Outcome combination described here.

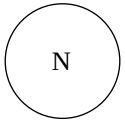
Figure 1. Overview matrix detailing potential for meta-analyses. The effect of minimum till and cover crops on yield was screened despite having found directly relevant meta-analyses as searching and screening of articles for data and meta-analyses took place concurrently.



Key to Figure 1.



Background colour indicates overall potential for meta-analysis: dark blue hashed represents high potential, not screened; dark blue solid, high potential, scoped; medium blue solid, medium potential, scoped; light blue, low



Number of potentially relevant articles identified through searches: number of articles detailed within circle; size of circle visually represents volume identified.

Number of articles identified as having potential for inclusion in meta-analysis. Number of articles (max=5) detailed within square.

Indicates whether relevant existing meta-analyses have been identified that are either directly (dark red circle) or indirectly (light red circle) relevant.

Not scoped as not identified as a priority by the SIP

3.2 Scoping of Intervention/Outcomes

3.2.1 What are the effects of adopting minimum or no tillage systems on system inputs (water, nitrogen, pesticide, fertiliser)?

PICO element:
- P Farms (arable) in temperate conditions equivalent to those in the UK.
- I No tillage, reduced depth or frequency of tillage.
- C Conventional ploughing.
- O Change in water, nitrogen, pesticide or fertiliser use efficiency.

Search String: (tillage OR plough* OR "Conservation tillage" OR "non-inversion tillage" OR "min till" OR "no till")
AND (water OR nitrogen OR pesticid* OR herbicid* OR fungicid* OR fertili*er AND efficien*)
AND (temperate OR UK OR "United Kingdom" OR "Great Britain" OR England OR Wales OR Scotland OR Ireland)

Summary of Results

Total number of articles retrieved:	1,475
Number of articles excluded at title & abstract:	1,421 (96%)
Number of articles identified as potentially relevant at abstract screening:	54
Number of articles screened at full text:	21
Number of studies suitable for meta-analysis: Number of studies potentially suitable:	5 N/A

Comment on potential for meta-analysis

Five articles [19-23] were identified as being potentially suitable for inclusion within a meta-analysis. The full sample of potentially relevant articles was therefore not screened. Between them, these studies considered water and nitrogen use efficiency, soil moisture content and the availability of plant nutrients.

In addition, a number of studies were identified [*e.g.* 20, 24] that examined the effect of different tillage systems and sources or concentrations of fertiliser inputs on yield. While these do not directly answer the current question identified by the SIP community, a meta-analysis may be possible to determine the most efficient levels of fertiliser under different till regimes.

No existing relevant meta-analyses were identified examining the effects of reduced tillage on system inputs.

Recommendations

Based on these findings, we consider there to be potential for meta-analyses although there are a range of Outcomes included within the sample assessed here. Prior to any systematic review or meta-analysis being undertaken, it is recommended that the following items are clarified:

- Determine the focus of interest, *i.e.* could system outputs (such as nitrogen balance) be used as a proxy for inputs;
- Consider the most meaningful ways to combine or separate the different Outcomes; and
- Define more specific inclusion criteria.

In order to identify and determine the number of studies investigating different variables, a systematic map or well-resourced systematic review may be a useful exercise to inform any subsequent meta-analysis. Such a systematic map or review would enable synergies between existing studies and study farms to be identified for potential meta-analyses.

3.2.2 What are the effects of adopting minimum or no tillage systems and planting over-winter cover crops on yield?

PICO element:
- P Farms (arable) in temperate conditions equivalent to those in the UK.
- I No tillage, reduced depth or frequency of tillage AND use of over-winter cover crops
- C Conventional ploughing.
- O Changes in yield.

Search String: (tillage OR plough* OR “Conservation tillage” OR “non-inversion tillage” OR “min till” OR “no till”)
AND (“over-winter cover crop*”OR “over winter cover crop” OR “cover crop”)
AND (temperate OR UK OR "United Kingdom" OR "Great Britain" OR England OR Wales OR Scotland OR Ireland)

Summary of Results

Total number of articles retrieved:	62
Number of articles excluded at title & abstract:	50 (81%)
Number of articles identified as potentially relevant at abstract screening:	12
Number of articles screened at full text:	12
Number of studies suitable for meta-analysis: Number of studies potentially suitable:	1 2

Comment on potential for meta-analysis

One article [25] was identified as being suitable for inclusion in a meta-analysis. Two additional articles were identified with potential relevance however raw data were not reported [26, 27]. The ability to incorporate these papers into any meta-analyses would rely on the ability to obtain relevant data. A further article [28] met the criteria for inclusion however it was confounded by different fertiliser use between control and Intervention plots. Consequently, this study might be suitable for inclusion if enough data exists to enable sensitivity analyses.

