Plant Health Centre
Scotland's Centre of Expertise

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Riaghaltas na h-Alba

Developing an assessment framework to identify plant health benefits and risks for emerging novel crops in Scotland

Project Final Report

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SRUC

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Content

1 Executive summary

Background

The UK's arable sector is dominated by cereal crops, which occupy 75% of cultivated land, with wheat, barley, and oilseed rape (OSR) being the most widely grown. In Scotland, barley accounts for 48% of arable production, followed by wheat (22%), OSR (7%), and potatoes (6%). However, these crops face yield plateaus or declines due to climate change, soil degradation, and escalating pest and disease pressures, with potential yield losses of 20–40%. Novel crops offer opportunities for economic and environment gains but may themselves be vulnerable to plant health risks or pose risks to other crops in a rotation or to plants in other key Scottish sectors such as forestry or the natural environment. OSR provides a valuable historic example. The crop was introduced to the UK as high value break crop and was initially low input and high yielding. However, OSR yield has declined due to pest and diseases, which highlights the need for a robust framework to evaluate both risks and benefits before introducing novel crops.

To address the need to diversify crop rotations, and to provide other environmental gains such as improved soil health, reduced carbon footprint, carbon sequestration or other environmental gains there is interest in novel crops in Scotland from farmers and policy makers. This project addresses the current gap in pre-emptive risk assessment for novel crops, defined as those present in the UK but not yet cultivated at large scale. By learning from the OSR case (history), the study aims to prevent future agricultural disruptions through a science-based, multidisciplinary approach.

Key Research Question

How can a comprehensive, predictive framework assess the plant health risks, pest spread potential, management feasibility, and downstream benefits of introducing novel crops in Scotland?

Research Undertaken

The project was broadly divided into two parts. The first was to develop a framework and test it with novel crops, and the second to follow this with feedback from stakeholder to make it flexible and appropriate to different sectors, and robust enough to evaluate the risks and benefits.

Framework: The project developed and validated a four-question framework by reviewing existing frameworks and using and adapting the Scottish Government's Animal Health and Welfare model as a basis for a Plant Health Risk Assessment: The 4 key component questions were:

1. Plant Health Risk: Evaluates pest and disease threats.
2. Pest Spread Potential: Assesses risks to other crops/ecosystems.
3. Pest Management Feasibility: Analysis control options.
4. Downstream Benefits: Quantifies environmental/agronomic impacts.

Methods

- Literature Review: Dual-phase review to inform framework design and crop selection (hemp, sugar beet, mustard).

- Framework Validation: Retrospective application to OSR using historical (1970s) and current (2020s) data to test predictive accuracy.
- Novel Crop Assessment: Applied the framework to three candidate novel crops under Scottish conditions. These examples were selected in discussion with policy and Plant Health Centre colleagues.
- Stakeholder Workshops: Engaged agronomists, policymakers, and farmers to refine the framework.

Main Findings

Framework Validation:

OSR's decline would have been predicted by the framework, with high scores for pest risk and spread potential in the 2020s. Historical data (1970s) showed lower but still significant risks, demonstrating the framework's adaptability.

Novel Crop Assessments:

- Sugar Beet: High risk due to virus yellows and soilborne pathogens, moderate management challenges, but low downstream risks.
- Industrial Hemp: Moderate pest risks and low downstream impacts, but knowledge gaps in pest management persist.
- Mustard (Cover Crop): High pest risks but significant downstream benefits for biocontrol.

Stakeholder Feedback:

- Broadly, the framework was felt to be useful and flexible as a tool to frame key risks and collate evidence on benefits.
- There were concerns around knowledge gaps which might hinder users from competing the framework. These were sector-specific (i.e. forestry) and feedback also highlighted that because of the long-term nature of tree plantings, this sector was particularly risk-averse and concerned about data gaps. This highlighted the need for tailored adjustments.
- Stakeholders were keen to see additional case studies, and legumes were suggested for future assessment.

Recommendations and Next Steps

- Expand Crop Testing: Apply the framework to legumes and to cover crops as emerging novel crop examples.
- Address Knowledge Gaps: Collaborate with sectors like forestry to improve pest and disease data.
- Policy Integration: Advocate for using the framework in agricultural decision-making to de-risk crop diversification.
- Continuous Refinement: Update the framework with emerging pest and climate data.

This study provides a scalable tool to balance productivity and resilience in Scottish agriculture, ensuring sustainable crop diversification amid climate and regulatory challenges.

2 Introduction

The UK's arable sector is dominated by cereal crops, which occupy up to 75% of the total cultivated area, with wheat, barley, and oilseed rape (OSR) being the most widely grown (Spink et al., 2009). In Scotland, the agricultural landscape is similarly structured, with barley accounting for 48% of arable production, followed by wheat (22%), OSR (7%), and potatoes (6%) (The Scottish Government, 2022). However, these staple crops have largely reached their yield plateau or started to decline due to a combination of factors, including shifting climatic conditions, soil degradation, increased pest and disease burdens, fewer agrochemical options, or the loss of key active ingredients. Among these challenges, the escalating pressure from pests and diseases has emerged as a primary constraint, with potential yield losses estimated at 20-40% in affected regions (Tchonkouang et al., 2024, Slater et al., 202, Grassini et al., 2013). In addition, there is the possibility that pests and diseases associated with novel crops could pose a risk to plant health in other sectors like the natural environment, horticulture or forestry.

Economic pressures, declining profitability, and persistent agronomic challenges associated with conventional crops, coupled with evolving agricultural policies, have driven farmers to explore alternative cropping systems and novel crops (Jaggard & Semenov 2007). Historically, the introduction of new crops has prioritised yield potential over resilience, often neglecting comprehensive risk assessments related to biotic and abiotic stressors. Furthermore, climate change and regulatory gaps have either introduced novel pest and disease threats or exacerbated existing ones. A well-documented example is the global spread of Fusarium wilt (Tropical Race 4) in banana cultivation, which has devastated production systems across Southeast Asia, Africa, and Latin America due to insufficient pre-emptive risk evaluation (Ploetz, 2005).

A particularly illustrative case within the UK is the rapid decline of OSR, which was initially introduced in the 1970s and 1980s as a high-value break crop in cereal rotations, valued for its versatile applications in food, biofuel, and animal feed industries. By the early 2000s, the UK had emerged as Europe's leading OSR producer, with cultivation peaking at 756,000 hectares in 2012 (AHDB, 2022). However, intensive monoculture practices, combined with the 2013 EU neonicotinoid ban, left the crop highly vulnerable to cabbage stem flea beetle (CSFB), resulting in yield losses of up to 50% in severely affected regions by 2019 (Pickering & White, 2021). Concurrently, fungal pathogens such as light leaf spot (imposing an estimated £120 million in annual losses) and phoma stem canker (reducing yields by 0.5–1.2 tonnes per hectare,) further compounded production challenges, leading to a dramatic reduction in planted area to just 356,000 hectares by 2023 (AHDB, 2024, n.d).

The rapid and unforeseen decline of OSR underscores the urgent need for a robust, science-based framework to systematically evaluate the risks and benefits associated with introducing novel crops at scale. Without such predictive modelling, agricultural systems remain vulnerable to catastrophic disruptions, as exemplified by the CSFB epidemic following neonicotinoid restrictions. An effective pre-emptive assessment system would integrate multi-disciplinary analyses, including climate resilience projections, pest and disease vulnerability assessments (e.g., Rothamsted's aphid forecasting models), and socio-economic viability studies, to simulate real-world performance under varying agronomic and environmental conditions. Such an approach is indispensable for de-risking agricultural innovation in an era

marked by climate uncertainty, evolving pest dynamics, and increasing regulatory constraints on agrochemical use.

Against this backdrop, this project seeks to develop a comprehensive decision-support framework to evaluate the risks and opportunities associated with introducing novel crops into the Scottish agricultural environment. For this study, "novel crops" are defined as those already present in the UK but not yet cultivated a large scale. The research is structured into three sequential phases. First, we establish a methodological framework to assess the agronomic, environmental, and economic feasibility of candidate crops. Second, we validate the framework's predictive accuracy by retrospectively applying it to OSR, using historical data from the mid-1990s to compare projected risks with actual outcomes observed in recent years. Third, we employ the framework to evaluate three prospective novel crops for Scottish cultivation, supplemented by stakeholder workshops to refine the model based on expert feedback from agronomists, policymakers, and farmers.

By integrating empirical data, predictive analytics, and stakeholder engagement, this study aims to deliver a scalable, evidence-based tool to guide sustainable crop diversification strategies in Scotland and beyond, ensuring that future agricultural innovations are both productive and resilient.

3 Materials and Methods

3.1 Design of the framework and the identification of novel crops

A comprehensive, two-phase literature review was conducted to inform both the framework development and the selection of novel crops. The initial search focused on framework design parameters, utilising multiple academic and policy databases, including Google Scholar, Semantic Scholar, and UK government publications (Gov.UK). Search terms were strategically selected to capture both scientific and grey literature, employing Boolean operators ("AND") to combine key phrases such as "risk assessment framework", "plant health", and "animal health".

The secondary literature review focused on novel crop identification, utilising search terms such as "novel crops UK", "alternative crops Scotland", and "emerging agricultural species". This dual-search approach ensured robust coverage of both theoretical frameworks and practical crop options suitable for Scottish agronomic conditions. Following preliminary research, the framework structure and final crop selections (hemp, sugar beet, and mustard as a cover crop) were validated through consultations with Plant Health Centre (PHC) representatives to ensure scientific rigour and practical relevance.

3.2 Framework test

The developed framework was tested using OSR as a model crop system. This validation process employed two distinct temporal scenarios to assess the framework's predictive capabilities:

For the national score, we have considered the whole UK, and for the local score, we have considered a farm in Edinburgh for both scenarios.

Scenario 1 (Current Conditions): The framework was applied using contemporary data (2020s) for both national (UK-wide) and local (Edinburgh farm-scale) conditions. Scoring incorporated current agronomic challenges, including cabbage stem flea beetle (CSFB) pressures, disease prevalence (e.g., light leaf spot), and modern cultivation practices.

Scenario 2 (Historical Baseline): To evaluate the framework's sensitivity to temporal changes, a retrospective analysis was conducted using literature from the 1980s-1990s using the filters to set years. This assessed whether the framework would have predicted the subsequent challenges faced by OSR, including the impacts of neonicotinoid restrictions and emerging pest pressures.

Scoring followed standardised metrics within the framework, with data extracted from peer-reviewed studies, government agriculture reports, and historical crop performance records.

3.3 Assessments of novel crops

Three candidate crops (industrial hemp, sugar beet, and mustard as a cover crop) were systematically evaluated using the framework under Scenario 1 parameters. Data sources included:

- Peer-reviewed agronomic studies

- Government and industry reports (grey literature)
- Specialist crop production seminars
- Current cultivation trials data

Each crop was assessed across multiple risk/benefit categories, with scoring weighted according to Scottish growing conditions.

3.4 Stakeholders workshop

Two structured workshops were conducted with nine key stakeholders representing diverse sectors of the plant health community (see Table 1 for participant distribution).

To ensure productive engagement:

- The complete framework documentation, including scoring guidance, was distributed to all participants one week prior.
- Workshops began with a detailed presentation of the framework's structure, scoring methodology, and initial results.

