



LegumES multi-actor workshop for UK-based stakeholders and actors concerned with legume production and consumption

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Alison Karley, Pietro Iannetta, Fanny Tran, Kenneth Loades, David Boldrin, Cathy Hawes (JHI)

Thomas Wilkinson, Nilar Win (ADAS)



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Executive Summary

A workshop conducted with 19 participants concerned with UK legume production, processing and consumption, carried out a series of activities to understand how the ecosystem services (ES) derived from legumes could be better recognized and valorised. Before the workshop, participants completed an online survey which highlighted that faba bean, pea and clover are most frequent food and feed legumes they encountered. The responses also showed that legumes are considered to support environmental ES and food/feed production, but their effects on other ES, particularly economic and socio-cultural outcomes, are considered variable.

During the workshop, participants discussed and formulated the list of ES and ES benefits (ESb) from legumes and voted for their top three priorities. The highest scoring ecosystem services in each category were:

- regulating and supporting ecosystem services: greenhouse gas mitigation, soil fertility and nutrient cycling, and biodiversity support;
- socio-cultural ecosystem services: ethical and traditional cultural values, healthy diets and lifestyles, recreation and tourism, and education and knowledge; and,
- provisioning ecosystem services: food and feed production by legumes and by the following crops in the rotation, and profitability.

The strengths, weaknesses, opportunities, and threats from valorising ecosystem services of legumes were assessed. Participants considered the strengths to be primarily economic and environmental (potential benefits for farm profitability, biodiversity, environmental health), while the weaknesses were mainly economic (market saturation, variability in legume performance). Business diversification, increased societal recognition, and monetising of legume ecosystem services, were viewed as the key opportunities, while competition of homegrown legumes with imported legumes, consumer misconceptions about legumes, and negative effects of the changing climate on delivering ecosystem services were regarded as threats.

When participants discussed the factors (drivers of change) determining whether the opportunities and threats occur, the drivers considered to have greatest potential impact on the valorisation of legume ecosystem services were: i) the capacity of the production system to grow and value chain to handle large volumes of legumes; ii) displacement of synthetic nitrogen fertiliser; and iii) introduction of compulsory legume production targets. Actions proposed to address these, and other, uncertainties included:

- maximising opportunities for premium markets for legume products;
- creating regulatory targets for legume production and legumes to further displace synthetic nitrogen fertilisers;
- increasing infrastructure and capacity for legume storage and processing;
- legislation to protect UK legume production and markets;
- societal education to encourage positive perceptions of legume ES and foods;
- routine inclusion of ecosystem service monitoring in legume field trials and applied research;
- develop legume varieties suited to UK pedoclimatic conditions.

Limitations were recognised in the degree to which the opinions expressed during the workshop represented the full diversity of views across the entire UK agri-food sector.

1. Introduction

1.1. Background and Objectives

Legumes are an important part of a healthy diet and healthy environment, but legume cropping and levels of consumption are still very low in Europe. Previous research has identified the practical barriers to uptake of legume cropping and legume consumption. The legumES project seeks to overcome some of these barriers by understanding how legumes can support ecosystem services and other benefits in agri-food systems. The UK multi-actor workshop asked legume stakeholders the question: *what you think are **the important benefits of legumes** in agriculture and diets and **how can we increase their value** in agri-food systems and society?*

By working with stakeholders to co-create knowledge about the ecosystem benefits of legume production and consumption, the study will understand how legumes could be integrated into national agri-food systems through existing or novel schemes, interventions or incentives. The workshop objectives were:

- **to prioritise the goals** for legume-associated ecosystem service valorisation from different stakeholder perspectives; and,
- identify likely **drivers of change affecting future scenarios for legume use** where legume ecosystem services are valorised.

The workshop findings will guide other project activities, such as prioritising ecosystem services to quantify and value in on-farm monitoring and devising actions that promote legume growing and use through education, training, and policy recommendations.

1.2. Workshop participants and methodology

1.2.1. Participants

Target participants were stakeholders involved in farming, supply chains, processing, end use, policy, and consumption of legumes and other crops. It includes those not yet involved but might become more involved (e.g., farmers not yet growing legumes).

Participants were invited to take part via emails to contacts where there are existing relationships with JHI and ADAS, providing the project information sheet (**Appendix 1**). The partners' previous work on legumes has led to them having a comprehensive network of stakeholders involved in legume production and consumption. Online searches of relevant UK organisations were conducted to identify suitable participants using public contact information. Some contacts forwarded the invitation to colleagues within their organisation.

A total of 25 participants was planned, but due to short notice cancellations (mainly through illness), there were 19 participants in total. The participants represented organisations in industry supply chain (farmers, farm equipment), value chain (processors, food and feed producers), research and education (Universities, research institutes), research transfer (applied research and advisory), and society (knowledge exchange, advocacy). Policy advisers in farming, food and the environment were not

represented (although they had been invited). In addition, there were five facilitators from JHI and ADAS.

Table 1. Number and type of participants in the UK multi-actor workshop

Stakeholder type	No. of participants
Industry - supply chain	4
Industry - value chain	3
Society	5
Policy	0
Research and education	4
Research transfer	3
Total	19

1.2.2. Methods

Participant consent was obtained by supplying a consent form and information sheet before the workshop or signing of printed sheets at the workshop. Participants were provided with a pre-event questionnaire (**Appendix 1**) asking about their perceptions of the benefits (social, economic, environmental) of legumes and which of these legume-related benefits they would prioritise in each of the following three categories:

- **Provisioning Services**, i.e., the products obtained from ecosystems such as harvested fruits and grain for food, feed, or fuel;
- **Regulating & Supporting Services**, i.e., ecosystem processes such as carbon sequestration, pollination or supporting biodiversity; and,
- **Cultural Services**, i.e., non-material benefits people obtain from ecosystems, for example from being part of traditional farming practices or culinary traditions.

The workshop began with an icebreaker to introduce participants and facilitators followed by an overview of the legumES project (by Pietro Iannetta). Afterwards, the workshop activities started with an explanation of ‘ecosystem services’ and what we mean by ‘valorising’ ecosystem services.

Before starting the first activity, an overview was given of the pre-workshop survey results (12 participants responded), showing that legumes are predominantly grown for food and feed purposes in the UK (**Table 2**), with field/faba beans and peas (dried, fresh) the dominant legume crop types. No legume crops were identified as being used for fibre and fuel purposes.

Table 2. Frequency of legume crop types identified as being used for food and feed in the UK.

Legume type	Food end use	Feed end use
Faba/field bean	9	10
*Peas (dried)	11	10
Phaseolus beans	2	-
*Peas (vining)	5	-
Chickpeas/lentils	1	-
Lupins	-	4
Clover	-	6
Vetch	-	4
Lucerne	-	5
Sainfoin	-	1
Black medic	-	1
Birds Foot Trefoil	-	1

*Participants did not always differentiate peas (dried) from vining (fresh) peas, meaning the latter group might be underestimated from the responses.