We identified three potentially relevant meta-analyses. Pittelkow *et al.* [3] conducted a global meta-analysis looking at the impacts of conservation agriculture practices on yield and, as well as all studies looking at tillage compared with no or reduced tillage, a proportion (not specified in the article) also look at cover crops (under the heading of crop rotation) and so could be used to identify relevant studies for meta-analysis. Tonitto *et al.* [29] focused on diversified crop rotations using cover crops and the effect on nitrogen retention and yields. Based on screening of this article, the authors appear to have found suitable data for inclusion in any meta-analysis examining the effect of reduced till and over-winter cover crops on yield; however, they have not reported the data as no significant results were found. As this meta-analysis is now 10 years old, it is considered likely that further data

would now be available. More recently, a potentially relevant synthesis by Preissel *et al.* [16] considered the economic value of grain legume pre-crop benefits in Europe, presenting economic data on the effects of planting grain legumes under reduced tillage on yield and input requirements of subsequent crops and farm gross margins.

Recommendations

Based on these findings, we consider that there may be potential for a meta-analysis examining the effect of reduced tillage and over-winter cover crops on yield but this topic may benefit from additional scoping using refined search terms and inclusion criteria.

Prior to any systematic review or meta-analysis being undertaken, it is recommended that the following items are clarified:

- Determine the focus of interest, *i.e.* whether interest lies in the use of cover crops planted for green manure or soil protection, planted in a crop rotation to achieve its own yield or both;
- Define more specific inclusion criteria (*e.g.* whether leguminous and non-leguminous cover crops are of equal interest); and
- Review existing meta-analyses to determine relevance.

3.2.3 What are the effects of implementing grazing management plans on greenhouse gas emissions?

PICO element:
- P Livestock farms (dairy or red meat) in temperate conditions equivalent to those in the UK.
- I Grazing management plan in place
- C No grazing management in place.
- O Change in GHG emissions from livestock at farm scale (N2O, CO2, CH4) / Life cycle GHG emissions of farm system (including imported feed).

Search String:
(livestock OR cattle OR dairy OR sheep)
AND ("grazing management" OR "rotational grazing" OR "set stocking" OR "paddock grazing" OR "deferred grazing" OR "all grass wintering" OR "cell grazing")
AND (“greenhouse gas” OR “carbon dioxide” OR methane OR “nitrous oxide” OR (“greenhouse gas” AND emission* OR “life cycle”))
AND (temperate OR UK OR "United Kingdom" OR "Great Britain" OR England OR Wales OR Scotland OR Ireland)

Summary of Results

Total number of articles retrieved:	42
Number of articles excluded at title & abstract:	29 (69%)
Number of articles identified as potentially relevant at abstract screening:	13
Number of articles screened at full text:	7
Number of studies suitable for meta-analysis: Number of studies potentially suitable:	5 N/A

Comment on potential for meta-analysis

Five articles were identified as having potential for meta-analysis [30-34]. The full sample of potentially relevant articles was therefore not screened. However, it is worth noting that while there may be potential for meta-analysis, studies may form a disparate dataset and the sample size may be low for particular species/treatments. Nonetheless, units appear to be relatively standardised and so the data are considered sufficient for meta-analysis.

In addition, we identified a number of studies that considered the effect of livestock grazing on soil carbon sequestration, a related field to GHG emissions. It is recommended that should this Intervention/Outcome be of interest in the future, consideration is given as to whether such studies should be included in any systematic review and/or meta-analysis.

No existing relevant meta-analyses were identified examining the effects of implementing grazing management plans on GHG emissions.

For the purposes of scoping, we have focused on effects on GHG emissions from grazing. However related data may exist on the impacts of animal excreta on GHG emissions [*e.g.* 32].

Recommendations

Prior to any systematic review or meta-analysis being undertaken, it is recommended that the following items are clarified:

- Define the scope of grazing management plan as an Intervention;
- Define the scope of GHG emissions as an Outcome, *e.g.* is carbon sequestration an appropriate Outcome?; and
- Define more specific inclusion criteria.

In order to identify and determine the number of studies investigating different variables, a systematic map may be a useful exercise to inform any subsequent meta-analysis. In addition, a systematic map would enable synergies between existing studies and study farms to be identified for potential meta-analyses.

3.2.4 What are the effects of planting legumes on:

Soil quality?

PICO element:
- P Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK.
- I Farms that plant legumes (including clover).
- C Farms that do not plant legumes / use alternative techniques (*e.g.* fallowing, fertiliser use).
- O Changes in soil quality.

Search String:
(livestock OR cattle OR dairy OR sheep OR arable)
AND (legume* OR pea* OR bean* OR clover)
AND (soil AND ("organic matter" OR humus OR moisture OR erosion OR runoff OR nutrient OR nitrogen OR structur* OR "biological activity" OR compact*))
AND (temperate OR UK OR "United Kingdom" OR "Great Britain" OR England OR Wales OR Scotland OR Ireland)

Summary of Results

Total number of articles retrieved:	1,264
Number of articles excluded at title & abstract:	1,219 (96%)
Number of articles identified as potentially relevant at abstract screening:	45
Number of articles screened at full text:	19
Number of studies suitable for meta-analysis: Number of additional studies potentially suitable:	5 2

Comment on potential for meta-analysis

Five articles [35-39] were identified with the potential for inclusion in a meta-analysis. The full sample of potentially relevant articles was therefore not screened. Between them these articles presented a range of data on soil quality indicators such as pH, concentrations of N, P, K or Mg as well as soil light fraction ad microbial biomass amongst others. Units appear to be relatively standardised and so the data are considered sufficient for meta-analysis.