Structured discussion sessions collected qualitative feedback on:

- Framework usability
- Scoring criteria appropriateness
- Sector-specific concerns

Feedback was systematically recorded and subsequently incorporated into framework refinements. This iterative validation process ensured the tool's relevance for both policy development and on-farm decision making.

Table 1: Stakeholders' representation and the sectors

Sector	Number of stakeholders
Agriculture and food	2
Environmental and ecosystem	2
Horticulture and amenity	2
Forestry	3

4 Results and Discussion

4.1 Design of the framework

Both the Scientific and the policy-oriented frameworks on plant and animal health were collected and screened. The Animal Health and Welfare Framework (2019–2022) served as the conceptual backbone due to its dual-level evaluation of risk at both national and local scales. This dual-structure enables the framework to be adaptable to various contexts, from farm-level assessments to national policy applications, ensuring that both broad and site-specific risk factors are considered.

Building on this foundation, the framework design incorporated structured methodologies from the GB Non-Native Species Risk Assessment Scheme (GB Non-Native Species Secretariat, 2019) and the Weed Risk Assessment (WRA) model by Pheloung, Williams and Halloy (1999). These models emphasise systematic, evidence-based evaluation through stages such as entry, establishment, spread, and impact, supported by quantitative scoring. Adapting these elements, the framework applies clear numerical ranges for national (0–15) and local (0–10) elements, providing transparency and alignment with international pest-risk analysis standards (IPPC and EPPO).

Further refinement was informed by Hulme (2020), whose work on New Zealand's plant-invasion management highlights the need to integrate national biosecurity policies with local implementation. Drawing on these insights, the framework adopts a two-tier structure in which national elements assess intrinsic crop and pest risks, while local elements account for regional ecological conditions and management capacity. Together, these components form a flexible yet scientifically rigorous tool capable of supporting both regulatory decisions and localised biosecurity planning.

4.2 Framework

The main aim of this framework is to assess the potential risk associated with the introduction of a new/novel crop in Scotland, but with the flexibility to be adapted later for use in other plant health sectors. The framework structure is derived in part from the 'Animal Health and Welfare' risk assessment from the Scottish Government website, which provided a useful conceptual framework for considering risks and benefits, having considered and rejected other approaches during the first phase of the literature review. The framework developed provides a comprehensive and structured approach to assessing the risks and benefits associated with introducing a new crop. The framework (see Table 2) consists of four questions (Q1-4). The first three questions are considered to be fixed questions because they deal with the risk associated with each crop. The questions are based on plant health risks (Q1), pest spread potential (Q2), pest management feasibility (Q3), and downstream environmental and agricultural benefits (Q4). Each question is further broken down into national and local elements, allowing for a nuanced evaluation that considers both broad trends and region-specific conditions. The intention is that the national scale element would be useful to plant health strategy leads such as policy makers, while the local elements would be useful to individual land managers, farmers and agronomists. The framework employs a scoring matrix to quantify risks and benefits, with clear categories (e.g., low, moderate, high) and weighted criteria to ensure consistency and objectivity in assessments. For example, Q1 evaluates pest risks based on the number of known pests and their potential impact, while Q3 assesses control methods based on availability, cost, and resistance. All the factors we equally weighted in the framework for enabling flexibility in various sectors. The aggregated scores provide a

clear, comparative measure to guide decision-making, ensuring risks and benefits are systematically weighed.

Note: When calculating the overall score from Q2 to Q4, please consider only the overall score at the bottom of the table, not each individual factor.

The framework with the instructions is in Appendix 1.

4.2.1 Adaptability and Practical Application

The framework is designed to be adaptable to diverse agricultural contexts, incorporating local factors such as climate, soil conditions, and farmer expertise. This dual focus on national and local elements ensures that the assessment is both globally relevant and locally actionable. The scoring system allows stakeholders to prioritise risks and benefits, facilitating informed decision-making. For instance, a crop with high pest spread potential (Q2) but excellent downstream benefits (Q4) may still be viable if local management capacity (Q3) is strong. By integrating ecological, economic, and practical considerations, the framework serves as a valuable tool for policymakers, agronomists, and farmers to evaluate new crops systematically and mitigate potential risks. The framework allows users to calculate risk scores and guides them to high (red), moderate (amber) or low (green) risk scores, but users are free to apply their own attitude to risk in reaching a final decision on whether to reject or proceed with any given example.

In discussion with stakeholders, it was evident that some sectors, such as forestry, might be particularly risk averse and might wish to adapt this framework further to give a more detailed approach.

Table 2: The framework skeleton:

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?
Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score.

National Element (Table 2 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table 2 (a) Framework skeleton for Q-1 national element

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)
1–2	0-1 (Low Risk)	2-3 (Low Risk)	5 (Low Risk)
3-5	4 (Low Risk)	7 (Moderate Risk)	10 (Moderate Risk)
6-8	6 (Moderate Risk)	9 (Moderate Risk)	12 (High Risk)
9+	8 (Moderate Risk)	11 (High Risk)	15 (High Risk)

Local Element (Table 2 (b)) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests).

Table 2 (b) Framework skeleton for Q-1 local element

Number of Known Pests	**Unfavourable Climate (Pests struggle to survive)**	**Moderately Suitable Climate (Pests can survive but not thrive)**	**Highly Suitable Climate (Ideal conditions for pest proliferation)**
0-1	0-1 (Low Local Risk)	2 (Low Local Risk)	3 (Low Local Risk)
2-4	3 (Low Local Risk)	5 (Moderate Local Risk)	7 (Moderate Local Risk)
5+	6 (Moderate Local Risk)	8 (High Local Risk)	10 (High Local Risk)

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pest based on Q1.

National Element (Table 2 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table 2 (c) Framework skeleton for Q-2 national element

Pest Mobility & Spread Factors	**Factors to Consider**	**Unfavourable Conditions (Limited spread, containment possible)**	**Moderate Conditions (Potential for spread under certain conditions)**	**Favourable Conditions (High risk of rapid and widespread infestation)**
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	- Pest relies on direct contact or short-range movement. - No natural dispersal mechanisms. - Requires human or animal movement for spread.	0–2 (Very Low Spread Risk)	3–5 (Low Spread Risk)	6–7 (Moderate Spread Risk)
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade). - Could establish in nearby areas under suitable conditions.	3–5 (Low Spread Risk)	6–8 (Moderate Spread Risk)	9–11 (Moderate-high Spread Risk)
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.	5–7 (Moderate Spread Risk)	8–10 (High Spread Risk)	11–15 (High Spread Risk)

Local Element (Table 2 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).
Note: For the combination of local factors, please consider all the factors that you have used to score the first two rows.

Table 2 (d) Framework skeleton for Q-2 local element

Local	**Factors to Consider**	**Low Local Spread Risk (Conditions limit spread)**	**Moderate Local Spread Risk (Conditions could facilitate spread)**	**High Local Spread Risk (Conditions highly conducive to spread)**
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.	0–1 (Very Low Local Spread Risk)	2–4 (Low Local Spread Risk)	5–6 (Moderate Local Spread Risk)
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.	1–2 (Very Low Local Spread Risk)	3–5 (Low Local Spread Risk)	6–7 (Moderate-high Local Spread Risk)
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.	2–3 (Low Local Spread Risk)	4–6 (Moderate Local Spread Risk)	7–10 (High Local Spread Risk)

Q-3 What is the maximum ability to control the pest/disease associated with this crop?
Note: Assess the feasibility of managing pests associated with the crop (e.g., availability of control options and their ability to manage pests)
Consider the major pest based on Q1.

National Element (Table 2 (e)) (0–15): Based on general knowledge of pest management options.
0–5: Easy to manage (effective control methods are available).
6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).
11–15: Difficult to manage (few or no effective control methods).
Note: For the overall score, please consider all the factors that you have considered in scoring first four rows.

Table 2 (e) Framework skeleton for Q-3 national element

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).	0–3 (Effective and cost-efficient methods available)	4–7 (Control methods available but costly or labour-intensive)	8–10 (Few or no effective control methods available)
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.	0–3 (Effective and cost-efficient methods available)	4–7 (Control methods available but costly or labour-intensive)	8–10 (Expensive or labour-intensive methods with limited effectiveness)
Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g., pesticide resistance, failure of biological control).	0–3 (No significant resistance to treatments)	4-7 (Some pest resistance, but manageable)	8–10 (High resistance, difficult to control pests)
Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).	0–3 (Highly resistant varieties available)	4-7 (Some resistant varieties available)	8–10 (No resistant varieties or limited options)
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.	0–3 (Effective control methods and resistant varieties available)	4-7 (Methods available but not optimal or cost-efficient)	8-10 (Few or no effective methods or resistant varieties)

Local Element (Table 2 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).
Note: For the overall score, please consider all the factors that you have considered in scoring first three rows.

Table 2 (f) Framework skeleton for Q-3 local element

Local Factors	**Factors to Consider**	**High Local Management Capacity (Well-resourced and knowledgeable)**	**Moderate Local Management Capacity (Some resources and knowledge available)**	**Low Local Management Capacity (Limited resources and knowledge)**
Access to Resources	- Availability of pesticides, equipment, and technology.	0–3 (Highly accessible resources)	4-7 (Moderate access to resources)	8-10 (Limited access to resources)
Access to Expertise	- Availability of local experts, training, and support networks.	0–3 (High access to local expertise)	4-7 (Some access to expertise, but gaps may exist)	8-10 (Limited or no access to expertise)
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.	0–3 (Farmers are well-trained and knowledgeable)	4-7 (Farmers have basic knowledge but may lack advanced skills)	8-10 (Farmers lack basic knowledge or training in pest management)
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.	0–3 (High local capacity)	4–7 (Moderate local capacity)	8–10 (Low local capacity)

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

National Element (Table 2 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.
0–5: Low downstream risk (positive impact on soil health).
6–10: Moderate downstream risk (neutral or slightly negative impact soil health).
11–15 High downstream risk (significant negative impact on soil health).
Note: For the overall, please consider all the factors that you have considered in scoring first five rows.

Table 2 (g) Framework skeleton for Q-4 national element

Downstream Impact Factors	**Factors to Consider**	**Low Downstream Risk (Positive impact)**	**Moderate Downstream Risk (Neutral/slightly negative impact)**	**High Downstream Risk (Significant negative impact)**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests	0–2 (Enhances biocontrol activity)	3–6 (Neutral or slightly negative)	7–10 (encourages more disease)
Biodiversity Impact	- Effect on species richness, pollinators, and habitat availability.	0–2 (Enhances biodiversity)	3–6 (Neutral or slightly reduces biodiversity)	7–10 (Reduces biodiversity, disrupts ecosystems)
Soil Health Impact	- Effect on soil structure, nutrient retention, and microbial activity.	0–2 (Improves or maintains soil health)	3–6 (Neutral or slightly degrades soil health)	7–10 (Significantly degrades soil health)
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.	0–2 (Improves nutrient cycling and fertility, residue decomposes easily)	3–6 (Neutral or minor imbalance, moderate degradation of the residue)	7–10 (Depletes key nutrients or causes imbalance, long time for the residues to delay and delays the next planting)
Overall Downstream Environmental Risk	- The combined impact on soil health.	0–5 (Low risk)	6–10 (Moderate risk)	11–15 (High risk)

Local Element (Table 2 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).
Note: For the overall, please consider all the factors that you have considered in scoring first five rows.