Legumes were rated as beneficial for most supporting and regulating ecosystem services and moderately beneficial for provisioning ecosystem services and socio-cultural ecosystem services, but equally likely to have neutral or variable effects (**Figure 1**). Additional ES were identified for provisioning (energy crops), regulating and supporting (greenhouse gas mitigation) and socio-cultural (human diet and health, local growing systems and economy, replacing soya feed imports, access to nature, therapeutic effects of allotment growing). Respondents rated legumes as having greatest impact on human nutrition (protein-rich food source), crop system diversity, soil health (structure, fertility) and synthetic N fertiliser reduction (**Figure 2**).

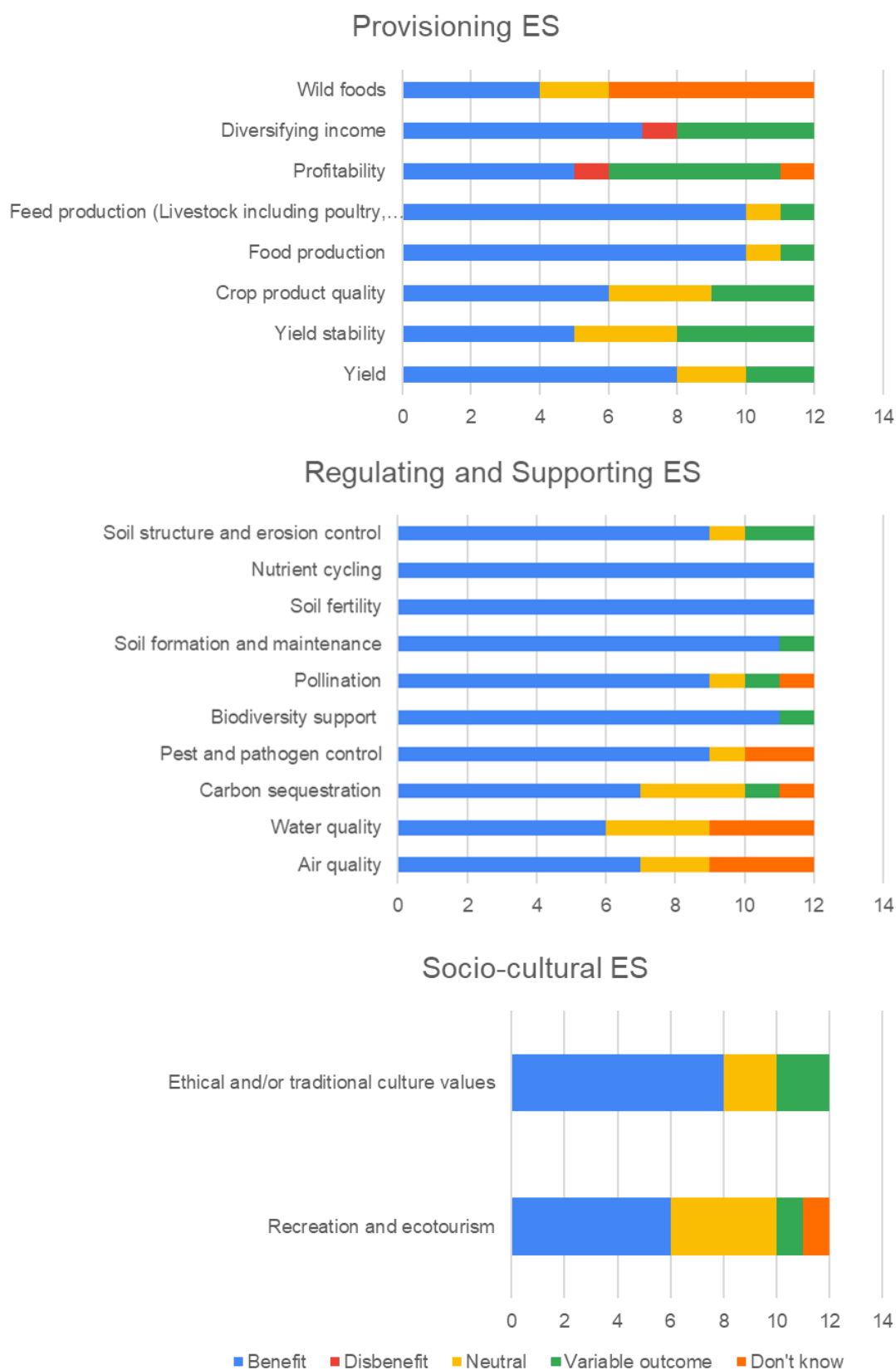


Figure 1. Pre-workshop survey results showing stakeholders perceptions of ‘regulating and supporting’ and ‘provisioning’ ES provided by legumes in UK farming and food systems.

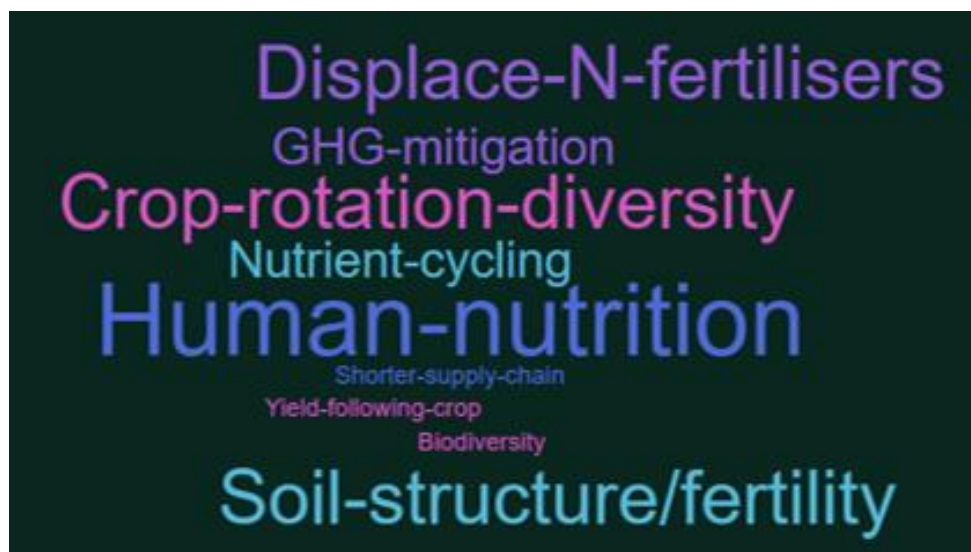


Figure 2. Pre-workshop survey results showing stakeholders perceptions of which legume ES or outcomes are most impactful in UK farming and food systems. Larger word size indicates a higher number of respondents choosing the outcome.