No existing relevant meta-analyses were identified examining the effects of planting legumes on soil quality.

Recommendations

Based on these findings, there is potential for meta-analysis.

Prior to any systematic review or meta-analysis being undertaken, it is recommended that the following items are clarified:

- Define the scope of soil quality as an Outcome, *e.g.* is nitrate leaching an appropriate Outcome?; and
- Define more specific inclusion criteria.

System inputs?

PICO element:
- P Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK.
- I Farms that plant legumes (including clover).
- C Farms that do not plant legumes / use alternative techniques (*e.g.* fallowing, fertiliser use).
- O Change in water, nitrogen, pesticide or fertiliser use efficiency.

Search String:
(livestock OR cattle OR dairy OR sheep OR arable)
AND (legume* OR pea* OR bean* OR clover)
AND (water OR nitrogen OR pesticid* OR herbicid* OR fungicid* OR fertili*er AND efficien*)
AND (temperate OR UK OR "United Kingdom" OR "Great Britain" OR England OR Wales OR Scotland OR Ireland)

Summary of Results

Total number of articles retrieved:	679
Number of articles excluded at title & abstract:	668 (98%)
Number of articles identified as potentially relevant at abstract screening:	11
Number of articles screened at full text:	9
Number of studies suitable for meta-analysis: Number of additional studies potentially suitable	3 3

Comment on potential for meta-analysis

One article was identified during scoping that specifically reported changes in system inputs as a result of planting legumes although farm-specific data are not presented [40]. Three articles were identified presenting nitrogen use efficiency [41-43] suggesting some potential for meta-analysis, although studies presenting data that could be used to calculate nitrogen use efficiency are also likely to exist, and studies presenting data on a range of related parameters (*e.g.* N uptake) were also identified.

Related Outcomes such as comparisons between planting legumes and fertiliser application on yield (crop, legume dry matter in pasture or for forage or animal weight/milk yield) or on *e.g.* N run-off could be used to infer impacts of planting legumes on the need for inputs and are likely to also yield sufficient data for meta-analysis.

Recommendations

Although there appears to be some potential for meta-analysis in this area, study Outcomes are disparate (across water, nitrogen etc.). Prior to any systematic review or meta-analysis being undertaken, it is recommended that the following items are clarified:

- Whether a subsequent systematic review or meta-analysis should focus across Outcomes or on a specific variable of interest (and whether it is meaningful or appropriate to consider them together;
- Define more specific inclusion criteria;
- Any meta-analysis in this area may benefit from a revised search to account more accurately for relevant Outcomes (*e.g.* “nitrogen use efficiency”);
- Based on the apparently limited number of studies directly addressing the question for each input, consideration of exploring alternative related Outcomes such as effect on yield could be considered if this topic was to be pursued.

In order to identify and determine the number of studies investigating different variables, a systematic map may be a useful exercise to inform any subsequent meta-analysis. In addition, a systematic map would enable synergies between existing studies and study farms to be identified for potential meta-analyses.

3.2.5 What are the effects of improving animal nutrition on veterinary medicine inputs?

PICO element:
- P Livestock farms (dairy or red meat) in temperate conditions equivalent to those in the UK.
- I Active change in the nutritional content or balance of feed or selected forage to enhance productivity (nitrogen, mineral or vitamin content, or other added supplements or probiotics).
- C Conventional feeding regime.
- O Veterinary medicine inputs.

Search String: (livestock OR cattle OR dairy OR sheep)
AND (nutrition* OR feed OR forage OR TMR OR "total mixed ration" OR DUP OR "digestible undegradable protein")
AND (“veterinary medic*” OR veterinary)
AND (temperate OR UK OR "United Kingdom" OR "Great Britain" OR England OR Wales OR Scotland OR Ireland)

Summary of Results

Total number of articles retrieved:	2,317
Number of articles excluded at title & abstract:	2,316 (99.9%)
Number of articles identified as potentially relevant at abstract screening:	1
Number of articles screened at full text:	1
Number of studies suitable for meta-analysis: Number of additional studies potentially suitable	1 n/a

Comment on potential for meta-analysis

There is some data available that could be used in a meta-analysis (for example on the effects of comparative diets on clinical symptoms in production animals), however there appears to be few data explicitly on the impacts on veterinary medicine inputs with only one relevant study retrieved [44].

There also appear to be no existing meta-analyses that assess the impacts of improved nutrition on veterinary medicine inputs.

Recommendations

It is unlikely to be worth pursuing a meta-analysis using veterinary medicine inputs as the Outcome, although it could be worth scoping the potential to use related Outcomes such as general health/clinical symptoms/morbidity/fertility/parasite burden as a proxy.

4. CONCLUSIONS

4.1 General findings

Based on the findings of this scoping exercise there appears to be the potential for meta-analyses on a number of Intervention/Outcomes identified as priorities by the SIP community. However, not all articles present sufficient data to allow direct reuse in meta-analysis and so study authors may therefore need to be contacted to obtain raw data.