Table 2 (h) Framework skeleton for Q-4 local element

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-postive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests	0–2 (Enhances biocontrol activity)	3–6 (Neutral or slightly negative)	7–10 (encourages more disease)
Local Biodiversity Impact	- Effect on native species, pollinators, and ecosystem balance.	0–2 (Enhances or maintains biodiversity)	3–5 (Some biodiversity loss, but within acceptable limits)	6–8 (Significant loss of biodiversity, ecosystem imbalance)
Local Soil Health Impact	- Soil structure, organic matter retention, and fertility changes.	0–2 (Maintains or improves soil health)	3–5 (Some degradation, but can be mitigated)	6–8 (Severe soil degradation, loss of fertility)
Soil Type Suitability	- Suitability of local soil for sustainable cultivation without degradation.	0–2 (Soils are well-suited for the crop)	3–5 (Some suitability concerns, but manageable)	6–8 (Soils are vulnerable, high risk of degradation)
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.	0–2 (Improves nutrient cycling and fertility, residue decomposes easily)	3–6 (Neutral or minor imbalance, moderate degradation of the residue)	7–10 (Depletes key nutrients or causes imbalance, long time for the residues to delay and delays the next planting)
Overall Local Downstream Risk	- The combined impact on local soil health.	0–3 (Low risk)	4–7 (Moderate risk)	8–10 (High risk)

Table 3 Overall score:

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	X	Y	X+Y
Q-2	X	Y	X+Y
Q-3	X	Y	X+Y
Q-4	X	Y	X+Y

Interpreting risk scores

The framework allows users to calculate risk scores and guides them to high (red), moderate (amber) or low (green) risk scores but users are free to reach their own final decision on whether to reject or proceed with any given example. They can use the framework to rank different options and consider potential mitigation options.

4.3 Oilseed Rape as a test crop

Scenario 1: Table 4 shows the overall value of OSR in the current scenario. Appendix 2 shows the detailed framework scoring of scenario 1.

Table-4 Overall score for Oilseed rape in 2025

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	15 (High)	7 (Moderate)	**22**
Q-2	11 (High)	**6** (Moderate)	**17**
Q-3	7 (Moderate)	**5** (Moderate)	**12**
Q-4	6 (Moderate)	6 (Moderate)	**12**

Scenario 2: Table 5 shows the overall value of OSR in scenario 2. Appendix 3 shows the detailed framework scoring of scenario 2.

Table-5 Overall score for Oilseed rape in 1970

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	12 (High)	6 (Moderate)	**18**
Q-2	10 (High)	**6** (Moderate)	**16**
Q-3	5 (Moderate)	**5** (Moderate)	**10**
Q-4	6 (Moderate)	6 (Moderate)	**12**

The framework effectively captured the differences in oilseed rape (OSR) cultivation risks between the two scenarios, demonstrating its adaptability to varying agricultural and historical contexts. In **Scenario 1**, Q-1 (Plant Health Risk) scored the highest (National: 15, Local: 7, Total: 22), reflecting the presence of multiple high-impact diseases such as *Phoma Stem Canker*, *Light Leaf Spot*, *clubroot*, *Sclerotinia Stem Rot*, *Verticillium Stripe*, and *downy mildew* (Smith et al., 2021; Greer et al., 2023; Hokkanen, 2008; AHDB Brassica Resource). Significant yield losses were also associated with pests like *Aphids*, *Cabbage Stem Flea Beetle*, and *Turnip Yellows Virus* (Bayer Oilseed Rape Diseases; AHDB Brassica Resource), while moderate yield impacts were linked to *wireworms*, *slugs*, and *Pollen Beetles* (Evans et al., 2010; Gladders et al., 2008).

Similarly, Q-2 (Pest Spread Potential) remained high (Total: 17), underscoring the mobility of these pests and their potential to infest neighbouring crops. In **Scenario 2**, Q-1 and Q-2 also scored high (Totals: 18 and 16, respectively), but the absence of *Turnip Yellows Virus,* a key driver of yield loss in modern systems, and reliance on historical pest data (e.g., *Cabbage Stem Flea Beetle* as the primary pest; Godan, 1950) resulted in slightly lower scores. Moderate yield losses in this scenario were attributed to aphids, wireworms, slugs, and Pollen Beetles (Strickland, 1965).

The difference in Q-3 (Pest Management Feasibility) between the two scenarios (Scenario 1: 12, Scenario 2: 10) reflects regulatory changes, particularly the ban of certain pesticides in modern agriculture (e.g., neonicotinoids), which reduced control options in Scenario 1 (Bokor et al., 1975). Meanwhile, Q-4 (Downstream Benefits) remained consistent (Total: 11 in both scenarios), as the environmental and agronomic impacts of OSR cultivation, such as its effects on soil health and biodiversity, were largely unchanged over time (Svenson & Lerenius, 1987). The framework's flexibility allowed it to account for temporal shifts in pest prevalence, regulatory constraints, and agricultural practices, proving its utility in evaluating crop risks across different eras. By distinguishing between localised and national factors, it provided a nuanced assessment, ensuring that both historical and contemporary challenges, such as the emergence of new pathogens (*Verticillium Stripe*) or the loss of chemical controls, were accurately represented. This demonstrates the framework's robustness in adapting to evolving agricultural landscapes while maintaining a structured, quantifiable approach to risk assessment.

The retrospective application of the framework shows that several oilseed rape (OSR) risks could have been anticipated and mitigated earlier. High plant health and pest spread scores in the 1970 scenario already indicated vulnerability to disease diversification and pest adaptation. Early use of this kind of framework could have predicted some of the current issues, such as

1. Light Leaf Spot and Verticillium Stripe. These diseases started to affect brassica crops in nearby/ similar temperate regions. The early identification of this problem could have led to investment in resistant varieties and coordinated surveillance.
2. Similarly, recognising the mobility of aphids and Cabbage Stem Flea Beetle might have encouraged national early-warning systems.
3. Further, this framework also highlights that most of the pest and disease control was based on chemical controls. This would have played a significant role in policies related to pesticide controls. Further alternative controls could have been developed in advance.

Overall, this analysis demonstrates the framework's value as a foresight tool, capable not only of assessing current risk but also of predicting and preventing future challenges through proactive, evidence-based crop health planning.

4.4 Novel crops

Based on the literature review, followed by the discussion with the experts (Consultants and PHC experts) and stakeholders, the following plants were considered for the test. Sugar beet, hemp, and mustard as a cover crop.

4.4.1 Sugar beet

Sugar beet (*Beta vulgaris*) production in the UK and Scotland faces growing threats from pests and diseases, exacerbated by climate change and regulatory restrictions, positioning it as a high-risk crop (Table 6, Appendix 4). The most pressing concern is virus yellows, a complex of aphid-transmitted viruses (Beet yellows virus, Beet mild yellowing virus, Beet chlorosis virus) vectored by *Myzus persicae*. Severe outbreaks, like the 2020 epidemic, caused >50% yield losses, with milder winters enabling earlier aphid activity (Bayer Crop Science, 2025). The loss of neonicotinoid seed treatments—unavailable in Scotland under emergency authorisations (Defra, 2025)—has further limited control options.

Fungal diseases, particularly Cercospora leaf spot (*Cercospora beticola*), thrive in warm, humid conditions and now show fungicide resistance (Farming UK, 2017; BBRO, 2021). Soilborne pathogens like *Rhizoctonia solani*, *Polymyxa betae* (vector of rhizomania), and beet cyst nematode (*Heterodera schachtii*) compound risks, especially in wetter seasons (AHDB, 2025).

Climate change, intensive farming, and pesticide restrictions demand integrated strategies—resistant varieties, rotation, and predictive modelling (BBRO, 2021). Given these cumulative threats, expanding sugar beet cultivation in Scotland remains highly constrained under current conditions.

Table 6: Overall score for sugar beet

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	11 (high)	10	21
Q-2	12 (high)	4	16
Q-3	6 (Moderate)	5	11
Q-4	4 (low)	3	10

4.4.2 Hemp

The expansion of industrial hemp (*Cannabis sativa L.*) cultivation in the UK and Scotland is constrained by limited understanding of pest and disease pressures under local field conditions (Table 7, Appendix 5). Soilborne fungal pathogens such as *Botrytis cinerea* may pose significant risks, particularly in Scotland's humid climate, where prolonged wet conditions during flowering can favour bud rot and grey mould development, which in similar temperate climates leads to quality and yield loss (Garfinkel, 2021). Additionally, the UK lacks systematic field trials or disease surveillance specific to hemp, creating a major knowledge gap in pest forecasting, resistance breeding, and integrated pest management. This uncertainty may be perceived as an increased risk associated with large-scale hemp cultivation in Scotland, where both climate and regulatory limitations reduce available crop protection tools (SAC Consulting / Scottish Enterprise, 2025). Considering these factors, the relative risk in the UK and Scotland is likely to be in the low to moderate range, which will largely be dictated by the weather conditions.

Table 7: Overall score for hemp

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	8 (Moderate)	6	14
Q-2	6 (Moderate)	3	9
Q-3	7 (Moderate)	2	9
Q-4	3 (low)	2	5

4.4.3 Mustard as a cover crop

Mustard (*Brassica juncea*) plants are an alternative crop in the UK (Table 8, Appendix 6). Since mustard belongs to the Brassica family, it is prone to all the pests and diseases that infect OSR (section 3.2). However, the mustard plants have additional downstream benefits to soil health and can enhance biological control agents against the potato cyst nematode (Lietzow, 2021).

Table 8: Overall score for mustard as a cover crop

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	15 (High)	**7**	**22**
Q-2	10 (High)	**6**	**16**
Q-3	7 (Moderate)	**5**	**12**
Q-4	1.5 (Positive)	**1.6**	**3**

Table 9 shows how the framework could be used to compare novel crop options such that hemp might be selected as a relatively low risk choice.

Table 9: Total risk scores derived from the case studies

Question	OSR 1970 Total Risk score	OSR 2025 Total Risk score	Mustard Total Risk score	Sugar Beet Total Risk score	Hemp Total Risk score
Q-1	18	22	18	21	14
Q-2	16	17	16	16	9
Q-3	10	12	10	11	9
Q-4	11	11	11	10	5

4.5 Stakeholders input

This section highlights the key points that have been suggested by the stakeholders for further improvement of the framework. Minor points and adaptations to wording suggested by stakeholders were incorporated into the final framework as presented in this report.

- Stakeholders were broadly supportive of the contextual framework and the flexibility of the framework.
- Most of the stakeholders suggest that the framework is useful to consider before introducing a novel crop in their sector
- Some of the stakeholders suggested that legumes as a cover crop are getting more uptake in Scotland. Hence, they suggested testing legumes as a cover crop as a further case study to those conducted as part of this project.

- Scores might change depending on the knowledge of the person who scores the framework.
- Stakeholders from forestry suggested that a huge knowledge gap exists in forest research, and hence, it would be difficult for them to score this framework. They were also more risk averse because of the long-term nature of tree plantings during which knowledge might change. The framework might need to be adapted to include more detail for this sector.