The first activity (~45 min) focussed on discussing the ES and benefits of legumes. Participants were divided into four groups, and each group discussed the list of ES and ES benefits (referred to as ES/ESb) grouped from the three categories presented in the pre-event survey (i.e., provisioning, regulating & supporting, socio-cultural), adding further Ecosystem Services/Ecosystem Services benefits (ES/ESb) that were missing. The ES/ESb were discussed for their outcomes (benefit, disbenefit, neutral, variable, don't know) and then participants were asked to vote for their top three ES/ESb priorities using dot stickers. This process was repeated twice so that each group scored ES and benefits in each of the three categories.

The second activity (~1.5 h) was a SWOT analysis, where participants were asked: *What are the strengths, weaknesses, opportunities and threats to valorising the ecosystem benefits of legume production/consumption systems?* In the same groups as activity 1, participants were first asked to discuss the strengths and weaknesses of valorising ecosystem benefits associated with legume production/consumption (i.e., the internal attributes of agri-food systems that favour or disfavour valorisation of legume ES/ESb). The participants wrote their ideas onto sticky notes and placed onto a poster board, one for each category (strengths, weaknesses). The process was repeated for identifying opportunities for, and threats to, valorising the ecosystem benefits of legume production/consumption (i.e., external attributes that might favour or prevent ecosystem service valorisation).

The third activity (~45 min) involved assessing the drivers of change affecting ecosystem service valorisation. In the break, facilitators assessed the Opportunities and Threats characterised in the previous activity and assigned them to one of the five STEEP categories – Society, Technology, Economic, Environment, Policy: the post-it notes were transferred to one of five new poster sheets each labelled with one of the STEEP headings. After the break, participants returned to their four groups and asked to consider: *What are the drivers of change affecting the impact of valorising the ecosystem benefits of legume production/consumption systems?* At each of the five poster boards, they examined the sticky notes and added any other drivers of change that were missing. They discussed within the group which drivers have most impact and which drivers are most uncertain to happen in

the future, then voted individually for the drivers that were likely to have greatest impact on the valorisation of legume ES/ESb, and the drivers that were most uncertain to happen. Each person had one vote per category for impact and one vote per category for uncertainty, and those drivers receiving high scores for both impact and uncertainty were considered most 'influential' on ES valorisation.

Prior to closing the workshop, it was explained that the workshop results will be summarised and combined with results from 11 other workshops in different European countries, and that both reports will be shared with participants. The results and key messages from this research will be disseminated to audiences in farming, policy, industry, education and training. The results will form the basis of recommended actions in policy, industry and society aiming to promote legume growing and use in the UK by valorising ES/ESb from legumes.

2. Outputs of Discussion

2.1. Ecosystem Function Prioritisation



Participants expanded the list of ES/ESb (see below), then voted for their top three priorities in each category. Participants prioritised the environmental services of nitrogen-provision from legumes, which both provides soil nutrients and mitigates the carbon footprint of synthetic fertilisers, and supply of resources to support biodiversity. The contribution of legumes to dietary health, knowledge, traditional cultural and enviro-tourism were also prioritised as socio-cultural services. The production of food, feed and profit, directly from legumes and from other crops in the rotation, were highly prioritised as economic services.

2.1.1. Environmental services and benefits

Greenhouse gas mitigation, soil fertility and nutrient cycling, and biodiversity support were the highest scoring ES from legumes in the regulating and supporting category. Positive effects of legumes on water quality and soil structure, erosion and biodiversity were also prioritised.

Ecosystem Service / Ecosystem Service benefits	
Nutrient cycling	8
Greenhouse Gas mitigation	8
Soil fertility	7
Biodiversity support	6
Water quality	5
Soil structure and erosion control	5
Pest and pathogen control	4
Soil quality and biodiversity	4
IPM	3
Air quality	2
Carbon sequestration	2
Soil formation and maintenance	2
Pollination	1
Water regulation & storage	1
Pesticide use	0
Blackgrass control	0

2.1.2. Socio-cultural services and benefits

Ethical and traditional cultural values (e.g., local food growing, access to nature), healthy diets and lifestyles, recreation and tourism, and education and knowledge were the highest scoring ES in the socio-cultural category. The important role of legumes in providing landscape beauty and contributing to attractive, tasty foods was also acknowledged.

Ecosystem Service / Ecosystem Service benefits	
Ethical and/or traditional culture values	11
Healthy diet, lifestyle, wellbeing	11
Recreation and ecotourism	8
Education & knowledge	7
Landscape beauty	5
Taste/pleasure/palate	5
Blended foods	5
Vegan and vegetarian diets	3
Modern food cultural values	2
Pricing and access	1
Cultural history (Gregor Mendell)	0
Cultural identity	0
Seasonality	0

2.1.3. Economic services and benefits

Food and feed production by legumes and following crops in the rotation, and profitability, were the highest scoring ES and benefits of legumes in the provisioning category. The contribution of legumes to crop yield and income diversification was also acknowledged.

Ecosystem Service / Ecosystem Service benefits	
Food production	11
Feed production (Livestock including poultry, Aquaculture)	10
Profitability	8
Rotational value and profitability	5
Yield	4
Diversifying income	4
Yield stability	3
IPM	3
Crop product quality	2
Food (rotation)	2
Sustainable Farm Incentive	1
Feed (rotation)	1
Co-products	1
Energy crops	1
Cropping diversity	1
Wild foods	0
Industrial feedstocks	0
Genetic diversity	0
Food for wildlife	0
Textiles	0

2.2. SWOT Analysis of the strengths and weaknesses of current legume production systems and ES/ESb

2.2.1. SWOT Analysis

A summary of the key findings from analysing the strengths, weaknesses, opportunities and threats associated with valorising the ES and benefits of legume production and consumption is shown in **Table 3**. The full list is provided in **Appendix 2**.



The **Strengths** of valorising legume ES/ESb were primarily economic and environmental. Legume valorisation could create benefits for farm profitability (reduced costs, increased income) and improve biodiversity and environmental health, which could be supported by enabling capacities, technologies and policies. Nutritional health and wellbeing were also strengths, which could be supported by improved public education.

The **Weaknesses** of valorising legume ES/ESb were mainly economic, associated with the potential for market saturation (from homegrown and imported legumes) due to greater legume production if consumer demand rises, leading to lower prices (although rising prices due to an inability to meet consumer demand is also possible). This could be exacerbated by poor consumer awareness of the environmental footprint of imported legumes (i.e. selecting these over homegrown legumes), and how to prepare legumes (which has the potential to reduce consumer approval and acceptance). Variability in achieving legume ES/ESb, linked with unpredictable weather and complex agronomic requirements, might inadvertently encourage unsuitable legume practices and deter farmers from growing legumes. The complexities of monitoring legume ES/ESb and fitting incentives within existing schemes and land ownership arrangements might limit progress in enabling policies.



