LandWISE

Te Ahikawariki
Vegetable Industry Centre of Excellence

Cover Crop Adoption

Barriers, Motivations, and Implementation Challenges

Report for Te Ahikawariki Vegetable Industry Centre of Excellence

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This study was completed as part of the "Cover Crop options for vegetable growers -- preliminary scoping study" project. LandWISE was responsible for project management and compilation of data and report preparation. The collaborative nature of this research reflects the shared commitment across New Zealand's horticultural sector to evidence-based innovation and sustainable farming practices.

NOTE: Use of Artificial Intelligence Tools

The preparation of this report utilised Claude AI (Anthropic) for literature review organisation, citation management, and document formatting. The survey methodology was developed by the research team. Claude AI was used to process and integrate quantitative and qualitative data. All reviews, substantive analysis, data interpretation, and recommendations were confirmed and curated by the authors.

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Executive Summary

This study examined cover crop adoption barriers among 32 experienced New Zealand horticultural growers, purposively selected by regional agronomists as "growers of interest," to identify key obstacles and opportunities for increased implementation.

Growers rated factors on a 5-point importance scale, revealing that **practical implementation challenges—not technical or economic factors—represent the primary barriers to adoption**.

Key Findings

Critical Barriers (requiring immediate attention):

1. **Establishment reliability (3.46/4.0)** - The highest-scoring factor overall, with 95.8% rating it as high importance
2. **Ease of termination (2.98/4.0)** - Critical operational requirement, ranking third overall
3. **Biological risk factors** - Six pest/disease considerations rank in top 15, including disease green-bridge risk (2.67) and pest increase risk (2.73)

Critical Implementation Challenges (from current users):

1. **Not enough time between crops (2.85/4.0)** - The highest challenge score, with 70% rating as high importance
2. **Difficulty terminating cover crop (2.30/4.0)** - Validates termination as ongoing challenge
3. **Cover crop establishment (2.25/4.0)** - Confirms establishment reliability remains critical even for experienced growers

Primary Motivation:

1. **Soil structure improvement (3.38/4.0)** - Overwhelming consensus with 87.5% rating as high importance

Strategic Implications

The survey engaged primarily experienced growers (75% with cover crop experience averaging 23 years), selected by regional agronomists as "growers of interest." Even among this experienced group, operational timing constraints represent the greatest ongoing challenge.

The dedicated "Challenges" analysis reveals that "Not enough time between crops" (2.85) scores higher than most adoption barriers, indicating this is a fundamental system constraint rather than a learning curve issue.

These findings suggest that addressing operational constraints and practical implementation challenges should be prioritised over traditional information-focused extension approaches, though results should be interpreted within the context of the study's purposive sampling methodology.

Recommendations

Research and policy should prioritise:

1. Establishment reliability protocols (highest priority)
2. Termination technology development (second priority)
3. Biological risk management tools (integrated approach)
4. Technical optimisation research (important but secondary)

The findings indicate a three-tier priority framework where **operational timing constraints must be addressed first**, followed by practical implementation support, before technical optimisation becomes relevant. The challenges analysis reveals that even experienced growers face significant operational constraints, with timing pressures representing the highest-scoring challenge (2.85).

1 Introduction and Context

Cover crops enhance soil health, reduce erosion, improve biodiversity, and support long-term agricultural productivity. Understanding decision-making factors is essential for developing targeted policies and programs to increase adoption in New Zealand's horticultural sector.

1.1 Study Overview

This research was conducted as part of "Cover crop options for vegetable growers -- preliminary scoping study" by LandWISE and associates for Te Ahikawariki. The project engaged with 32 horticultural operations across five regions: Manawatu, Gisborne, Canterbury, Pukekohe, and Hawke's Bay. Together, the operations represent over 19,880 ha of farming.

Important Note: Growers were selected by regional agronomists as "growers of interest" based on research needs, not as representative samples of regional populations. This purposive sampling means results reflect experiences of growers with relevant insights rather than population averages.

1.2 Research Context

New Zealand has some of the world's most diverse crop rotations, combined with virtual elimination of winter fallow periods, which creates unique opportunities for cover crop integration. However, adoption barriers remain significant despite proven benefits.

International research reveals that adoption challenges extend beyond individual farm management to encompass broader agricultural system infrastructure. The distinction between field-level barriers (basic agronomic practices) and structural barriers (market and policy drivers) provides important context for New Zealand's situation.

2 Cover Crop Research and Adoption Barriers

2.1 Government Frameworks

2.1.1 MPI Policy and Research Framework

MPI's "Future Requirements for Soil Management in New Zealand" report identifies three major pressures on soil resources: intensification, land use change, and legacy effects from deforestation and climate change (MPI, 2015). This framework positions cover crops as a soil health strategy within recognition that soil is effectively a non-renewable resource requiring active protection. The report's focus on intensification pressures directly supports survey findings that growers prioritise soil structure improvement (3.38 mean score) as their primary motivation.