5 Conclusion

This project successfully developed and validated a comprehensive risk assessment framework to evaluate the feasibility of introducing novel crops in Scotland, addressing critical gaps in plant health, pest management, and environmental impacts. By applying the framework to oilseed rape (OSR) under both historical and contemporary scenarios, the study demonstrated its ability to capture evolving agricultural risks, such as the emergence of new pests (e.g., *Verticillium Stripe*) and regulatory constraints (e.g., neonicotinoid bans). The evaluation of prospective crops such as sugar beet, industrial hemp, and mustard as a cover crop has highlighted varying risk profiles, with sugar beet posing the highest biotic risks due to virus yellows and soilborne pathogens, while hemp and mustard showed moderate-to-low risks with potential downstream benefits. Stakeholder feedback underscored the framework's practical utility while identifying areas for refinement, such as expanding the case studies to include legumes and addressing sector-specific knowledge gaps.

Future Recommendations

- **Expand Crop Testing case studies**: Apply the framework to legumes as a cover crop and other emerging cover crops to assess their suitability for Scottish agriculture.
- **Address Knowledge Gaps**: Collaborate with forestry and horticulture sectors to improve pest and disease data for understudied crops.

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7 Appendix

Appendix-1- Framework with instructions

Instructions for the users

Step-1: Before scoring, compile all available data on the specific crop and its major known pests. This process should include the collection and review of relevant information from both national and international sources. For example, national plant protection organisations (e.g. Defra's plant health risk register and international equivalents), international plant health bodies (e.g. EPPO, IPPC), scientific literature and review papers, extension services (e.g. university crop protection guides), crop-specific databases/compendia (e.g. CABI) etc. Consider data from all regions with agroecological or climatic conditions similar to the area of interest to ensure a comprehensive and contextually relevant dataset.

This includes:

1. Pest lists and their biology (mobility, impact).
2. Available control methods (chemical, biological, cultural).
3. The crop's characteristics (growth habits, resistance traits).
4. Local conditions (climate, soil, existing farms, farmer expertise).
5. Origin of the seed/planting material

Follow the instructions under each question to score.

Step 2: Score Each Question (Q1-Q4)
For each question, provide two separate scores: a National Element Score (0-15) and a Local Element Score (0-10).

Step 3: Calculate the Total Risk Score
Total Risk Score = (Q1 National + Q1 Local) + (Q2 National + Q2 Local) + (Q3 National + Q3 Local) + (Q4 National + Q4 Local)

Step 4: Interpret the Total Score
0 - 30: Low Risk - Introduction is likely acceptable.
31 - 60: Moderate Risk - Introduction requires caution and a management plan.
61 - 100: High Risk - Introduction is not recommended or requires a stringent containment plan.

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?
Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score. This question assesses the direct threat pests pose to the health and yield of the new crop itself. Consider pests, disease and weeds.

Example: Determine the total "Number of Known Pests". Then, assess the "Impact" of the most severe pest in that category (e.g., if you have 4 pests, but one can cause crop failure, use the "Severe Impact" column).

National Element (Table 1 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table 1 (a) Framework skeleton for Q-1 national element

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)
1–2	0-1 (Low Risk)	2-3 (Low Risk)	5 (Low Risk)
3-5	4 (Low Risk)	7 (Moderate Risk)	10 (Moderate Risk)
6-8	6 (Moderate Risk)	9 (Moderate Risk)	12 (High Risk)
9+	8 (Moderate Risk)	11 (High Risk)	15 (High Risk)

Consider how local climate and conditions (e.g., humidity, temperature) affect those same pests. Find the row for the number of pests and the column that best describes the local climate's suitability for them. The intersecting cell gives your Local score.

Local Element (Table 1 (b)) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests).

Table 1 (b) Framework skeleton for Q-1 local element

Number of Known Pests	Unfavourable Climate (Pests struggle to survive)	Moderately Suitable Climate (Pests can survive but not thrive)	Highly Suitable Climate (Ideal conditions for pest proliferation)
0-1	0-1 (Low Local Risk)	2 (Low Local Risk)	3 (Low Local Risk)
2-4	3 (Low Local Risk)	5 (Moderate Local Risk)	7 (Moderate Local Risk)
5+	6 (Moderate Local Risk)	8 (High Local Risk)	10 (High Local Risk)

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pests based on Q1. Also consider other crops in rotation that are susceptible to the pests and pathogens of the novel crop.
Use the top table. Categorise the pest's "Mobility & Spread Factors" (e.g., soil-borne = Low Mobility; airborne fungus = Highly Mobile). Then, judge the "Conditions" for spread on a national scale (e.g., widespread host crops = Favourable). The corresponding score range is your national score.

National Element (Table 1 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table 1 (c) Framework skeleton for Q-2 national element

Pest Mobility & Spread Factors	**Factors to Consider**	**Unfavourable Conditions (Limited spread, containment possible)**	**Moderate Conditions (Potential for spread under certain conditions)**	**Favourable Conditions (High risk of rapid and widespread infestation)**
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	- Pest relies on direct contact or short-range movement. - No natural dispersal mechanisms. - Requires human or animal movement for spread.	0–2 (Very Low Spread Risk)	3–5 (Low Spread Risk)	6–7 (Moderate Spread Risk)
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade). - Could establish in nearby areas under suitable conditions.	3–5 (Low Spread Risk)	6–8 (Moderate Spread Risk)	9–11 (Moderate-high Spread Risk)
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.	5–7 (Moderate Spread Risk)	8–10 (High Spread Risk)	11–15 (High Spread Risk)

Use the bottom table. Analyse local factors like "Proximity to Other Crops" and "Natural Barriers". Score each factor based on the descriptions, then use the "Combination of Local Factors" row to determine your overall Local score, considering both proximity and barriers together.

Local Element (Table-1 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).
Note: For the combination of local factors, please consider all the factors that you have used to score the first two rows.

Table 1 (d) Framework skeleton for Q-2 local element

Local	**Factors to Consider**	**Low Local Spread Risk (Conditions limit spread)**	**Moderate Local Spread Risk (Conditions could facilitate spread)**	**High Local Spread Risk (Conditions highly conducive to spread)**
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.	0–1 (Very Low Local Spread Risk)	2–4 (Low Local Spread Risk)	5–6 (Moderate Local Spread Risk)
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.	1–2 (Very Low Local Spread Risk)	3–5 (Low Local Spread Risk)	6–7 (Moderate-high Local Spread Risk)
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.	2–3 (Low Local Spread Risk)	4–6 (Moderate Local Spread Risk)	7–10 (High Local Spread Risk)

Q-3 What is the maximum ability to control the pest/disease associated with this crop?

Note: Assess the feasibility of managing pests associated with the crop (e.g., availability of control options and their ability to manage pests)

Consider the major pest based on Q1.

Use the table. Evaluate the five "Pest Management Factors" (e.g., Availability of Control Methods, Cost and Labour, etc.). For each factor, select the description that best fits and note its score. Your final National score is based on the "Overall Feasibility" row, which should be a summary judgment informed by your scores in the other four factors.

National Element (Table 1 (e)) (0–15): Based on general knowledge of pest management options.

0–5: Easy to manage (effective control methods are available).

6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).

11–15: Difficult to manage (few or no effective control methods).

Note: For the overall score, please consider all the factors that you have considered in scoring first four rows.

Table 1 (e) Framework skeleton for Q-3 national element

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).	0–3 (Effective and cost-efficient methods available)	4–7 (Control methods available but costly or labour-intensive)	8–10 (Few or no effective control methods available)
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.	0–3 (Effective and cost-efficient methods available)	4–7 (Control methods available but costly or labour-intensive)	8–10 (Expensive or labour-intensive methods with limited effectiveness)

Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g., pesticide resistance, failure of biological control).	0–3 (No significant resistance to treatments)	4-7 (Some pest resistance, but manageable)	8–10 (High resistance, difficult to control pests)
Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).	0–3 (Highly resistant varieties available)	4-7 (Some resistant varieties available)	8–10 (No resistant varieties or limited options)
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.	0–3 (Effective control methods and resistant varieties available)	4-7 (Methods available but not optimal or cost-efficient)	8-10 (Few or no effective methods or resistant varieties)

Use the bottom table. Assess the "Local Factors" that influence on-the-ground control. Consider "Access to Resources," (consider the affordability as well) "Access to Expertise," and "Farmer Knowledge & Skills." Your final Local score is based on the "Overall Local Management Capacity" and the row, which summarises the three previous factors.

Local Element (Table 1 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).
Note: For the overall score, please consider all the factors that you have considered in scoring first three rows.

Table 1 (f) Framework skeleton for Q-3 local element

Local Factors	**Factors to Consider**	**High Local Management Capacity (Well-resourced and knowledgeable)**	**Moderate Local Management Capacity (Some resources and knowledge available)**	**Low Local Management Capacity (Limited resources and knowledge)**
Access to Resources	- Availability of pesticides, equipment, and technology.	0–3 (Highly accessible resources)	4-7 (Moderate access to resources)	8-10 (Limited access to resources)
Access to Expertise	- Availability of local experts, training, and support networks.	0–3 (High access to local expertise)	4-7 (Some access to expertise, but gaps may exist)	8-10 (Limited or no access to expertise)
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.	0–3 (Farmers are well-trained and knowledgeable)	4-7 (Farmers have basic knowledge but may lack advanced skills)	8-10 (Farmers lack basic knowledge or training in pest management)
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.	0–3 (High local capacity)	4–7 (Moderate local capacity)	8–10 (Low local capacity)

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

Note on Scoring: In this question, a LOWER score is positive (a benefit), indicating low environmental risk or high benefit. A HIGHER score is negative (a risk), indicating potential harm

National Element (Table 1 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.

0–5: Low downstream risk (positive impact on soil health).

6–10: Moderate downstream risk (neutral or slightly negative impact on soil health).

11–15 High downstream risk (significant negative impact on soil health).

Note: For the overall, please consider all the factors that you have considered in scoring the first five rows.

Table 1 (g) Framework skeleton for Q-4 national element

Downstream Impact Factors	**Factors to Consider**	**Low Downstream Risk (Positive impact)**	**Moderate Downstream Risk (Neutral/slightly negative impact)**	**High Downstream Risk (Significant negative impact)**
Biocontrol potential for any disease	-Crop's ability to control any diseases/pests	0–2 (Enhances biocontrol activity)	3–6 (Neutral or slightly negative)	7–10 (encourages more disease)
Biodiversity Impact	-Effect on species richness, pollinators, and habitat availability.	0–2 (Enhances biodiversity)	3–6 (Neutral or slightly reduces biodiversity)	7–10 (Reduces biodiversity, disrupts ecosystems)
Soil Health Impact	-Effect on soil structure, nutrient retention, and microbial activity.	0–2 (Improves or maintains soil health)	3–6 (Neutral or slightly degrades soil health)	7–10 (Significantly degrades soil health)
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.	0–2 (Improves nutrient cycling and fertility, residue decomposes easily)	3–6 (Neutral or minor imbalance, moderate degradation of the residue)	7–10 (Depletes key nutrients or causes imbalance, long time for the residues to delay and delays the next planting)
Overall Downstream Environmental Risk	-The combined impact on soil health.	0–5 (Low risk)	6–10 (Moderate risk)	11–15 (High risk)

Local Element (Table 1 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).
Note: For the overall, please consider all the factors that you have considered in scoring first five rows.