The **Opportunities** from valorising legume ES/ESb were mainly societal and economic, associated with business diversification from legume markets and value chains, including legume byproducts and processed products, and monetising ES/ESb, encouraged by societal recognition of human and environmental health benefits and consumer demand for food and associated goods in the public and private sector. This could create a favourable policy environment, if policies recognise and differentiate the different types of legumes and ES they provide.

The **Threats** from valorising legume ES/ESb were mainly economic, resulting from competition with commodities on global markets, especially if legume prices rise and other protein or nonprotein crops therefore become cheaper and preferred by consumers and feed merchants. Consumer misunderstanding could arise from misconceptions, hostility to dietary 'fads', concerns about allergens, or disinformation. This might be exacerbated by negative effects of climate change on legume ES/ESb or agro-technical complexities associated with legume-rich cropping systems. Limited policy commitments over long timescales could undermine government investment in incentive schemes.

Table 3. The strengths, weakness, opportunities, and threats presented by valorising the ecosystem benefits of legume production/consumption.

Strengths	Weakness
<p>Economic (n=11): improved income from reduced input costs, access to incentives, on-farm feed production, market opportunities and higher premiums</p> <p>Environment (n=10): Increased use of IPM, improved biodiversity, reduced pollution and better air/water/soil quality</p> <p>Society (n=5): Improved mental and physical health from better nutrition and food security and public understanding of legumes</p> <p>Technology (n=1): investment in legume variety development</p> <p>Policy (n=1): Policy environment conducive to ES/ESb valorisation</p>	<p>Economic (n=8): Legume prices fall (market saturation, cheaper imports, alternative protein sources), high investment cost of processing infrastructure, job losses in existing supply chains, ES value not realised</p> <p>Society (n=6): poor consumer awareness and understanding (about legume sources, food preparation, balanced nutrition), resistance to funding agriculture, lowers public acceptance of legumes</p> <p>Environment (n=5): legume benefits compromised (variable ES/ESb, pest & disease issues, climate change), increased environmental damage (greater imports, inappropriate practices)</p> <p>Policy (n=5): existing environmental schemes compromised (trade-offs between ES), complex monitoring required, adds complexity to tenancy agreements, exacerbates food insecurity abroad</p> <p>Technology (n=0):</p>
Opportunities	Threats
<p>Society (n=12): Increased legume demand (education, promotion) and connection to food producers, better food traceability, supports public procurement, local food outlets and enviro-tourism</p> <p>Economic (n=9): job creation and investment (legume R&D, new value chains, byproducts), ES as saleable products (N fixation), business diversification, product premiums</p> <p>Environment (n=2): Increased rotation diversity, reduced input dependency, larger areas of legumes</p> <p>Policy (n=1): greater industry and consumer support for enabling policies</p> <p>Technology (n=1): new biogas source</p>	<p>Economic (n=9): Outcompeted by global commodity markets (legume, nonlegume), costly food regulation requirements, lack of seed/varieties, cannot meet quality requirements or generate market demand, resistance from big players and vested interests</p> <p>Society (n=5): consumer misconceptions or hostility or lack of trust, social media disinformation, processing industry resistance (e.g. allergens)</p> <p>Policy (n=5): lack of continuity in policy or investment in subsidies, political resistance (nanny state-ism), half-hearted policy support</p> <p>Environment (n=2): climate change compromises legume benefits</p> <p>Technology (n=2): agronomically complex crop rotations, existing quantitative technologies inadequate (carbon calculators)</p>

2.3. Drivers of Change

The full list of the potential ‘drivers of change’ identified from the SWOT analysis (opportunities and threats) and expanded through group discussion is shown in **Appendix 3**. The drivers voted as having greatest potential impact on valorisation of ES/ESb from legumes were as follows:

- **Technology:** Access to infrastructure to handle large volumes of legumes/pulses (n=13 votes);

- **Environment:** Changing use of synthetic N fertilisers (n=10 votes);
- **Policy:** Introduction of policies for ensuring a minimum level of legume production, whether through compulsory (n=9 votes) or voluntary (n=6 votes) measures;
- **Social:** Changing public perception about legumes (n=5 votes), facilitated by education or tools that increase consumption of homegrown legumes (n=5 votes);
- **Economic:** Global commodity or financial markets affecting legume prices (n=5 votes).

This exercise highlighted that capacity to handle large legume volumes, the displacement of synthetic nitrogen fertilisers, and the use of policy to set targets for legume production are key factors in promoting the valorisation of ES from legumes.

In some cases, the drivers considered most impactful were also identified as having greatest uncertainty about whether they would happen (**Table 4**). For example, changing public perception about legumes (society), global commodity markets affecting legume prices (economic), and policies supporting legume production (policy) were considered highly uncertain. These drivers of change are, therefore, deemed 'critical uncertainties' and we need to consider a variety of potential outcomes for these drivers (negative and positive) when predicting future scenarios affecting legume ES/ESb valorisation.

Other critical uncertainties included: public procurement actions to increase legume consumption and changes in population health (society); robust valorisation data, business diversification and positive feedback along the supply and value chains (economic); and lack of political will (policy). Technological critical uncertainties were associated with abilities to optimize legume growing and processing and to collect accurate ES data. Environmental critical uncertainties related to variability in productivity due to the changing climate, pest and disease issues, and limitations imposed by crop breeding progress.

Table 4. STEEP drivers of change ranked as having significant impact on valorising the ES/ESb of legumes and considered uncertain to happen (i.e., 'critical uncertainties').

STEEP Category	Drivers considered as 'critical uncertainties' in each STEEP category
Society	<ul style="list-style-type: none"> • Improved population health • Creating value through public procurement • Changing public perception about legumes
Technology	<ul style="list-style-type: none"> • Carbon calculators not supporting accurate ES data collection • Optimising of legume harvesting and processing technologies
Environment	<ul style="list-style-type: none"> • Limits to what legume breeding can achieve for environmental resilience • Legume pest and disease build up and yield losses/environmental damage • Rapid climate change invalidating existing data and discrediting conclusions
Economic	<ul style="list-style-type: none"> • Multiplication effect of ES valorisation on crop area, ES values and supportive supply chain and policy • Business diversification opportunities • Reduced legume value due to global commodity market prices • Lack of consensus data
Policy	<ul style="list-style-type: none"> • Lack of coherent policy to promote support / safeguard legume production and subsequent ES co-benefit • Policies to ensure minimum level of legume production for agro-ecological system resilience • Lack of political support to accept valorisation output is either necessary, accurate, meaningful

Summary

The ES and ES benefits from legumes ranked highly by participants were: productivity and profitability (economic); environmental improvement and climate mitigation; and socio-cultural values spanning diets, lifestyles, recreation, and education. This prioritisation can be used to guide the selection of ES and ES benefits to monitor in research and on-farm trials of legumes.