Prior to undertaking any systematic reviews or meta-analyses a number of items require clarification including: climatic boundaries and crops/species for inclusion, relevance of search strings and identification of relevant Outcomes (*i.e.* alternative measures of inferring desired Outcomes for example, nitrate leaching may be a suitable proxy for changes in system inputs).

In order to enable the refinement of questions and inclusion criteria, a series of systematic maps to enable the identification of synergies with study farms may be a useful step forward. This would summarise the existing evidence-base to inform subsequent more focused systematic reviews and meta-analyses. Where multiple studies spread over disparate Outcomes exist then synopses that provide summaries of individual studies may provide a useful overview of the evidence. Alternatively, the conduct of systematic reviews specifically focused on study farm Interventions and Outcomes of interest would enable the collection of data to compare with and enhance the results from study farms.

A further description of types of evidence is included in Appendix 4.

4.2 Prioritisation Workshop

A workshop was held on 22 May 2015 to present these results and to identify future priorities for the SIP Community based on the use of systematic reviews and / or meta-analyses to support ongoing field/practice based work. The objectives of the workshop were to:

> *Evaluate whether or not systematic reviews and/or meta-analyses of key questions would add significant value to SIP, and the feasibility of this; and*
>
> *Propose prioritisation and scope of works for any such work as well as alternative approaches such as summaries or systematic evidence mapping.*

Twelve delegates attended the workshop (Appendix 5). Of these, nine took part in a prioritisation exercise to determine Intervention/Outcomes with the highest priority for sustainable intensification (SI) and SIP relative to each other. Details of the prioritisation exercise are provided in section 4.2.1 and the Outcomes are presented in section 4.2.2.

4.2.1 Prioritisation Exercise

The nine people involved in the prioritisation process are indicated in Appendix 5. As a group, they provide a broad range of expertise across all specific Outcomes identified in livestock and arable farming. At the workshop, each individual was given a table showing the five Interventions and the possible Outcomes to be considered, similar to Figure 1 but without contents.

The group decided during an opening discussion to prioritise all possible Intervention/Outcome combinations in the table, rather than just those already prioritised and scoped for meta-analysis potential. Six combinations were not considered, because the Outcome was considered to be unrelated to the Intervention (hashed in Figure 2).

Each Intervention/Outcome combination was discussed in turn, and each participant privately recorded a priority level of High, Medium or Low. This private recording of opinion reduces the cognitive biases common to such group settings, such as 'group think', which can affect decision outcomes [45]. After the discussions, the number of Highs, Mediums and Lows was counted for each Intervention/Outcome combination independently by two workshop organisers, and the combinations were sorted to rank them. Sorting was undertaken initially in descending order by number of Highs, then descending by the number of Mediums and then ascending by the number of Lows. Consequently, the combinations with the lowest number of Highs and Mediums and highest number of Lows had the lowest rank.

Combinations with identical numbers of High, Medium and Low were considered tied, as indicated in Figure 2. For those tied pairs ranking in the first 15 (three of the five pairs), the tie was resolved by a second round of prioritisation, in which each participant chose one of the pair as having highest priority, and the one of each pair selected by the most people was given the higher rank. Final ranks are shown in Figure 2. Intervention/Outcome combinations were labelled High, Medium or Low in the ratio 10:10:9, to give approximately equal groups.

4.2.2 Priorities for Sustainable Intensification

Figure 2 presents the ranked priority assigned to each Intervention/Outcome by workshop delegates.

4.2.3 Prioritisation for future conduct of systematic reviews and meta-analyses

Each Intervention/Outcome combination scoped was mapped according to their potential for meta-analysis and their relative priority for SIP (Figure 3). Areas of high potential for meta-analyses indicate that sufficient data are likely to be available to address specific questions using meta-analysis within Intervention/Outcome areas. Areas of high relative priority for SIP and high potential for meta-analysis suggest that these areas should be prioritised for future work. Areas of low relative priority for SIP and low potential for meta-analysis suggest Intervention/Outcome areas where more primary research is likely to be required to undertake meaningful meta-analysis. Where there is medium potential that data may be available on part or all of a question however we would recommend undertaking systematic maps to better define the evidence base available to determine how to proceed.

Figure 2. Results of the prioritisation exercise. Intervention/Outcome combinations prioritised as High are shown in green, Medium in amber and Low in red. Numbers in brackets represents the rank assigned to each Intervention/Outcome. Tied Intervention/Outcomes are highlighted with an asterisk. Hashed cells indicated Outcomes not considered relevant to the Intervention by workshop delegates.