Table 1 (h) Framework skeleton for Q-4 local element

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-positive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**
Biocontrol potential for any disease	-Crop's ability to control any diseases/pests	0–2 (Enhances biocontrol activity)	3–6 (Neutral or slightly negative)	7–10 (encourages more disease)
Local Biodiversity Impact	-Effect on native species, pollinators, and ecosystem balance.	0–2 (Enhances or maintains biodiversity)	3–5 (Some biodiversity loss, but within acceptable limits)	6–8 (Significant loss of biodiversity, ecosystem imbalance)
Local Soil Health Impact	-Soil structure, organic matter retention, and fertility changes.	0–2 (Maintains or improves soil health)	3–5 (Some degradation, but can be mitigated)	6–8 (Severe soil degradation, loss of fertility)
Soil Type Suitability	-Suitability of local soil for sustainable cultivation without degradation.	0–2 (Soils are well-suited for the crop)	3–5 (Some suitability concerns, but manageable)	6–8 (Soils are vulnerable, high risk of degradation)
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.	0–2 (Improves nutrient cycling and fertility, residue decomposes easily)	3–6 (Neutral or minor imbalance, moderate degradation of the residue)	7–10 (Depletes key nutrients or causes imbalance, long time for the residues to delay and delays the next planting)
Overall Local Downstream Risk	-The combined impact on local biodiversity, and soil health.	0–3 (Low risk)	4–7 (Moderate risk)	8–10 (High risk)

Table 2 Overall score:

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	X	Y	X+Y
Q-2	X	Y	X+Y
Q-3	X	Y	X+Y
Q-4	X	Y	X+Y

Interpreting risk scores

The framework allows users to calculate risk scores and guides them to high (red), moderate (amber) or low (green) risk scores but users are free to reach their own final decision on whether to reject or proceed with any given example. They can use the framework to rank different options and consider potential mitigation options.

National element: Whole UK

Local Element: Edinburgh, Scotland

The national and the local elements are constant for all case studies.

Appendix 2- Framework score for oilseed rape for Scenario 1.

Table-3 List of pathogens and their biology

Mobility	Pathogen / Pest Name	Biology
High Mobility	Light Leaf Spot	Airborne spores
	Sclerotinia Stem Rot	Airborne spores
	Clubroot	Soil-borne; resting spores persist >7 years
	Cabbage Stem Flea Beetle (CSFB)	Flying insect
	Aphids	Flying insect
	Turnip Yellows Virus (TuYV)	Vector-borne
Moderate Mobility	Downy Mildew	Airborne spores and water-splashed
	Phoma Stem Canker	Rain-splashed spores
	Cabbage Root Fly	Flying insect
	Cabbage Seed Weevil	Flying insect
	Pollen Beetle	Flying insect
Low Mobility	Verticillium Stripe	Soil-borne and seed-borne
	Slugs	Crawling
	Wireworms	Soil-dwelling

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?

Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score.

National Element (Table 4 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table-4 (a) Framework for Q-1 national element-OSR Scinario-1

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)	Reasons
1–2				More than 10 high-impact pathogens are in the list
3-5				
6-8				
9+			15 (High Risk)	

Local Element (Table 4 (b)) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests).

Table-4 (b) Framework for Q-1 local element element-OSR Scinario-1

Number of Known Pests	Unfavourable Climate (Pests struggle to survive)	Moderately Suitable Climate (Pests can survive but not thrive)	Highly Suitable Climate (Ideal conditions for pest proliferation)	Reasons
0-1				Most of the insect pests are climate-sensitive. Hence, their survival and reproduction are significantly reduced.
2-4			7 (Moderate Local Risk)	
5+				

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pest based on Q1.

National Element (Table 4 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table-4 (c) Framework for Q-2 national element-OSR Scinario-1

Pest Mobility & Spread Factors	**Factors to Consider**	**Unfavourable Conditions (Limited spread, containment possible)**	**Moderate Conditions (Potential for spread under certain conditions)**	**Favourable Conditions (High risk of rapid and widespread infestation)**	**Reasons**
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	- Pest relies on direct contact or short-range movement. - No natural dispersal mechanisms. -Requires human or animal movement for spread.				9 out of 14 pathogens are considered highly mobile.
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade).				

	- Could establish in nearby areas under suitable conditions.				
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.			11 (High Spread Risk)	

Local Element (Table-4 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).

Table-4 (d) Framework for Q-2 local element-OSR Scinario-1

Local	**Factors to Consider**	**Low Local Spread Risk (Conditions limit spread)**	**Moderate Local Spread Risk (Conditions could facilitate spread)**	**High Local Spread Risk (Conditions highly conducive to spread)**	**Reasons**
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.		6 (Low Local Spread Risk)		Out of 9 highly mobile pests and pathogens, 5 of them are insects that are sensitive to climatic conditions.
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.		6 (Low Local Spread Risk)		
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.		6 (Moderate Local Spread Risk)		

Q-3 What is the maximum ability to control the pest/disease associated with this crop?
Note: Assess the feasibility of managing pests associated with the crop (e.g., availability of control options and their ability to manage pests) Consider the major pest based on Q1.

National Element (Table 4 (e)) (0–15): Based on general knowledge of pest management options.
0–5: Easy to manage (effective control methods are available).
6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).
11–15: Difficult to manage (few or no effective control methods).

Table-4 (e) Framework for Q-3 national element-OSR Scinario-1

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**	**Reasons**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).			8 (Few or no effective control methods available)	Restriction of neonicotinoid seed treatments and widespread pyrethroid resistance in CSFB have created a critical gap. Effective, reliable controls are largely unavailable.
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.			8 (Expensive or labour-intensive methods with limited effectiveness)	Reliance on multiple sprays, delayed sowing, and intensive monitoring is costly and labour-intensive, yet offers limited and unreliable effectiveness.
Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g.,		3 (Some pest resistance, but manageable)		While CSFB resistance is severe, resistance in other key pests (e.g., pollen beetles) is

	pesticide resistance, failure of biological control).				less widespread, and fungicides remain partially effective for now.
Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).		6 (Some pest resistance, but manageable)		Good resistance exists for diseases like Phoma and Light Leaf Spot, but no effective varietal resistance is available for the primary pest, CSFB.
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.		7 (Methods available but not optimal or cost-efficient)		Management is possible but fragile, inefficient, and costly.

Local Element (Table 4 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).

Table-4 (f) Framework for Q-3 local element-OSR Scinario-1

Local Factors	**Factors to Consider**	**High Local Management Capacity (Well-resourced and knowledgeable)**	**Moderate Local Management Capacity (Some resources and knowledge available)**	**Low Local Management Capacity (Limited resources and knowledge)**	**Reasons**
Access to Resources	- Availability of pesticides, equipment, and technology.		7 (Moderate access to resources)		Again, the restriction to neonicotinoids plays a significant role.
Access to Expertise	- Availability of local experts, training, and support networks.	2 (High access to local expertise)			Strong support networks (SRUC, AHDB, agronomists) provide excellent, accessible advice and training
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.		5 (Farmers have basic knowledge but may lack advanced skills)		Foundation knowledge is good, but the universal knowledge is a bit uncertain.
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.		5 (Moderate local capacity)		Strong expertise is undermined by a lack of effective control tools, resulting in a moderate overall capacity to manage pests successfully.

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

National Element (Table4 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.
0–5: Low downstream risk (positive impact on soil health).
6–10: Moderate downstream risk (neutral or slightly negative impact on soil health).
11–15 High downstream risk (significant negative impact soil health).

Table-4 (g) Framework for Q-4 national element -OSR Scinario-1

Downstream Impact Factors	**Factors to Consider**	**Low Downstream Risk (Positive impact)**	**Moderate Downstream Risk (Neutral/slightly negative impact)**	**High Downstream Risk (Significant negative impact)**	**Reason**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests			7 (encourages more disease)	It acts as a carrier for the soilborne pathogens
Biodiversity Impact	- Effect on species richness, pollinators, and habitat availability.			7 (Reduces biodiversity, disrupts ecosystems)	Limited value for biodiversity. With monoculture bloom, this shifts the biodiversity in pollinators.
Soil Health Impact	- Effect on soil structure, nutrient retention, and microbial activity.		6 (Neutral or slightly degrades soil health)		No positive or negative impacts were observed

Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.		5 (Neutral or minor imbalance, moderate degradation of the residue)		No positive or negative impacts were observed. However, this crop required high input of fertilisers.
Overall Downstream Environmental Risk	- The combined impact on soil health.		6 (Moderate risk)		Mixed impacts, but the potential for disease carry-over and biodiversity loss creates a moderate risk.

Local Element (Table 4 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).

Table-4 (h) Framework for Q-4 local element-OSR Scinario-1

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-positive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**	**Reasons**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests			7 (encourages more disease)	Disease carryover. Especially the soilborne pathogens

Local Biodiversity Impact	- Effect on native species, pollinators, and ecosystem balance.			7 (Significant loss of biodiversity, ecosystem imbalance)	Limited value for biodiversity. With monoculture bloom, this shifts the biodiversity in pollinators.
Local Soil Health Impact	- Soil structure, organic matter retention, and fertility changes.		5 (Some degradation, but can be mitigated)		No positive or negative impacts were observed
Soil Type Suitability	- Suitability of local soil for sustainable cultivation without degradation.		5 (Some suitability concerns, but manageable)		No positive or negative impacts were observed
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.		5 (Neutral or minor imbalance, moderate degradation of the residue)		No positive or negative impacts were observed. However, this crop required high input of fertilisers.
Overall Local Downstream Risk	- The combined impact on local soil health.		6 (Moderate risk)		Mixed impacts, but the potential for disease carry-over and biodiversity loss creates a moderate risk.

Table 5-Overall score-OSR scenario-1

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	15	7	**22**
Q-2	11	**6**	**17**
Q-3	7	**5**	**12**
Q-4	6	6	**12**

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Appendix-3- Framework score for oilseed rape for Scenario 2.

Table -6 List of pathogens and their biology

Mobility	Pathogen / Pest Name	Biology
High Mobility	Light Leaf Spot	Airborne spores
	Sclerotinia Stem Rot	Airborne spores
	Clubroot	Soil-borne (resting spores persist for more than 7 years)
	Cabbage Stem Flea Beetle (CSFB)	Flying insect
	Aphids	Flying insect
	Turnip Yellows Virus (TuYV)	Vector-borne
Moderate Mobility	Downy Mildew	Airborne spores and water-splashed
	Cabbage Seed Weevil	Flying insect
	Pollen Beetle	Flying insect
	Phoma Stem Canker	Rain-splashed spores
	Cabbage Root Fly	Flying insect
Low Mobility	Verticillium Stripe	Soil-borne and seed-borne
	Slugs	Crawling
	Wireworms	Soil-dwelling

Verticillium Stripe has been identified in various parts of the world, but it was considered to have little/no impact on OSR in the UK. CSFB and aphids are considered less impact due to the prevalence of insecticides.

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?
Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score.

National Element (Table 7 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table-7 (a) Framework for Q-1 national element-OSR Scinario-2

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)	Reasons
1–2				At this time, OSR was new to the UK and it was disease-free. However, various parts of the world have identified most of the pathogens.
3-5				
6-8				
9+			15 (High Risk)	

Local Element (Table 7 (b) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests).