The main disbenefits of legumes were related to income risk, for example from legumes achieving their yield and market value potential (profitability), especially when displacing other crop types (diversification). This finding suggests that research and innovation should focus on increasing the value of grain to be traded, for example by targeting premium markets/value chains, or that their suitability (processing etc.) for use in different markets should be prioritised to increase demand and value.

Economic factors dominated the analysis of strengths, weaknesses, opportunities and threats from valorising ES and benefits of legumes, although environmental strengths and social opportunities also scored highly. This emphasises the need to understand the financial costs/benefits of ES from legumes but also highlights the importance of gathering data to evidence the environmental benefits and of engaging society in understanding legume ES to maximise the economic and environmental outcomes from legume growing and consumption.

The factors considered as having greatest impact on achieving the valorisation of legume ES and benefits were: i) infrastructure to increase the scale of production and processing of legumes in the UK; ii) environmental motivations to reduce the use of synthetic nitrogen fertilisers; and iii) setting of policy targets (voluntary or compulsory) to ensure a minimum level of legume production is reached. In the UK, peas and field beans are established legume crops, and the main opportunity to scale production of these crops is as ingredient sources. Pulses that are more attractive to consumers, such as lentils, chickpeas and types of *Phaseolus* bean, suffer from issues in scaling of production because there are neither suitable varieties ideal for the UK climate nor scales of production of reliable yield or quality that can displace imports at commercially acceptable prices.

Other factors included global market impacts on legume prices and consumer perceptions about legumes, highlighting the need for policies to control or mitigate the impacts of global markets and to improve public awareness of legume-associated benefits and opportunities. Policies and actions to promote the ES from legumes should distinguish between legumes grown for feed and/or environmental reasons (e.g. forage, companion crops) and legumes grown for food (fresh, dried pulses) to ensure the goal is met and avoid unintended outcomes (e.g. favouring forage production over food production).

Some of these factors were highlighted as critical uncertainties in future scenarios for valorising legume ES and benefits, for example, through the impacts of changing consumer perceptions about legumes, global events affecting legume markets, and changing environmental priorities. Political will and the development of supporting technologies and infrastructure were also critically uncertain.

The workshop was attended by 19 participants representing commercial interests (supply and value chains), research and research transfer, and society; policy representatives were invited but unable to attend. The information summarised in this report represents the participants' opinions based on their own experiences, which might not reflect the diversity of views held across the UK agri-food sector. It is also recognised that negative views about the role of legumes in UK agri-food systems were

infrequent in the workshop. These points highlight limitations in the degree to which the workshop opinions can be translated across the UK agri-food sector. Actions are proposed (below) in response to the workshop findings and to address the workshop limitations.

What action should be taken?	By whom?	To achieve which outcome?
Include priority ES in legume trials	Researchers	Maximise the evidence base for legume-associated ES (to allow valorisation)
Investigate opportunities for premium markets/value chains	Commercial and research innovators	Reduce the financial risk and increase the economic return on legume production and ES
Present workshop results to policy representatives and engage in discussion	Researchers	Ensure the constraints on valorising UK legumes are understood and mitigations are incorporated into relevant legislation
Further regulate synthetic N fertiliser use / promote legumes as alternatives	Policy	Encourage legume growing as an alternative to synthetic N fertilisers
Targets for legume production (food)	Policy	Increase UK legume production, reduce legume imports
Consumer education about legume ES and value	Research, policy, knowledge brokers	Encourage positive consumer perceptions about legume ES, promote legume food choices
Identify / develop new legume varieties suited to UK climate	Research, commercial companies	Widen the choice and availability of UK-grown legumes for consumers
Increase infrastructure and capacities for legume storage and processing	Policy, commercial companies	Ensure greater volumes of legume production can be handled effectively and reach their markets
Policy instruments to protect UK legume production	Policy	Mitigate competition from global markets and protect UK legume markets from geopolitical events

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Disclaimer

Views and opinions expressed in this report are those of the author(s) and workshop participants only and do not necessarily reflect those of the European Union, UK Research, and Innovation (UKRI), European Research Executive Agency (REA) or Swiss State Secretariat for Education, Research, and Innovation (SERI). Neither the European Union nor any other granting authority can be held responsible for them.

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Appendix 1 Pre-event information sheet and survey

How can we increase the value of legume ecosystem benefits in UK agri-food systems.

About this research.

Legumes are an important part of a healthy diet and healthy environment, but legume cropping and levels of consumption are still very low in the UK. This research is about consulting stakeholders involved in agri-food systems to find out what they consider to be the important benefits of legumes and how their value could be increased in agri-food systems and society.

The project is carried out by Alison Karley, Pietro Iannetta and Fanny Tran, scientists at the James Hutton Institute, and Thomas Wilkinson (ADAS). The project is funded by UKRI.

Why should I participate?

Your participation is very valuable for this research. This research will help with understanding which benefits of legumes, whether environmental, economic or societal, are most valued by people involved in agri-food systems. The information you provide will be used to determine how legume benefits can be prioritised for monitoring and valorisation in current and future UK agri-food systems. The results will be communicated widely to inform work in policy, agri-food industries and research.

Research Approach.

This research consists of a one-day workshop. A short (10 minute) survey will be supplied prior to attending the workshop to gather your preliminary ideas of legume benefits, and afterwards you will have the opportunity to provide feedback on the workshop results (the report will be shared by email). The workshop timetable and activities are shown below.