		Outcomes						
		Yield	**Soil biodiversity**	**Soil quality**	**System inputs**	**Greenhouse gas emissions**	**Animal welfare**	**Veterinary medicine inputs**
Interventions	**What are the effects of implementing minimum or no tillage on**	High (9)	Low (21)*	High (6)*	Medium (13)	Medium (17)		
	What are the effects of adopting minimum or no tillage systems and planting over-winter cover crops on:	Medium (18)*	Low (21)*	High (4)*	Low (23)	Medium (14)		
	What are the effects of implementing grazing management plans on:	High (1)	Low (26)	High (5)*	Medium (12)*	High (10)	Medium (16)	Low (24)
	What are the effects of planting legumes on:	High (2)	Low (27)	Low ()	Medium (11)*	High (8)	Low (29)	Low (28)
	What are the effects of improved animal nutrition on:	High (7)			Medium (20)	High (3)*	Medium (15)	Medium (18)*

Figure 3. Results of the prioritisation exercise mapped with the potential for meta-analysis. Intervention/Outcomes reported in order of priority as ranked by workshop delegates.

Potential for meta-analysis / Priority for SIP	High	Medium	Low
High	- Grazing management plan on yield - Planting legumes on yield - Improved animal nutrition on GHG emissions - Minimum or no till on soil quality - Improved animal nutrition on yield - Minimum or no till on yield - Grazing management plan on GHG emissions	- Minimum or no till on system inputs	
Medium	- Grazing management plan on animal welfare - Minimum or no till & cover crops on yield	- Planting legumes on system inputs	- Improved animal nutrition on veterinary medicine inputs
Low	- Minimum or no till on soil biodiversity	- Planting legumes on soil quality	

5. RECOMMENDATIONS AND FURTHER WORK

Specific discussions were held at the workshop to decide on the appropriate next steps with regard to the use of types of evidence syntheses to add value to SIP. Three specific recommendations for Defra were agreed at the workshop:

1. Conduct two systematic reviews and/or meta-analyses focusing on one high priority arable Intervention (minimum/no-till or planting legumes) and one high priority livestock Intervention (grazing management plan or improved animal nutrition) as a demonstration of the power of this approach to add weight behind evidence-based decision-making. Outcomes should be prioritised prior to undertaking any review according to those identified as high relative priority for SIP for each Intervention (figure 3) and those that could be most meaningfully combined with data from study farms;

2. Concurrently, undertake systematic mapping to characterise the evidence base for a suite of related areas (for example, all of the Population/Outcome combinations associated with a specific Intervention); and

3. Compile a synopsis (summaries of studies) across all Intervention/Outcome combinations discussed here.

It is considered that these would add value to SIP as follows:

- The work proposed would provide wider research context when communicating the results of the field/practice based approach adopted on the SIP case study farms;
- Recommendation 1 would add depth to the study farm Outcomes, where the Interventions chosen for review are relevant to those being tested on the farms;
- Recommendation 2 would add breadth to the study farm work, and could highlight opportunities for further Intervention/Outcome evaluation;

Recommendation 3 would provide additional evidence to underpin the mapping of farm management practices to Outcomes, which is a key part of the work to develop a framework for more effective decision support / guidance around Integrated Farm Management (IFM).

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7. APPENDICES

Appendix 1: Interventions and Outcomes of Interest to the SIP Community

Table A1. Original list of interventions and outcomes (measures of sustainable intensification) of interest to the SIP Community as provided to CEBC in March 2015.

SI intervention	Population	Intervention	Comparator	Outcome
Integrated farm management	Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK. This could include USA or north-western Europe.	Integrated Farm Management (should be named in the studies. Always a combination of specific interventions)	Conventional farm management	Yield (crop or livestock). Fertilizer inputs. Pesticide inputs. Nutrient loss or runoff. Species abundance or diversity (any taxon). Habitat diversity.
Cooperation among farmers at landscape scale to enhance sustainability	Farmed landscapes in temperate conditions equivalent to those in the UK.	Farmers in a landscape co-operate on decisions about natural resource management	Landscape with similar structural and socio-economic characteristics, but farmers do not cooperate on natural resource management decisions	Average per farm, or total across landscape: Yield (crop or livestock). Fertilizer inputs. Pesticide inputs. Nutrient loss or runoff. Species abundance or diversity (any taxon). Habitat diversity.
Grow crop varieties with increased tolerance to stresses such as drought, pests or disease	Farms (arable) in temperate conditions equivalent to those in the UK.	Farmer selects crop varieties on the basis of tolerance (NOT resistance) to drought, pests or diseases	Farmers who don't take tolerance into account when selecting crop varieties	Yield (quantity). Yield (quality/level of damage). Pesticide inputs. Number of pest/disease outbreaks.
Reduce tillage to minimum or no till	Farms (arable) in temperate conditions equivalent to those in the UK.	No tillage Reduced depth or frequency of tillage.	Conventional ploughing.	Crop yield (any crop). Fertilizer inputs. Pesticide inputs. Nutrient loss or runoff. Soil organic matter content. Soil compactness. Sediment runoff / erosion rate. Soil biodiversity (abundance or diversity, any taxon).
Incorporate cover crops, green manures and other sources of organic matter to improve	Farms (dairy, red meat or arable) in temperate conditions equivalent to	Active incorporation into the soil of: Cover crop/green manure residues	Either no organic matter or crop residue incorporated OR only straw from	Yield (crop or livestock). Fertilizer inputs. Pesticide inputs. Nutrient loss or runoff. Soil organic matter content.