The Sustainable Farming Fund has supported 27 soil-related projects over 10 years, including ongoing Foundation for Arable Research cover crop studies on nitrogen management and pest integration (MPI, 2023). This farmer-led research approach validates the survey methodology and supports recommended extension strategies prioritising peer knowledge transfer over traditional research-extension models.

MPI's climate change framework recognises agriculture's unique contribution (>50% of national emissions) and funds regenerative agriculture through SFF Futures, including the Synlait-Danone-AgResearch partnership studying soil health across 10 farms in three regions (MPI, 2024). The partnership's focus on pasture diversity and reduced nitrogen fertiliser aligns directly with cover crop benefits identified by survey respondents.

Government co-ownership of OverseerFM® provides practical frameworks for quantifying cover crop benefits within existing farm management systems, addressing nitrogen immobilisation concerns (2.73 mean score) while providing economic valuation capabilities that growers identified as critical knowledge gaps (MPI, 2023). This institutional alignment demonstrates that survey recommendations for practical implementation support fit within established government priorities and funding mechanisms.

2.1.2 Ministry for the Environment Regulatory Framework

The Ministry for the Environment's National Policy Statement for Freshwater Management (NPS-FM) establishes mandatory water quality standards that create regulatory drivers for agricultural nitrogen management, positioning cover crops as compliance tools alongside their soil health benefits (MfE, 2024). The Essential Freshwater package, including synthetic nitrogen fertiliser caps and stock exclusion requirements, creates policy pressure for alternative nitrogen management approaches that directly align with cover crop nitrogen cycling and soil protection benefits identified by survey respondents.

Regional council soil quality monitoring programmes, coordinated under MfE's National Environmental Standards, provide measurement protocols for seven key soil indicators (total carbon, nitrogen, mineralisable nitrogen, acidity, phosphorus, bulk density, and macroporosity) that cover crops can influence (MfE, 2024). This framework addresses grower-identified knowledge gaps around soil health measurement and quantification of long-term benefits.

The integration between MfE's freshwater management objectives and MPI's agricultural productivity goals demonstrates institutional recognition that environmental compliance and production benefits can be achieved simultaneously through practices like cover cropping. This cross-agency coordination validates survey findings that environmental motivations (biodiversity enhancement: 2.71 mean score) represent significant secondary drivers for adoption, while regulatory compliance provides additional economic justification for cover crop investment.

2.2 New Zealand Institutional Research Framework

2.2.1 Foundation for Arable Research (FAR)

The Foundation for Arable Research has established New Zealand as having some of the world's most diverse crop rotations. This diversity provides unique opportunities for cover crop integration, particularly given the documented success of late-season establishment (May plantings) for species including forage brassica, oats, and oat-legume mixtures. Research demonstrates that oat-pea and oat-tare (oat-vetch) combinations provide superior weed suppression compared to monocultures, while the virtual elimination of winter fallow periods in the South Island creates increased opportunities for cover crop implementation through autumn sowing strategies (Foundation for Arable Research, 2006).

2.2.2 BHU Future Farming Centre Research

Merfield's pioneering work on crimper-roller technology represents the most comprehensive investigation of mechanical termination methods adapted to New Zealand conditions (Merfield, 2009). Adapting South American techniques from the 1980s, this research identified critical species-specific responses to mechanical termination, with complete kill achieved in rye (*Secale cereale*) and field beans (*Vicia faba*), while oats (*Avena sativa*) showed minor regrowth and common vetch (*Vicia sativa*) demonstrated complete regrowth and was "impossible to kill by crimping" (Merfield, 2009). These findings establish a clear hierarchy of species suitability for mechanical termination systems, directly addressing termination reliability concerns identified in adoption surveys.

The research emphasises that successful crimping requires crops to reach anthesis (full flowering), representing the physiological switch from vegetative to reproductive growth. However, this timing requirement often conflicts with Canterbury cash crop planting schedules, with anthesis occurring in late November after standard planting dates for most summer crops, illustrating the complex temporal coordination challenges inherent in cover crop system design (Merfield, 2009).

2.2.3 AgResearch Soil Health Research

AgResearch's five-year collaborative study with Synlait Milk and Danone across Waikato, Canterbury, and Otago focused on soil health measurement methodologies and the quantification of regenerative practice benefits, particularly regarding increased pasture diversity and reduced synthetic nitrogen applications (Grelet et al., 2021).

Schon's research on soil structure identified this parameter as critical to multiple soil functions including water storage, oxygen supply, and carbon-nitrogen mineralisation processes (Grelet et al., 2021). This mechanistic understanding provides scientific justification for the prioritisation of soil structure improvement as a primary cover crop adoption motivation, supporting the empirical evidence from grower surveys regarding this factor's dominance.

2.2.4 Manaaki Whenua Landcare Research

Landcare Research's soil biodiversity framework establishes living organism diversity as a fundamental soil health indicator, with soil organisms responsible for nearly all vital soil functions. Their analysis reveals that approximately 50% of New Zealand soils exhibit suboptimal macroporosity levels, directly impacting productivity and contributing to erosion and nutrient runoff challenges. This research provides the ecological foundation for understanding cover crop benefits while highlighting the biological complexity underlying pest and disease risk considerations identified in grower decision-making processes.