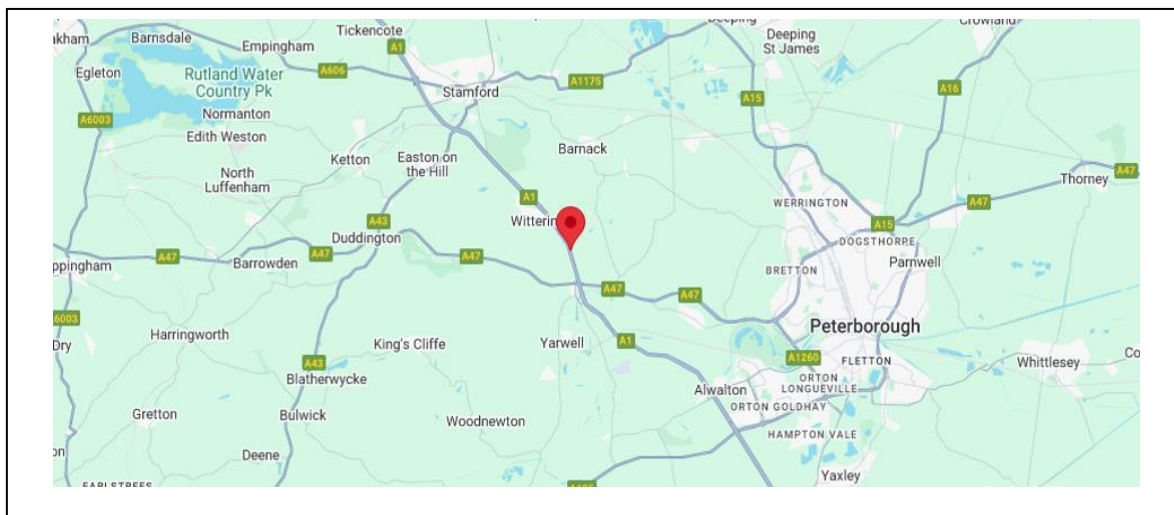
10 am	Refreshments
10.30 am	Welcome: introduce the workshop aims and activities, and answer questions
11 am	Activity 1: identify ecosystem benefits of legumes through discussion and using visual aids; and prioritise these benefits
12 pm	Lunch
1 pm	Activity 2: assess Strengths, Weaknesses, Opportunities and Threats of valorising legume benefits through discussion and using interactive poster boards
2.30 pm	Refreshment break
3 pm	Activity 3: Identify the Opportunities and Threats that could have most impact or that are most uncertain to happen through discussion and participant ranking
4 pm	Summary and next steps: Explain how the workshop results will be used and the timeline, and opportunities for further involvement

4.30 pm

Event close

Practical information

The event will take place on **Thursday 16th January 2025** at the headquarters of the Processors and Growers Research Organisation (PGRO) near Peterborough.



The Research Station **Tel: +44(0) 1780 782585**

Great North Road

Thornhaugh

Peterborough

PE8 6HJ

Find the venue using what3words: belonging.crumb.swoop

Directions by train. The nearest mainline station is Peterborough. PGRO is approx. 20 min by taxi. There is a taxi rank outside the station entrance and a private hire firm is based at the station. Peterborough Taxis: 01733 777 000

Directions by car. PGRO is located on the southbound carriageway of the A1 at Thornhaugh, approximately 6 miles from Peterborough and 4 miles south of Stamford, Lincolnshire. There is plenty of car parking space at PGRO.

A1 South Bound: Turn off the A1 carriageway directly into the main entrance. Turn immediately left again and the site is clearly sign posted.

A1 Northbound: Turn off at the A47 junction, pass over the A1 and head towards Peterborough, after approx. 200m turn left into the Sacrewell Farm Centre entrance and follow the PGRO signs.

West Bound: A47 From the direction of Peterborough head towards the A1 junction, at the first roundabout take the 2nd exit and come back on yourself, after approx. 200m turn into the Sacrewell Farm Centre entrance on the left. Follow the PGRO signs turning right immediately before joining the A1 Southbound.

East Bound: A47 Travelling from the direction of Leicester pass over the A1. Continue towards Peterborough and after approx. 200m turn into the Sacrewell Farm Centre entrance on the left. Follow the PGRO signs turning right immediately before joining the A1 Southbound

Most sat nav's when using the postcode will take you to the village of Thornhaugh which is across the two dual carriageways of the A1. To avoid an eight-mile detour follow the directions as above.

Data analysis and confidentiality: what will happen to the data I provide?

All data you provide will be treated as confidential. Only Hutton researchers will have access to raw data. It will not be shared and to avoid unintended disclosure, confidential data will be imported to password-protected electronic files, stored on a secure network server.

All responses will be anonymised before data analysis and nothing in the research outputs will make you identifiable. The data from this workshop will be summarised in a workshop report, which will be shared with you for feedback. The data from this workshop will be combined with datasets from 11 other workshops conducted in European countries for a meta-analysis and synthesis of the findings. Individual participant responses will not be identifiable in the workshop report or in the meta-analysis/synthesis or any other research outputs. We will keep the anonymised data for a period of 10 years after the end of the project as stipulated by the funding body. When published, the anonymised dataset will be assigned a licence that maximises accessibility and re-use, as required by the funder.

Your personal data will be stored in a password-protected file and will only be shared between Hutton and ADAS for the purposes of workshop organisation. It will be maintained for a maximum period of three years and then destroyed. Further information about the James Hutton Institute's privacy notice can be found here: <https://www.hutton.ac.uk/privacy-notice/>.

Do I have to take part?

Your participation is voluntary, and you can withdraw at any time. If you would like to withdraw, please contact Alison.Karley@hutton.ac.uk. The data you provide will be withdrawn before analysis, but once anonymised and/or published it cannot be withdrawn.

There are no incentives for participating in this research. We will reimburse travel costs incurred by attending the workshop and we will provide refreshments and food.

Are there any possible risks from taking part?

The risks of disclosing confidential information provided are minimal as the research does not collect sensitive personal information and participants are requested not to share the views of other participants outside the workshop. Any confidential information collected during the workshop will be anonymised. Mitigations will be put in place regarding any health and safety risks identified in a risk assessment of the venue. Please inform us if you have specific physical, mental or dietary health needs that we should accommodate.

Further questions and who to contact.

If you have any questions, please do not hesitate to contact us:

Alison Karley alison.karley@hutton.ac.uk

Pre-workshop online questionnaire to prioritise ecosystem functions from legumes

1. Country (scroll down and click)
2. Region (scroll down and click)
3. Farmer, researcher, advisor, industry, other (choose one perspective)
4. Which legume crops are grown in your country/region for
 - Food:
 - Feed:
 - Fibre:
 - Fuel:

Legumes include crops grown for fresh green pods or grain, or dried grain (faba/field beans, peas, soybean, lupin, chickpea, lentil, common beans, cowpea, grass pea, etc.), as cover/forage crops (vetch, clovers, lucerne, etc.). Also, species of semi-natural systems including woody species (such as gorse, and broom), and other wild legumes (e.g., *Astragalus*, *Oxytropis*).