SI intervention	Population	Intervention	Comparator	Outcome
soil structure	those in the UK.	Straw Biosolids (slurry) Farmyard manure Compost	harvested crops incorporated.	Sediment runoff / erosion rate. Soil biodiversity (abundance or diversity, any taxon).
Improve animal nutrition to optimise productivity (and quality) and reduce the environmental footprint of livestock systems	Livestock farms (dairy or red meat, not pigs or poultry) in temperate conditions equivalent to those in the UK.	Active change in the nutritional content or balance of feed or selected forage to enhance productivity (nitrogen, mineral or vitamin content, or other added supplements or probiotics).	Conventional feeding regime	Yield (milk or meat). Veterinary medicine inputs. Nutrient loss or runoff. GHG emissions from livestock at farm scale (N_2O, CO_2, CH_4) Life cycle GHG emissions of farm system (including imported feed)? Animal welfare.
Reseed pasture for improved sward nutrient value and / or diversity	Livestock farms (dairy or red meat, not pigs or poultry) in temperate conditions equivalent to those in the UK.	Pasture re-seeded for improved nutritional value or diversity of plant species.	Pasture managed conventionally (could be re-seeded but not for improved nutritional value)	Yield (milk or meat). Veterinary medicine inputs. Nutrient loss or runoff. GHG emissions from livestock at farm scale (N_2O, CO_2, CH_4).
Predict disease and pest outbreaks using weather and satellite data, and use this information to optimise inputs	Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK.	Use predicted disease and pest outbreaks to adjust or optimise pesticide inputs.	Pesticide inputs planned without reference to predicted outbreaks.	Yield (crop or livestock quantity). Yield (quality/level of damage). Pesticide inputs. Number of pest/disease outbreaks.
Adopt precision farming: using the latest technology (e.g. GPS) to target delivery of inputs (water, seeds, pesticides, fertilisers, livestock manures)	Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK.	Use precision farming technology	Farms that do not use precision farming technology.	Yield (crop or livestock). Fertilizer inputs. Pesticide inputs. Water use efficiency. Nitrogen use efficiency. Nutrient loss or runoff. Species abundance or diversity (any taxon).
Monitor and control on-farm energy use	Farms (dairy, meat or arable) in temperate conditions equivalent to those in the UK.	Monitor total energy use (including fuel and heating) and take appropriate steps to reduce it	Farms without energy monitoring or energy reduction measures	Total on farm energy use. Farm-scale GHG emissions.
Improve the use of agriculturally marginal land for	Farms (dairy, meat or arable) in temperate	Natural habitats planned and located on farm to	Natural habitats randomly located on farm, without	Yield (crop or livestock). Fertilizer inputs. Pesticide inputs.

SI intervention	Population	Intervention	Comparator	Outcome
natural habitats to provide benefits such as soil improvement, pollution control or pollination, and allow wildlife to thrive	conditions equivalent to those in the UK.	maximise ecosystem service delivery and minimise impact on overall productivity	optimised location.	Nutrient loss or runoff. Species abundance or diversity (any taxon). Habitat diversity.
Provide training for farm staff on how to improve sustainability / environmental performance	Farms (dairy, meat or arable) in temperate conditions equivalent to those in the UK.	Provide staff training on environment and/or sustainability	Do not provide staff training on environment/ sustainability	Yield (crop or livestock). Fertilizer inputs. Pesticide inputs. Water use efficiency. Nitrogen use efficiency. Nutrient loss or runoff. Species abundance or diversity (any taxon). Habitat diversity. Farm-scale GHG emissions.
Use soil and plant analysis with technology to use fertiliser more efficiently[1]	Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK.	Farms that employ chemical or biophysical analysis of soil, crop or forage plants.	No chemical or biophysical analysis.	Yield (crop or livestock). Fertilizer inputs. Pesticide inputs. Water use efficiency. Nitrogen use efficiency. Nutrient loss or runoff.
Plant legumes - includes peas and beans, for forage and other products	Farms (dairy, red meat or arable) in temperate conditions equivalent to those in the UK.	Farms with legumes.	Farms with no legumes.	Yield (crop or livestock). Fertilizer inputs. Nitrogen use efficiency. Nutrient loss or runoff. Soil organic matter content. Sediment runoff/erosion rate. Species abundance or diversity (any taxon, including soil biota).
Use animal health diagnostics to enhance livestock productivity and animal welfare	Livestock farms (dairy or red meat, not pigs or poultry) in temperate conditions equivalent to those in the UK.	Use animal health diagnostics	No use of animal health diagnostics.	Yield (milk or meat). Veterinary medicine inputs. Animal welfare.
Keep more productive / prolific livestock - genetics, breeding technologies (EBVs, AI, ET)	Livestock farms (dairy or red meat, not pigs or poultry) in temperate conditions equivalent to those in the UK.	Farms that use genetics or breeding technology to enhance livestock productivity.	Farms that do not use genetics or breeding technology to enhance livestock productivity	Yield (milk or meat). Veterinary medicine inputs. Animal welfare?

[1] This very similar to number 8 but more focused.