Table-7 (b) Framework for Q-1 local element-OSR Scinario-2

Number of Known Pests	Unfavourable Climate (Pests struggle to survive)	Moderately Suitable Climate (Pests can survive but not thrive)	Highly Suitable Climate (Ideal conditions for pest proliferation)	Reasons
0-1				The cooler Scottish climate provided some natural suppression of pest populations compared to warmer regions, though conditions remained favourable for key diseases like light leaf spot.
2-4				
5+	7 (Moderate Local Risk)			

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pest based on Q1

National Element (Table 7 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table-7 (c) Framework for Q-2 national element-OSR Scinario-2

Pest Mobility & Spread Factors	**Factors to Consider**	**Unfavourable Conditions (Limited spread, containment possible)**	**Moderate Conditions (Potential for spread under certain conditions)**	**Favourable Conditions (High risk of rapid and widespread infestation)**	**Reasons**
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	- Pest relies on direct contact or short-range movement. - No natural dispersal mechanisms. - Requires human or animal movement for spread.				The biology and the mobility of all the key pathogens were well studied. But it wasn't established in the field of the UK
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade).				

	- Could establish in nearby areas under suitable conditions.				
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.			11 (High Spread Risk)	

Local Element (Table 7 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).

Table-7 (d) Framework for Q-2 local element-OSR Scinario-2

Local	Factors to Consider	Low Local Spread Risk (Conditions limit spread)	Moderate Local Spread Risk (Conditions could facilitate spread)	High Local Spread Risk (Conditions highly conducive to spread)	Reasons
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.				Local landscape features and farming patterns provided some natural containment, though the potential for spread between fields remained moderate.
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.				
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.		6 (Moderate Local Spread Risk)		

Q-3 What is the maximum ability to control the pest/disease associated with this crop?
Note: Assess the feasibility of managing pests associated with the (e.g., availability of control options and their ability to manage pests)
Consider the major pest based on Q1.

National Element (Table 7 (e)) (0–15): Based on general knowledge of pest management options.
0–5: Easy to manage (effective control methods are available).
6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).
11–15: Difficult to manage (few or no effective control methods).

Table-7 (e) Framework for Q-3 national element-OSR Scinario-2

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**	**Reasons**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).		6 (Control methods available but costly or labour-intensive)		Effective controls are available but mostly chemical, so it is expensive.
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.		6 (Control methods available but costly or labour-intensive)		It is labour-intensive because this crop requires high inputs.
Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g., pesticide resistance, failure of biological control).	0 (No significant resistance to treatments)			No significant resistance to treatments.

Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).	0			Few varieties were available at that time.
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.		5 (Methods available but not optimal or cost-efficient)		Effective control methods are available, but slightly expensive.

Local Element (Table 7 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).

Table-7 (f) Framework for Q-3 local element-OSR Scinario-2

Local Factors	Factors to Consider	High Local Management Capacity (Well-resourced and knowledgeable)	Moderate Local Management Capacity (Some resources and knowledge available)	Low Local Management Capacity (Limited resources and knowledge)	Reasons
Access to Resources	- Availability of pesticides, equipment, and technology.		5 (Moderate access to resources)		Moderate access to resources.
Access to Expertise	- Availability of local experts, training, and support networks.		5 (Some access to expertise, but gaps may exist)		Some access to expertise, but gaps may exist. Because the crop is new to the environment.
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.		4 (Farmers have basic knowledge but may lack advanced skills)		Farmers have basic knowledge but may lack advanced skills.
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.		5 (Moderate local capacity)		Moderate local capacity.

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

National Element (Table 7 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.
0–5: Low downstream risk (positive impact on soil health).
6–10: Moderate downstream risk (neutral or slightly negative impact soil health).
11–15 High downstream risk (significant negative impact soil health).

Table-7 (g) Framework for Q-4 national element-OSR Scinario-2

Downstream Impact Factors	**Factors to Consider**	**Low Downstream Risk (Positive impact)**	**Moderate Downstream Risk (Neutral/slightly negative impact)**	**High Downstream Risk (Significant negative impact)**	**Reasons**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests			7 (encourages more disease)	It acts as a carrier for the soilborne pathogens.
Biodiversity Impact	- Effect on species richness, pollinators, and habitat availability.			7 (Reduces biodiversity, disrupts ecosystems)	Limited value for biodiversity. With monoculture bloom, this shifts the biodiversity in pollinators.
Soil Health Impact	- Effect on soil structure, nutrient retention, and microbial activity.		6 (Neutral or slightly degrades soil health)		No positive or negative impacts were observed
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.		5 (Neutral or minor imbalance, moderate degradation of the residue)		No positive or negative impacts were observed. However, this crop required high input of fertilisers.
Overall Downstream Environmental Risk	- The combined impact on soil health.		6 (Moderate risk)		Mixed impacts, but the potential for disease carry-over and biodiversity loss creates a moderate risk.

Local Element (Table 7 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).

Table-7 (h) Framework for Q-4 local element-OSR Scinario-2

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-positive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**	**Reasons**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests			7 (encourages more disease)	Disease carryover. Especially the soilborne pathogens
Local Biodiversity Impact	- Effect on native species, pollinators, and ecosystem balance.			7 (Significant loss of biodiversity, ecosystem imbalance)	Limited value for biodiversity. With monoculture bloom, this shifts the biodiversity in pollinators.
Local Soil Health Impact	- Soil structure, organic matter retention, and fertility changes.		5 (Some degradation, but can be mitigated)		No positive or negative impacts were observed
Soil Type Suitability	- Suitability of local soil for sustainable cultivation without degradation.		5 (Some suitability concerns, but manageable)		No positive or negative impacts were observed
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.		5 (Neutral or minor imbalance, moderate degradation of the residue)		No positive or negative impacts were observed. However, this crop required high input of fertilisers.

Overall Local Downstream Risk	- The combined impact on local soil health.		6 (Moderate risk)		Mixed impacts, but the potential for disease carry-over and biodiversity loss creates a moderate risk.

Table 8: Overall score-OSR scenario-2

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	12 (High)	6	**18**
Q-2	10 (High)	**6**	**16**
Q-3	5 (Moderate)	**5**	**10**
Q-4	6 (Moderate)	6	**12**

Reason: OSR is considered to be a crop that is prone to numerous pests and diseases. Scenarios 1 & 2 were scored almost similarly. Although OSR was disease-free in the UK at the time of introduction, various other parts of the world have identified and reported most of the pests and diseases that are affecting OSR now. However, the difference in the score is visible in the Q3 score regarding the available control methods. This is due to the ban on a few pesticides, especially the neonicotinoids.

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Appendix 4- Framework score for sugar beet.

Table -9 List of pathogens and their biology

Type	**Disease / Pest**	**Mobility**
Soil-borne / Very Low Mobility	Beet cyst nematode (*Heterodera schachtii*)	Soil-borne; cysts persist in soil for many years and spread via soil movement (machinery, water, or plants).
	Rhizomania (*Beet necrotic yellow vein virus* via *Polymyxa betae*)	Soil-borne; virus transmitted by *P. betae* resting spores that persist in soil for long periods.
	Fusarium spp. (root rots)	Soil-borne fungi causing root rots; spread through infected soil and plant residues.
	Rhizoctonia solani	Soil-borne; infects roots and crowns; spreads slowly via soil contact.
Local / Intermediate Mobility	Cercospora leaf spot (*Cercospora beticola*)	Airborne or rain-splashed spores; moderate local spread within and between nearby fields.
	Powdery mildew (*Erysiphe betae*)	Airborne spores; spread locally by wind currents under warm, dry conditions.
	Ramularia leaf spot (*Ramularia beticola*)	Spread by wind and rain splash; infections generally localised.
	Beet leaf miner (*Pegomya hyoscyami*)	Limited adult flight; larvae mine leaves; spread confined to nearby crops.
High Mobility / Vector-borne / Airborne	Virus yellows complex (e.g. *Beet yellows virus*, *Beet mild yellowing virus*, *Beet chlorosis virus*)	Transmitted by aphid vectors (*Myzus persicae*, *Aphis fabae*); rapid regional spread via migration of winged aphids.
	Aphids (*Myzus persicae*, *Aphis fabae*, etc.)	Flying insects; winged forms migrate long distances on wind currents.
	Rusts (*Uromyces betae*, etc.)	Airborne urediniospores dispersed over long distances by wind.

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?
Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score.

National Element (Table 10 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table-10 (a) Framework for Q-1 national element-Sugar beet

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)	Reasons
1–2				
3-5				
6-8				
9+		11 (High Risk)		

Local Element (Table 10 (b)) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests)

Table-10 (b) Framework for Q-1 local element-Sugar beet

Number of Known Pests	Unfavourable Climate (Pests struggle to survive)	Moderately Suitable Climate (Pests can survive but not thrive)	Highly Suitable Climate (Ideal conditions for pest proliferation)	Reasons
0-1				
2-4				
5+			10 (High Local Risk)	

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pest based on Q1

National Element (Table 10 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table-10 (c) Framework for Q-2 national element-Sugar beet

Pest Mobility & Spread Factors	Factors to Consider	Unfavourable Conditions (Limited spread, containment possible)	Moderate Conditions (Potential for spread under certain conditions)	Favourable Conditions (High risk of rapid and widespread infestation)	Reasons
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	- Pest relies on direct contact or short-range movement. - No natural dispersal mechanisms. - Requires human or animal movement for spread.				
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade). - Could establish in nearby areas under suitable conditions.				
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.			12 (High Spread Risk)	

Local Element (Table 10 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).

Table-10 (d) Framework for Q-2 local element-Sugar beet

Local	Factors to Consider	Low Local Spread Risk (Conditions limit spread)	Moderate Local Spread Risk (Conditions could facilitate spread)	High Local Spread Risk (Conditions highly conducive to spread)	Reasons
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.				
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.				
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.		4 (Moderate Local Spread Risk)		

Q-3 What is the maximum ability to control the pest/disease associated with this crop?
Note: Assess the feasibility of managing pests associated with the crop (e.g., availability of control options and their ability to manage pests)
Consider the major pest based on Q1

National Element (Table 10 (e)) (0–15): Based on general knowledge of pest management options.
0–5: Easy to manage (effective control methods are available).
6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).
11–15: Difficult to manage (few or no effective control methods).

Table-10 (e) Framework for Q-3 national element-Sugar beet

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**	**Reasons**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).		5 (Control methods available but costly or labour-intensive)		
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.		5 (Control methods available but costly or labour-intensive)		
Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g., pesticide resistance, failure of biological control).		6 (Some pest resistance, but manageable)		
Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).		6 (Some resistant varieties available)		
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.		6		

Local Element (Table 10 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).

Table-10 (f) Framework for Q-3 local element-Sugar beet

Local Factors	**Factors to Consider**	**High Local Management Capacity (Well-resourced and knowledgeable)**	**Moderate Local Management Capacity (Some resources and knowledge available)**	**Low Local Management Capacity (Limited resources and knowledge)**	**Reasons**
Access to Resources	- Availability of pesticides, equipment, and technology.		5 (Moderate access to resources)		
Access to Expertise	- Availability of local experts, training, and support networks.		5 (Some access to expertise, but gaps may exist)		
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.		5 (Farmers have basic knowledge but may lack advanced skills)		
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.		5 (Moderate local capacity)		

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

National Element (Table 10 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.
0–5: Low downstream risk (positive impact on soil health).
6–10: Moderate downstream risk (neutral or slightly negative impact soil health).
11–15 High downstream risk (significant negative impact on soil health).