5. In your experience, how do stakeholders value the impact of legumes on the following: [using a rating scale: benefit, disbenefit, neutral, or variable outcome, allow respondents to select all that apply in the list below]

Provisioning

- Yield
- Yield stability
- Crop product quality
- Food production
- Feed production (Livestock including poultry, Aquaculture)
- Profitability
- Diversifying income
- Wild foods
- Allow other options to be added and scored by the respondent

Regulating and supporting

- Air quality
- Water quality
- Carbon sequestration
- Pest and pathogen control
- Biodiversity support
- Pollination
- Soil formation and maintenance
- Soil fertility
- Nutrient cycling
- Soil structure and erosion control
- Allow other options to be added and scored by the respondent

Cultural

- Recreation and ecotourism
 - Ethical and/or traditional culture values
 - Allow other options to be added and scored by the respondent
 - Please explain your selections [free text]
6. Which of these legume benefits are most important to quantify and how would you recommend their value is recognised? (e.g. through product labelling, environmental incentive schemes, or other means) [free text response]

Appendix 2 SWOT Analysis

Table S1. SWOT analysis: Strengths from valorising the ES/ESb from legumes

Society	Technology	Economy	Environment	Policy
Less pressure on NHS from diet and health benefits	Greater investment in new variety development	Increased domestic production and self-sufficiency	Reduced water pollution and clean-up costs from improved water quality	Better policy environment (quantifying value, marketisation)
Improved mental health and societal engagement from enviro-tourism and increased recreation		Local & high-quality animal feeds	Reduced respiratory illness from improved air quality	
Better protein and food security and resilience		Improved livestock enterprises and local economies	Lower carbon footprint incentivises supply chains	
Increased nutritional diversity		Reduced synthetic input costs and reduced need for farm cash flow, allows other costs to be prioritised better	Reduced N loss incentivises policy measures on N.	
Better education in society (growers, markets, policy)		Higher premiums associated with quality valorisation	More uptake from better awareness of soil quality value	
		Increased side stream production and market opportunities.	Increase break crop frequency	
		Increased profitability from well-funded legume environmental options.	Farmer willingness to support biodiversity	
		Reduced global footprint from imports, improving the reputation of farming/farmers	Increased landscape beauty	

Society	Technology	Economy	Environment	Policy
		Entrepreneurship innovation	Increased biodiversity from creating habitats for invertebrates	
		Legumes compete with ultra-processed meat-free products	Increased use of integrated pest management	
		Increased growing of less favourable legumes		

Table S2. SWOT analysis: Weaknesses from valorising the ES/ESb from legumes

Society	Technology	Economy	Environment	Policy
Potential dietary imbalance if public messaging is not clear (e.g. eating less of nonlegume food groups)		High demand and more legume growing could saturate markets and reduce legume prices, plus competition from imports, leading to no financial benefit to farmers	Increased incidence of legume disease and pests, and greater use of legume crop protection products	ES of other crops might need to be valorised for comparison with legumes; could identify ES trade-offs and feedbacks
Public might prefer public funds to support the NHS rather than agriculture		If legume prices increase, feed companies might switch to other protein sources (rapemeal, soya)	Increased environmental footprint from imported legumes increasing to meet consumer demand, including increased deforestation	Legume demand from richer countries deplete production from poorer countries, increasing food security inequalities
Bad press might lead to even lower public acceptance of legumes		Increased legume growing competes with other crops (e.g. cereals) and land uses	Variable environmental benefits of legumes could happen in some years	Risk of assuming that ES benefits are robust, more complex monitoring might be needed
Adding value to legume products might reduce affordability to some parts of society		Costs associated with additional legume storage capacity	Changing climate might become less suited to legume production (e.g. shorter growth period)	Tenant farmers might have cropping rules added to their tenancy agreements

Society	Technology	Economy	Environment	Policy
Constraints of consumer awareness about legume preparation and homegrown legume types (vs imports) might restrict legume markets		Payments for ES might lead to farmer financial losses if baseline ES levels are not achieved	Incentives might encourage inappropriate practices	Existing environmental incentive schemes might be weakened (e.g. legume fallows)
Consumer concerns around flatulence		Low ES valuation or over-valuation might disincentivise legume growing		
		Costs associated with establishing processing pipelines for multiple markets and each legume type, and avoiding cross-contamination		
		Shortening supply chains with homegrown legumes might lead to loss of jobs and economies of scale in existing supply chains		

Table S3. SWOT analysis: Opportunities from valorising the ES/ESb from legumes

Society	Technology	Economy	Environment	Policy
Encourages promotion of homegrown legume products	Production of biogas from legumes	Creation of novel products or value chains	Better/more diverse crop rotations and less dependency on imported inputs (fertiliser)	Improved value awareness increases policy support and grower enthusiasm
Encourages mainstream education on healthy food		More investment in R&D of minor crops	Positive feedbacks from greater awareness and valuing of ES leading to larger areas grown and more ES achieved	
Potential for cross-cultural learning and cooking, breaking down barriers for minor crops as foods		More jobs in legume processing and side-stream processing and ancillary industries		

Society	Technology	Economy	Environment	Policy
Better food/feed traceability and assurance		More demand encourages investment in regional processing infrastructure and job creation		
More water sports tourism from better water quality		N fixation could be quantified and monetised		
More short supply chain restaurants		Greater industry collaboration to reduce costs and create value		
Uptake into schools, universities and public sector workplaces through public procurement		Potential for better representation and marketing of livestock products and to add premiums		
New training opportunities for agronomists and farmers		Business diversification from new markets		
Higher prices of legumes might be offset by public understanding and communication of health benefits – ‘selling the story’ and establishing a new norm		More support and enthusiasm from growers based on better realisation of the agronomic value of legumes		
Increased food security/resilience from greater crop diversity				
Legumes as a vehicle to communicate sustainability in agriculture				
Improved population health				

Table S4. SWOT analysis: Threats from valorising the ES/ESb from legumes

Society	Technology	Economy	Environment	Policy
Public misconception about legume benefits/disbenefits (e.g. European grown soya seen as bad)	New legume-based systems require more complex agchem input recommendations	Subsidies for energy crops compete for area devoted to legumes, with nitrogenous residues dumped into protein markets	Extreme weather events and limited capacity for plant breeding to address yield gaps	Conflicting incentive schemes for crops other than legumes
Consumer resistance to legumes from hostility to veganism	Carbon calculators do not support collection of accurate local data on ES	Low global commodity prices prevent UK farmer uptake	Changing climate reduces viability of legume-based systems and/or affects ES data collection	Reduced government investment in environmental schemes
Negative or fake information about legumes on social media		Lack of end market for legume produce		Lack of continuity in government agendas and schemes
Resistance from industry to process legumes due to allergen concerns		Lack of multiplied seed or appropriate varieties		Policy held back by fear of 'nanny state' resistance from the public
Lack of trust in protein content, lack of consensus due to lack of data		Legume products not able to meet market quality requirements		Lack of coherent policy to support/safeguard legume production and accept the accuracy and need for ES valorisation
		Expensive and onerous food regulation requirements		
		Increased legume imports due to farmer reticence for homegrown crops with variable yield		
		Saturation of global market by soya		
		Vested interests which might be negatively impacted by increased		

		legume production, acting to divert attention		
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Appendix 3 Scoring the STEEP drivers of change