SI intervention	Population	Intervention	Comparator	Outcome
Controlled traffic farming to minimise soil compaction and energy use	Farms (dairy, meat or arable) in temperate conditions equivalent to those in the UK.	Farms where controlled traffic farming used.	Farms where controlled traffic farming not used.	Crop yield (any crop). Fertilizer inputs. Nitrogen use efficiency. Soil organic matter content. Soil compactness. Sediment runoff/erosion rate.
Reduce the risks associated with pesticide use by adopting IPM techniques	Arable farms in temperate conditions equivalent to those in the UK.	Integrated Pest Management: farmer uses all suitable techniques and methods in as compatible a manner as possible to maintain pest populations at levels below those causing economic injury.	Conventional pest control, following standard agronomic advice without reference to pest population dynamics.	Yield (crop or livestock quantity). Yield (quality/level of damage). Pesticide inputs. Number of pest/disease outbreaks.
Optimise grazing management to reduce bought-in feeds and increase nitrogen use efficiency	Livestock farms (dairy or red meat, not pigs or poultry) in temperate conditions equivalent to those in the UK.	Farms where grazing is optimised for nitrogen use efficiency. Bought-in feeds reduced.	Farms where grazing is not optimised for nitrogen use efficiency. No attempt to reduce bought-in feeds.	Yield (milk or meat). Nitrogen use efficiency. GHG emissions from livestock at farm scale (N2O, CO2, CH4). Life cycle GHG emissions of farm system (including imported feed)? Animal welfare.
Benchmarking of environmental, in addition to financial, performance	Farms (dairy, meat or arable) in temperate conditions equivalent to those in the UK.	Monitor, report and compare with other farms any element of environmental performance[2]	Farms without monitoring.	Total on farm energy use. Farm-scale GHG emissions. Fertilizer inputs. Pesticide inputs. Water use efficiency. Nitrogen use efficiency. Nutrient loss or runoff. Species abundance or diversity (any taxon). Habitat diversity.[3]

Integrated Pest Management is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, uses all suitable techniques and methods in as compatible a manner as possible to maintain pest populations at levels below those causing economic injury.

[2] Overlaps with monitoring farm energy use, but here a comparison with other farms (benchmarking) is required.
[3] Could include any environmental performance metric, whatever is being benchmarked.

Appendix 2: Record of consultation in Question Setting

Table A2. Record of consultation

Date of Consultation	Activity	Outcome
11th March 2015	List of interventions / outcomes of interest to the SIP Community provided by Lynn Dicks (University of Cambridge) to CEBC.	Initial questions and search terms formulated on the basis of those interventions / outcomes that were more clearly defined.
13-16th March 2015	BO/HB consultation email with Dave Chadwick & Prysor Williams (both Bangor University) re draft scoping questions prior to formal consultation with SIP Community	Additional search terms incorporated. Additional questions put to SIP Community to clarify scope of particular questions (e.g. whether clover was to be included as a cover crop and sheep as a population)
16th March 2015	10 draft scoping questions issued to SIP Community. Responses: Steve Aston (DEFRA) 21/03/2015 Lynn Dicks (University of Cambridge) 20/03/2015 Stuart Knight (NIAB) 24/03/2015	Questions amended to reflect a greater range of outcomes per intervention in response to consultation feedback. Priority areas for scoping identified to best match the study farm interventions. Additional priority (beyond initial interventions / outcomes provided) identified, question 1a (see below) added to scoping list. Additional search terms incorporated.

Appendix 3: Meta-analyses identified in broad overview for areas not scoped

Reduced till

Pittelkow CM, Liang X, Linquist BA, van Groenigen KJ, Lee J, Lundy ME, van Gestel N, Six J, Venterea RT, van Kessel C. 2015. Productivity limits and potentials of the principles of conservation agriculture. *Nature* 517, 365–368.

Ogle SM, Swan A, Paustian K. 2012. No-till management impacts on crop productivity, carbon input and soil carbon. *Agriculture, Ecosystems and Environment* 149, 37-49.

Ugarte CM, Kwon H, Andrews SS, Wander MM. 2014. A meta-analysis of soil organic matter response to soil management practices: an approach to evaluate conservation indicators. *Journal of Soil and Water Conservation* 69, 422-430.

Spurgeon *et al*. 2013. Land-use and land-management change: relationships with earthworm and fungi communities and soil structural properties. *BMC Ecology* 13, 46.

Improve animal nutrition

Zanton *et al*. 2014. Meta-analysis of lactation performance in dairy cows receiving supplementary dietary methionine sources or postruminal infusion of methionine. *Journal of Dairy Science* 97, 7085-7101.

Huhtanen P, Nousianen J. 2012. Production responses of lactating dairy cows fed silage-based diets to changes in nutrient supply. *Livestock Science* 148, 146-158.

Robinson PH. 2010. Impacts of manipulating ration metabolizable lysine and methionine levels on the performance of lactating dairy cows: a systematic review of the literature. *Livestock Science* 127, 115-126.

Dias *et al.* 2013. A meta-analysis of the effects of dietary copper, molybdenum, and sulfur on plasma and liver copper, weight gain, and feed conversion in growing-finishing cattle. *Journal of Animal Science* 91, 5714-5723.