Table-10 (g) Framework for Q-4 national element-Sugar beet

Downstream Impact Factors	Factors to Consider	Low Downstream Risk (Positive impact)	Moderate Downstream Risk (Neutral/slightly negative impact)	High Downstream Risk (Significant negative impact)	Reasons
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests				
Biodiversity Impact	- Effect on species richness, pollinators, and habitat availability.				
Human Nutrients Impact	- Nutrient density, dietary benefits compared to existing crops		3		
Soil Health Impact	- Effect on soil structure, nutrient retention, and microbial activity.	2 (Improves or maintains soil health)			
Water & Nutrient Use Efficiency	- Crop's impact on water retention, nutrient runoff, and pollution.			7 (High water/nutrient demand, pollution risk)	
Overall Downstream Environmental Risk	- The combined impact on soil health.	4 (Low risk)			

Local Element (Table 10 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).

Table-10 (h) Framework for Q-4 local element-Sugar beet

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-positive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**	**Reasons**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests				
Local Biodiversity Impact	- Effect on native species, pollinators, and ecosystem balance.				
Local Soil Health Impact	- Soil structure, organic matter retention, and fertility changes.				
Soil Type Suitability	- Suitability of local soil for sustainable cultivation without degradation.				
Overall Local Downstream Risk	- The combined impact on local soil health.	3 (Low risk)			

Table 11: Overall score-Sugar beet

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	11 (High)	10	21
Q-2	12	4	16
Q-3	6	5	11
Q-4	4	3	10

Reason: Growing sugar beet in Scotland carries a high plant health risk due to the crop's susceptibility to several diseases and pests that are exacerbated by the region's cool, wet climate. Prolonged moisture increases the risk of soil-borne fungal infections such as *Rhizoctonia solani*, which causes crown and root rot, and *Pythium* species, which can lead to damping-off in young plants. Additionally, foliar diseases like powdery mildew and cercospora leaf spot can thrive in damp conditions, reducing yield and sugar content. The potential spread of virus yellows, transmitted by aphids, also presents a significant risk. Given these vulnerabilities and the intensive management required to mitigate them, sugar beet cultivation in Scotland involves substantial plant health challenges.

Appendix 5- Framework score for hemp.

Table -12 List of pathogens and their biology

Mobility Type	Disease / Pest	Biology
Soil-borne / Very Low Mobility	Fusarium oxysporum, Fusarium solani (root and stem rots)	Soil-borne fungi; infect through roots; spread slowly via contaminated soil, debris, or irrigation water.
	Pythium spp. (seedling damping-off)	Soil-borne oomycetes; spread via infested soil and water; mobility limited to soil movement and water flow.
	Rhizoctonia solani (root and stem rot)	Soil-borne; persists in plant residues; spread through soil contact or infected debris.
	Verticillium albo-atrum / V. dahliae (wilt)	Soil-borne; long-lived microsclerotia; spread by movement of contaminated soil or tools.
Local / Intermediate Mobility	Botrytis cinerea (grey mould)	Airborne conidia spread locally under humid conditions; thrives in dense canopies.
	Alternaria alternata (leaf spot)	Spores dispersed by wind and rain splash; moderate local spread.
	Powdery mildew (Golovinomyces cichoracearum or Leveillula taurica)	Airborne spores; spread locally by wind currents; infection favoured by warm, dry air.
	Sclerotinia sclerotiorum (stem rot)	Airborne ascospores from soil sclerotia; moderate range via wind and water splash.
	Hemp flea beetle (Psylliodes attenuata)	Adult beetles with limited flight ability; local spread between adjacent crops.

Mobility Type	Disease / Pest	Biology
High Mobility / Vector-borne / Airborne	Aphids (Myzus persicae, Phorodon cannabis)	Winged forms migrate long distances; vectors of several viruses.
	Cannabis aphid (Phorodon cannabis)	Highly mobile flying insect; vector for hemp mosaic and latent viruses.
	Whiteflies (Trialeurodes vaporariorum, Bemisia tabaci)	Flying insects; high dispersal potential under warm greenhouse conditions.
	Hemp mosaic viruses (e.g., Cannabis cryptic virus, Hemp streak virus)	Transmitted by sap-feeding insects (aphids/whiteflies); spread regionally with vectors.
	Thrips (Frankliniella occidentalis, Thrips tabaci)	Winged insects; capable of regional movement on air currents; vector some minor viruses.
	Two-spotted spider mite (Tetranychus urticae)	Crawling arthropod but capable of ballooning; moderate to high mobility in warm, dry conditions.

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?
Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score

National Element (Table 13 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table-13 (a) Framework for Q-1 national element-Hemp

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)	Reasons
1–2				
3-5				
6-8				
9+	8 (Moderate Risk)			

Local Element (Table 13 (b)) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests).

Table-13 (b) Framework for Q-1 local element-Hemp

Number of Known Pests	Unfavourable Climate (Pests struggle to survive)	Moderately Suitable Climate (Pests can survive but not thrive)	Highly Suitable Climate (Ideal conditions for pest proliferation)	Reasons
0-1				
2-4				
5+	6 (Moderate Local Risk)			

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pest based on Q1

National Element (Table 13 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table-13 (c) Framework for Q-2 national element-Hemp

Pest Mobility & Spread Factors	Factors to Consider	Unfavourable Conditions (Limited spread, containment possible)	Moderate Conditions (Potential for spread under certain conditions)	Favourable Conditions (High risk of rapid and widespread infestation)	Reasons
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	- Pest relies on direct contact or short-range movement. - No natural dispersal mechanisms. - Requires human or animal movement for spread.		3(Low Spread Risk)		
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade).		6 (Moderate Spread Risk)		

	- Could establish in nearby areas under suitable conditions.				
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.	6 (Moderate Spread Risk)			

Local Element (Table 13 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).

Table-13 (d) Framework for Q-2 local element-Hemp

Local	Factors to Consider	Low Local Spread Risk (Conditions limit spread)	Moderate Local Spread Risk (Conditions could facilitate spread)	High Local Spread Risk (Conditions highly conducive to spread)	Reasons
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.		3 (Low Local Spread Risk)		
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.		3 (Low Local Spread Risk)		
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.	3 (Low Local Spread Risk)			

Q-3 What is the maximum ability to control the pest/disease associated with this crop?
Note: Assess the feasibility of managing pests associated with the crop (e.g., availability of control options and their ability to manage pests) Consider the major pest based on Q1.

National Element (Table 13 (e)) (0–15): Based on general knowledge of pest management options.
0–5: Easy to manage (effective control methods are available).
6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).
11–15: Difficult to manage (few or no effective control methods).

Table-13 (e) Framework for Q-3 national element-Hemp

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**	**Reasons**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).		5 (Control methods available but costly or labour-intensive)		
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.		6 (Control methods available but costly or labour-intensive)		
Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g., pesticide resistance, failure of biological control).		7 (Some pest resistance, but manageable)		
Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).			9 (No resistant varieties or limited options)	
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.		7 (Methods available but not optimal or cost-efficient)		

Local Element (Table 13 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).

Table-13 (f) Framework for Q-3 local element-Hemp

Local Factors	**Factors to Consider**	**High Local Management Capacity (Well-resourced and knowledgeable)**	**Moderate Local Management Capacity (Some resources and knowledge available)**	**Low Local Management Capacity (Limited resources and knowledge)**	**Reasons**
Access to Resources	- Availability of pesticides, equipment, and technology.	2 (Highly accessible resources)			
Access to Expertise	- Availability of local experts, training, and support networks.	2 (High access to local expertise)			
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.	2 (Farmers are well-trained and knowledgeable)			
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.	2 (High local capacity)			

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

National Element (Table 13 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.
0–5: Low downstream risk (positive impact on soil health).
6–10: Moderate downstream risk (neutral or slightly negative impact soil health).
11–15 High downstream risk (significant negative impact on soil health).

Table-13 (g) Framework for Q-4 national element-Hemp

Downstream Impact Factors	Factors to Consider	Low Downstream Risk (Positive impact)	Moderate Downstream Risk (Neutral/slightly negative impact)	High Downstream Risk (Significant negative impact)	Reasons
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests				
Biodiversity Impact	- Effect on species richness, pollinators, and habitat availability.	1 (Enhances biodiversity)			
Human Nutrients Impact	- Nutrient density, dietary benefits compared to existing crops				
Soil Health Impact	- Effect on soil structure, nutrient retention, and microbial activity.	2 (Improves or maintains soil health)			
Water & Nutrient Use Efficiency	- Crop's impact on water retention, nutrient runoff, and pollution.		4 (Moderate water/nutrient demand)		
Overall Downstream Environmental Risk	- The combined impact on soil health.	3 (Low risk)			

Local Element (Table 13 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).

Table-13 (h) Framework for Q-4 local element-Hemp

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-positive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**	**Reasons**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests				
Local Biodiversity Impact	- Effect on native species, pollinators, and ecosystem balance.	2 (Enhances or maintains biodiversity)			
Local Soil Health Impact	- Soil structure, organic matter retention, and fertility changes.	2 (Maintains or improves soil health)			
Soil Type Suitability	- Suitability of local soil for sustainable cultivation without degradation.	2 (Soils are well-suited for the crop)			
Overall Local Downstream Risk	- The combined impact on soil health.	2 (Low risk)			

Table 14: Overall score-Hemp

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	8 (Moderate)	6	14
Q-2	6 (Moderate)	3	9
Q-3	7 (Moderate)	2	9
Q-4	3 (low)	2	5

Reason: The plant health risk associated with growing hemp in Scotland was considered low due to the crop's novelty in the region that limits the spread of many pathogens, and its natural resilience. Hemp grows quickly and densely, which helps suppress weeds and reduces the need for herbicides. While monitoring for potential issues like grey mould (*Botrytis*) or aphids is still necessary, the overall risk to plant health remains reduced, making hemp a robust and low-risk option for cultivation in Scotland.

Appendix 6- Framework score for mustard as a cover crop.

Table 15: List of pathogens and their biology

Mobility	Pathogen / Pest Name	Biology
High Mobility	Light Leaf Spot	Airborne spores
	Sclerotinia Stem Rot	Airborne spores
	Clubroot	Soil-borne (resting spores persist for more than 7 years)
	Cabbage Stem Flea Beetle (CSFB)	Flying insect
	Aphids	Flying insect
	Turnip Yellows Virus (TuYV)	Vector-borne
Moderate Mobility	Downy Mildew	Airborne spores and water-splashed
	Cabbage Seed Weevil	Flying insect
	Pollen Beetle	Flying insect
	Phoma Stem Canker	Rain-splashed spores
	Cabbage Root Fly	Flying insect
Low Mobility	Verticillium Stripe	Soil-borne and seed-borne
	Slugs	Crawling
	Wireworms	Soil-dwelling

This list closely aligns with that of OSR. While certain pests such as CSFB, aphids, and TuYV are currently less prevalent in Scotland, rising temperatures associated with climate change could increase their presence and impact, making them potential pests of significant concern in the future.

Q-1 What is the maximum potential plant health risk associated with the introduction of this new crop?
Note: consider the potential likelihood of introducing or attracting pests (this includes insect diseases, weeds and other harmful agents)-use the matrix to score.

National Element (Table 16 (a)) (0–15): Based on general knowledge of the crop's pest risks.
0–5: Low risk (few known pests associated with the crop).
6–10: Moderate risk (some known pests, but manageable).
11–15: High risk (many known pests, including invasive species).