Social	Impact	Uncertainty
Creating an understanding to establish a norm.		
Improved population health.	3	1
Understanding and communicating the health values supports uptake and contradiction of high price [unclear handwriting].		
More opportunities or health tool to promote home grown legume products.	5	
Selling the story of legumes outside the farming community.	1	
Opportunity for mainstream cooking education esp. on healthy food.	2	
Potential for cross cultural learning/cooking à vibrant English food culture.	1	
Increased food resilience through increased crop diversity.		
Establishing a legume supply chain will build communities.		
Breaking down barriers between minority groups through food. Typically ethnic groups produce better/tastier food.		
Creating value for the supply chain for public procurement and uptake into schools, universities and public sector workplace.	1	1
Legumes as a vehicle to communicate sustainability in agriculture.		
Public facing engagement for the wider industry and help understand.		
New training opportunity for agronomists and farm advisors.		
Choosing home-grown gives citizens opportunity to exercise agency to influence the environmental		
Health benefits "at home".		
Politics of food. Changes in global market leading to starvation. Rich countries buying food at prices, poorer countries cannot afford.		
Consumer resistance including hostility to vegan and ignorance.		3
Reticence to use more complicated agchem impact recommendations, if they differ based on previous crop type.		
Complex monitoring required of the service.		
Negative/fake social media feedback on legume ecosystems (& sci + trade press).		3
Change in public perception of the value legumes.	5	6
Miseducation/Misdirected learning around eating legumes.		1
Trust by farmers of protein content.		1
Vested interests which might be negatively impacted by increased legume production, acting to divert attention.		
Public perception and potential misinformation on the potential benefits/disbenefits of legume systems, e.g., European grown soya.		
Poor quantification of the service, or poor understanding of how it differs from site to site, or context to context (e.g., between crop species).		1
Farmer resistance.		

Technology	Impact	Uncertainty
Lack of infrastructure to deal with large quantities of pulses/legumes.	13	

Soya/Peanut/Lupin allergenicity <ul style="list-style-type: none"> resistance to uptake resistance from industry to handle crop 		1
Production of more biogas from legumes		1
More knowledge on non-nutrition aspects of food/feed + role in 'one' or 'global' health.		1
AI to design and optimise legume-based rotations.		1
Carbon calculator not supporting the development of accurate, localised data.	4	5
Development of tech to biorefine whole crops.		1
Optimisation of harvesting +Sorting technology	2	5
Remote sensing, e.g., water + soil qualities.		2
Co-ops + Sharing of technology, e.g., sorting + harvesting	2	

Environmental	Impact	Uncertainty
Initial starting point for soil health.		1
Extreme weather / Climax change.		1
Limits to how/whether plant-breeding can address this.	3	3
Legume pest and disease build up - lead to yield decrease/environmental/ecosystem damage.	4	3
Climate change reducing the viability of legume-based ecosystem.		6
Weather patterns interrupting standard growing cycles and data collection.		1
Value could be overestimated and damaged by climate uncertainty.		1
Benefits of Syn N fertilise reduction.	10	
Benefits to Soil, and water qualities.		1
Sudden and rapid climate change invalidating conclusions at the time of publication and discrediting outcomes	1	2

Economics	Impact	Uncertainty
Quantifying the value of carbon reduction potential within the supply chain.		
Valuing positive ES leads to policy and growers and supply chain support = multiplication of crop areas and multiplication of the ES values realised as a result. A positive chain reaction.	1	1
Supply chain resilience.	1	1
Short supply chain and reduced imports (carbon footprint ↓ job losses in value chain? reduced capacity for high volume products (economy of scale).	2	
Tenant farmers have cropping rules added into their tenancy agreements.		
Creation of novel products or value chains e.g., vegan diets, novel legumes.		
More market share & legumes = more research funding available or expertise development for these minor crops.		1
More demand might give opportunity for more investment for regional processing/capacity/facilities = jobs and infrastructure.		2

Economics	Impact	Uncertainty
Increasing legume production gives opportunities for diversification into new by-products leading to more business opportunities.	1	1
Better crop rotations, less dependency on imports. Less reliance on imported/artificial nitrogen fertiliser.	1	
Better water quality = more water sports tourism activities.		
Opportunity to quantify/monetise nitrogen fixation.		7
If we valorise: more diverse crop production = more opportunities for short chain restaurants.		
Industry collaboration to reduce costs and create value.		
Representation and marketing of livestock production – add premiums and standard products.		
New business diversification as new markets develop.		1
Legumes offer opportunity to increase profitability.	2	
Better realisation of agronomic value leading to more support and enthusiasm from growers.		
Energy crops: heavy subsidies make them more attractive than legumes, take away continental acreage and nitrogenous residues are dumped into protein markets.		
Low commodity prices prevent UK farmer uptake.	1	
World commodity/financial markets reducing the value of legumes.	5	2
Lack of end market for produce.	1	
Lack of multiplied seed available and varieties.		
Produced pulses not being able to meet market quality requirements.	1	
SFI competing with farmers for growing legumes. Hope income security through SFI than growing a crop that might have a low yield.		1
SFI increasing legume imports due to reticence for UK farmers to grow crops due to risk of non-consistent yield.		
Other countries diversity previously exported legumes and displace other UK markets (e.g. produce meat using previously exported soya and exported meat).		
Saturation of the global market by soya.		
Lack of data (consensus).	1	1
Increasing value of legumes may increase uptake but vulnerable to climate (as with other crops) affecting yield, which may reduce profitability, especially if SFI payments reduce due to popularity.		2

Policy	Impact	Uncertainty
Better food traceability - food/feed assurance.	1	
Improved realisation of value leading to improved & targeted policy-making decisions.		
Improved value awareness leading to better policy support and grower enthusiasm will lead to greater supply chain investment in agronomy products and inputs and also in R&D.		
Diversification of rotation can be incentivised.		
Subsidy / policy to pay farmers to meet regionally for implementation of agroecological solutions and systems monitoring.		1
Public procurement + training/skills in public kitchens.	1	

Policy	Impact	Uncertainty
Policy promoting S.F.I. options is undermining production of legumes here in the UK.		
Changes in government policy reducing funding to environmental projects promoting legumes.		1
Public support for funding legume-based ecosystems.		3
Food regulation à expensive and onerous.		
Non-conducive policy environment, e.g., incentive <u>not</u> for legumes.		1
Government policy continuity or change.		6
Donald Trump – Climate change denying.		1
Lack of coherent policy to promote support / safeguard legume production and subsequent ES co-benefit.	1	2
Policies to ensure minimum level of legume production for agro-ecological system resilience.	9	1
Lack of political support to accept valorisation output is either necessary, accurate, meaningful.	2	1
Fear of this perception of nanny state accusations inhibiting policy makers from supporting the process.		1
Policies to incentivise legume production voluntary not mandated.	6	