Overton TR, Yasui T. 2014. Practical applications of trace minerals for dairy cattle. *Journal of Animal Science* 92, 416-426.

Knapp *et al.* 2014. Invited review: Enteric methane in dairy cattle production: quantifying the opportunities and impact of reducing emissions. *Journal of Dairy Science 97*, 3231-3261.

Sauvant *et al.* 2014. Relationship between CH4 and urinary outputs in ruminants fed forages: a meta-analysis of the literature. *Production Science* 54, 1423-1427.

Grainger C, Beauchemin KA. 2011. Can enteric methane emissions from ruminants be lowered without lowering their production? *Animal Feed Science and Technology* 166-167, 308-320.

Plant legumes, including peas, beans and clover

Iverson AL *et al*. 2014. Do polycultures promote win-wins or trade-offs in agricultural ecosystem services? A meta-analysis. *Journal of Applied Ecology* 51, 1593-1602.

Preissel S *et al.* 2015. Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. *Field Crops Research* 175: p. 64-79.

Optimise grazing management

McCarthy *et al*. 2011. Meta-analysis of the impact of stocking rate on the productivity of pasture-based milk production systems. *Animal* 5,784-794.

Perez-Prieto LA, Delagarde R. 2012. Meta-analysis of the effect of pregrazing pasture mass on pasture intake, milk production, and grazing behaviour of dairy cows strip-grazing temperate grasslands. *Journal of Dairy Science* 95, 5317-5330.

Appendix 4: Types of Evidence

There is a hierarchy of evidence synthesis, known as the 4S hierarchy, described by Dicks *et al*. [1]. Individual studies are synthesised into systematic reviews, which are in turn synthesised into summaries, and these feed into decision support systems for real decision-making contexts. The scoping exercise demonstrated here provides crucial information for policy makers to decide the best level of evidence synthesis in which to invest.

Systematic reviews provide a gold standard for rigorous scientific evidence synthesis of individual studies. They use *a priori* methods for the identification, appraisal and synthesis of relevant evidence to address a single carefully defined question [2]. Where sufficient quantitative data are available, a systematic review should result in a meta-analysis of the evidence to identify any trends and patterns in the data. By conducting a meta-analysis as part of a full systematic review of both the published and grey literature, many of the potential biases associated with meta-analyses relating to, for example, missing information or reviewer selection can be minimised.

Systematic maps use the same rigorous *a priori* planning and systematic search for relevant materials as a full systematic review, but can be applied to a broader less well-defined question. Rather than resulting in qualitative or quantitative description and analysis of evidence, they seek to categorise and characterise the available evidence base, highlighting knowledge gluts and gaps [2]. Most systematic maps do not explicitly describe or analyse the evidence contents, but they provide the evidence dataset either for systematic reviews of specific questions, or for summaries of the evidence they identify.

Summaries of evidence provide essential information about scientific findings to decision makers, in plain, jargon-free language and across a range of options or issues. They might comprise synopses of individual studies, collated together by subject or action, as demonstrated by Conservation Evidence synopses [*e.g.* 46]. They can also provide clear guidance, such as recommendations or categories of effectiveness for different actions, based on results of meta-analyses or expert assessment of summarised evidence. It is most appropriate to develop summaries when there is a moderate to large evidence base, including systematic reviews or meta-analyses, and a broad policy question that involves a range of possible sub-questions.

Table A3 provides approximate costings and guidance on when to develop systematic reviews, maps and summaries.

Table A3. A comparison of systematic reviews and summaries. Adapted from Dicks et al. [1].

Level of evidence synthesis	**When to develop**	**Approximate No. of questions addressed**	**Cost (£)**
Systematic Review	When multiple studies have asked similar questions and their results can be synthesised (e.g. meta-analysis) to increase explanatory power.	1 - 3	£19,000–£190,000 per review
Systematic Mapping	When multiple applications and Outcomes exist for a broader question. Maps out the distribution and abundance of evidence in studies across Population/Intervention/ Outcome combinations. Does not synthesise data.	10-20	£10,000-£100,000 per map
Summary	When multiple sources of relevant evidence exist across a very broad subject, including studies and systematic reviews. Does not synthesise data but catalogues information	59 - 457	Initial cost of collating full synopses: £45,000–£480,000 per subject. Update cost: 20% of initial cost.

Appendix 5: Workshop attendees

Table A4. Workshop attendees. Delegates who took part in the prioritisation exercise are marked with an asterisk.

Name	**Organisation**
Helen Bayliss	Centre for Evidence-based Conservation
Dave Chadwick*	Bangor University
Lynn Dicks*	University of Cambridge
Richard Gunton*	University of Leeds
Dewi Jones*	Welsh Government
Stuart Knight*	NIAB
John Lynch*	University of Nottingham
Bethan O'Leary	Centre for Evidence-based Conservation
Andrew Pullin	Centre for Evidence-based Conservation
Bill Sutherland*	University of Cambridge
Bob Webb*	University of Nottingham (RAG)
Prysor Williams*	Bangor University