Table-16 (a) Framework for Q-1 national element-mustard as a cover crop

Number of Known Pests	Minimal Impact (Cosmetic damage, no yield loss)	Moderate Impact (Yield reduction, requires management)	Severe Impact (High yield loss, crop failure risk)	Reason
1–2				Mustard, as a brassica, shares numerous pests with OSR. These pose a severe risk of yield loss and crop failure in subsequent brassica cash crops by acting as a carrier of soil pathogens.
3-5				
6-8				
9+			15 (High Risk)	

Local Element (Table 16 (b)) (0–10): Adjust based on local conditions (e.g., existing pest populations, climate suitability for pests).
0–3: Low local risk (local conditions are unfavourable for pests).
4–7: Moderate local risk (some local conditions favour pests).
8–10: High local risk (local conditions are highly favourable for pests).

Table-16 (b) Framework for Q-1 local element-mustard as a cover crop

Number of Known Pests	Unfavourable Climate (Pests struggle to survive)	Moderately Suitable Climate (Pests can survive but not thrive)	Highly Suitable Climate (Ideal conditions for pest proliferation)	Reason
0-1				Scotland's cool, wet climate is highly suitable for the proliferation of key pathogens like Light Leaf Spot, Sclerotinia and also pests like slugs. On the other hand, cold can negative impact on various insect pests.
2-4			7 (Moderate Local Risk)	
5+				

Q-2 What is the maximum potential of pests associated with this crop that could spread to other crops, regions and other ecosystems?
Note: Consider the major pest based on Q1.

National Element (Table 16 (c)) (0–15)**:** Based on the crop's characteristics and pest biology.
0–5: Low spread potential (pests are unlikely to spread).
6–10: Moderate spread potential (pests could spread under certain conditions).
11–15: High spread potential (pests are highly mobile or invasive).

Table-16 (c) Framework for Q-2 national element-mustard as a cover crop

Pest Mobility & Spread Factors	**Factors to Consider**	**Unfavourable Conditions (Limited spread, containment possible)**	**Moderate Conditions (Potential for spread under certain conditions)**	**Favourable Conditions (High risk of rapid and widespread infestation)**	**Reasons**
Low Mobility Pests (e.g., soil-borne pests, localised insect species)	-Pest relies on direct contact or short-range movement. -No natural dispersal mechanisms. -Requires human or animal movement for spread.				The major risks are highly mobile.
Moderate Mobility Pests (e.g., wind-dispersed fungi, pests with moderate travel ability)	- Can spread via wind, water, or moderate movement. - May be assisted by human activity (e.g., transport, trade).				

	- Could establish in nearby areas under suitable conditions.				
Highly Mobile/Invasive Pests (e.g., airborne pathogens, migratory pests like locusts)	- High dispersal ability (e.g., airborne spores, long-distance flying insects). - Can spread rapidly through trade, wind, water, or human activity. - Establishes easily in new environments, even with minimal introduction.			10 (High Spread Risk)	

Local Element (Table 16 (d)) (0–10): Adjust based on local factors (e.g., proximity to other crops, natural barriers).
0–3: Low local spread risk (local conditions limit pest spread).
4–7: Moderate local spread risk (some local conditions could facilitate spread).
8–10: High local spread risk (local conditions are highly conducive to pest spread).

Table-16 (d) Framework for Q-2 local element-mustard as a cover crop

Local	Factors to Consider	Low Local Spread Risk (Conditions limit spread)	Moderate Local Spread Risk (Conditions could facilitate spread)	High Local Spread Risk (Conditions highly conducive to spread)	Reasons
Proximity to Other Crops	- Distance to neighbouring susceptible crops. - Presence of buffer crops or space between crops.		6		The natural barrier would make this a moderate risk compared to the one without barriers.
Natural Barriers	- Presence of mountains, rivers, or other natural barriers to pest movement. - Wind patterns that could impede pest spread.		6		
Combination of Local Factors	- Combination of proximity to other crops and natural barriers. - Assessment of overall risk based on proximity and barrier presence.		6 (Moderate Local Spread Risk)		

Q-3 What is the maximum ability to control the pest/disease associated with this crop?
Note: Assess the feasibility of managing pests associated with the crop (e.g., availability of control options and their ability to manage pests) Consider the major pest based on Q1.

National Element (Table 16 (e)) (0–15): Based on general knowledge of pest management options.
0–5: Easy to manage (effective control methods are available).
6–10: Moderately difficult to manage (some control methods exist but may be costly or labour-intensive).
11–15: Difficult to manage (few or no effective control methods).

Table-16 (e) Framework for Q-3 national element-mustard as a cover crop

Pest Management Factors	**Factors to Consider**	**Easy to Manage (Effective control methods are available)**	**Moderately Difficult to Manage (Some control methods exist, but may be costly or labour-intensive)**	**Difficult to Manage (Few or no effective control methods)**	**Reasons**
Availability of Control Methods	- Availability and effectiveness of control methods (e.g., pesticides, biological control, physical barriers).			8 (Few or no effective control methods available)	For a non-cash crop, the application of chemical control is not a viable option. On another, it is a carrier for various soil-borne pathogens.
Cost and Labor	- Cost-effectiveness and labour intensity of available control methods.			8 (Expensive or labour-intensive methods with limited effectiveness)	Any control method would be expensive and labour-intensive for a crop with no direct financial return, making it impractical.
Resistance to Treatments	- Degree of pest resistance to existing control methods (e.g.,		3 (Some pest resistance, but manageable)		This is similar to OSR when it is considered for pesticides.

	pesticide resistance, failure of biological control).				
Resistance Variety (Crop Resistance)	- Availability of resistant crop varieties (e.g., pest-resistant plant strains or varieties).		6 (Some pest resistance, but manageable)		This is a key mitigating factor. Specifically, White Mustard (*Sinapis alba*) offers good resistance to Clubroot, providing a targeted management option for that specific pathogen.
Overall Feasibility	- Overall feasibility of managing pest populations with available methods and resistant varieties.		7 (Methods available but not optimal or cost-efficient)		It is considered moderate because the resistance variety is not available for all the diseases and pests.

Local Element (Table 16 (f)) (0–10): Adjust based on local resources and expertise.
0–3: High local management capacity (local farmers have the resources and knowledge to manage pests).
4–7: Moderate local management capacity (some resources and knowledge are available).
8–10: Low local management capacity (local farmers lack resources or expertise to manage pests).

Table-16 (f) Framework for Q-3 local element-mustard as a cover crop

Local Factors	Factors to Consider	High Local Management Capacity (Well-resourced and knowledgeable)	Moderate Local Management Capacity (Some resources and knowledge available)	Low Local Management Capacity (Limited resources and knowledge)	Reasons
Access to Resources	- Availability of pesticides, equipment, and technology.			8 (Limited access to resources)	The high cost and lack of economic return for treating a cover crop.
Access to Expertise	- Availability of local experts, training, and support networks.	2 (High access to local expertise)			Strong support networks (SRUC, AHDB, agronomists) provide excellent, accessible advice and training
Farmer Knowledge & Skills	- Local farmers' knowledge of pest management practices and skills.		5 (Farmers have basic knowledge but may lack advanced skills)		Scottish farmers are generally knowledgeable about pest lifecycles and the risks similar to OSR.
Overall Local Management Capacity	- The overall local capacity to manage pests based on available resources, knowledge, and support.		5 (Moderate local capacity)		Strong foundational knowledge is present, but it is critically undermined by the lack of economically viable control tools for a cover crop, resulting in a moderate overall capacity.

Q-4 what is the maximum downstream benefit associated with the cultivation of this crop?

National Element (Table 16 (g)) (0–15): Based on general knowledge of the crop's downstream impacts.
0–5: Low downstream risk (positive impact on soil health).
6–10: Moderate downstream risk (neutral or slightly negative impact soil health).
11–15 High downstream risk (significant negative impact on soil health).

Table-16 (g) Framework for Q-4 national element-mustard as a cover crop

Downstream Impact Factors	**Factors to Consider**	**Low Downstream Risk (Positive impact)**	**Moderate Downstream Risk (Neutral/slightly negative impact)**	**High Downstream Risk (Significant negative impact)**	**Reason**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests	1 (Enhances biocontrol activity)			Mustard can suppress some soil-borne pathogens and nematodes through biofumigation (if incorporated), which is a positive biocontrol contribution.
Biodiversity Impact	- Effect on species richness, pollinators, and habitat availability.		3 (Neutral or slightly reduces biodiversity)		Floral benefit is outweighed by the disease carrier potential.

Soil Health Impact	- Effect on soil structure, nutrient retention, and microbial activity.	2 (Enhances soil health)			crop, mustard improves soil structure, reduces erosion, and adds organic matter, directly enhancing soil health.
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.	2 (Improves nutrient cycling and fertility, residue			It captures residual soil nutrients (especially nitrogen), preventing leaching and recycling them for the next crop, improving nutrient use efficiency.
Overall Downstream Environmental Risk	- The combined impact on soil health.	1.5 (low)			The positive impacts on soil health, nutrient cycling, and potential biofumigation significantly outweigh the pest risks in this general assessment, indicating a net downstream benefit.

Local Element (Table 16 (h)) (0–10): Adjust based on local conditions (e.g., local biodiversity, economic needs).
0–3: Low local downstream risk (local conditions minimize negative impacts).
4–7: Moderate local downstream risk (some local conditions could lead to negative impacts).
8–10: High local downstream risk (local conditions are highly vulnerable to negative impacts).

Table-16 (h) Framework for Q-4 local element-mustard as a cover crop

Local Impact Factors	**Factors to Consider**	**Low Local Downstream Risk (Minimal negative-postive impacts)**	**Moderate Local Downstream Risk (Some negative impacts, but manageable)**	**High Local Downstream Risk (Significant negative impacts, high vulnerability)**	**Reason**
Biocontrol potential for any disease	- Crop's ability to control any diseases/pests	1 (Enhances biocontrol activity)			Similar to the national element
Local Biodiversity Impact	- Effect on native species, pollinators, and ecosystem balance.		3 (Some biodiversity loss, but within acceptable limits)		Similar to the national element
Local Soil Health Impact	- Soil structure, organic matter retention, and fertility changes.	2 (enhances soil health impact)			Improving soil structure is highly valuable in Scotland, where soils can be wet and prone to compaction.

Soil Type Suitability	- Suitability of local soil for sustainable cultivation without degradation.	1 (Soils are well-suited for the crop)			Mustard is adaptable and grows well on a range of soil types common in Scotland.
Nutrient Cycling, Residual Fertility and Management	-Effect of crop's influence on nutrient balance and fertility contribution.	1 (Improves nutrient cycling and fertility, residue decomposes easily)			Mustard is adaptable and grows well on a range of soil types common in Scotland.
Overall Local Downstream Risk	- The combined impact on local soil health.	1.6 (Low risk)			The local conditions in Scotland (soil types, climate challenges) mean the soil health and nutrient retention benefits of a mustard cover crop are highly valuable, representing a significant positive downstream impact.

Table 17: Overall score-Mustard as cover crop

Question	National (0-15)	Local (0-10)	Total (0-25)
Q-1	15 (High)	**7**	**22**
Q-2	10 (High)	**6**	**16**
Q-3	7 (Moderate)	**5**	**12**
Q-4	1.5 (Positive)	**1.6**	**3**

Reason: The score of mustard is almost similar to that of OSR in the current situation. This is because mustard and OSR are brassica crops and both of it are pronoun is similar pests and diseases. However, the major difference between them is the in Q-4 the mustard crop when ploughed and incorporated into the soil, releases thiocyanide components that have biocontrol properties against various soilborne pathogens.

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