2.2.5 LandWISE Technology Integration Research

LandWISE's Carbon Positive project, a partnership with the Hawke's Bay Future Farming Trust, provides unique insights into the practical implementation challenges of cover crop systems in intensive annual cropping operations. Their research reveals unexpected management complexity, with cover crops evolving from "something that happens between cash crops" to recognition of "growing twelve or thirteen crops in six years" (LandWISE, 2024). Species diversity trials using seven-species mixtures (black oats, tillage radish, vetch, buckwheat, sunflowers, crimson clover, and Persian clover) identified significant management challenges including differential frost tolerance and unintended weed establishment risks.

The research documents tensions between regenerative principles and annual cropping system realities, particularly regarding livestock integration and winter soil damage concerns.

LandWISE pioneered strip-tillage development in New Zealand following severe erosion of cropping land in spring, particularly on the light ash soils of Hawke's Bay that are at extreme risk when cultivated (Farmers Weekly, 2013). This led to their broader expertise in controlled traffic farming and precision agriculture applications, developing knowledge directly relevant to cover crop adoption challenges (LandWISE, 2025).

2.2.6 Plant & Food Research (now Bioeconomy Science Institute)

Plant & Food Research established comprehensive research platforms investigating cover crop integration within New Zealand's diverse horticultural systems (Plant & Food Research, 2019). Their research capabilities span from fundamental soil biology and plant-microbe interactions to applied systems research addressing practical implementation challenges in commercial horticulture. The institute's work on soil health indicators and measurement protocols provides scientific foundation for quantifying cover crop benefits, particularly regarding soil structure improvements and biological activity enhancement (Plant & Food Research, 2019).

Plant & Food Research's integrated pest management (IPM) research framework addresses the complex biological risk factors identified as critical in grower decision-making. Their studies on cover crops as beneficial insect habitat while managing pest host risks provide evidence-based guidance for species selection and system design (Plant & Food Research, 2019). The research particularly focuses on timing strategies that maximise beneficial insect conservation while minimizing pest population carryover between seasons.

2.3 International Research Context

2.3.1 Barrier Classification Framework

International research from the USA Corn Belt provides crucial context for understanding adoption barriers across multiple systemic levels (Roesch-McNally et al., 2018). The distinction between field-level barriers (basic agronomic practices) and structural barriers (broader agricultural system infrastructure) reveals that adoption challenges extend beyond individual farm management decisions to encompass market and policy drivers inherent in agriculturally intensive systems.

Research demonstrates that timing management challenges, particularly fall establishment and spring termination coordination, represent universally significant adoption barriers (Roesch-McNally et al., 2018). This finding validates New Zealand research on temporal coordination challenges between cover crop phenology and cash crop scheduling requirements.

2.3.2 Cover Crop Benefits and Implementation Research

Comprehensive US research has established the foundational understanding of cover crop benefits for soil and water quality improvement (Dabney et al., 2001). This seminal work documented how cover crops reduce sediment production, increase solar energy harvest and carbon flux into soil, and provide food for soil organisms while simultaneously increasing evapotranspiration. The research established that cover crops growing during periods when soil might otherwise be fallow create multiple ecosystem benefits that directly parallel the soil structure improvements identified as the primary motivation (3.38 mean score) among New Zealand growers.

2.3.3 Economic Barrier Complexity

Contrary to assumptions regarding economic barriers, USA research indicates that "extra economic costs" and "no measurable economic returns" are not perceived as major adoption hindrances by many farmers, with only 16% viewing "no measurable economic return" as a major challenge, while 40% perceived it as no challenge at all and 44% perceived it as a minor challenge (Sustainable Agriculture Research and Education/Conservation Technology Information Center, 2016). That is in-line with this study's findings that economic factors were not highest ranked.

2.3.4 Motivation Consensus

International research establishes consistent soil-focused motivations across global contexts, with the top three benefits of cover crops perceived by farmers being: 1) increased soil health; 2) increased soil organic matter; and 3) reduced soil erosion (Sustainable Agriculture Research and Education/Conservation Technology Information Center, 2016). This international consensus directly parallels New Zealand findings, validating soil structure improvement as a universal primary motivation across diverse agricultural systems.

2.4 Termination Technology Challenges

2.4.1 Roller-Crimper Research and Development

Extensive North American research demonstrates that termination effectiveness is highly species and phenology-dependent, with incomplete termination potentially causing cash crop yield losses (Reberg-Horton et al., 2011). The dependence of roller-crimper effectiveness on variety selection, termination timing, and method selection demonstrates the sophisticated technical knowledge required for successful implementation (Reberg-Horton et al., 2012).

Comprehensive analysis of seven years of on-farm trials by Practical Farmers of Iowa, involving 15 different research trials on roller-crimping, reveals that timing precision is critical for success. The research confirms that roller-crimping too early in cereal rye's growth stage might not terminate well because the green stems don't break or the immature plants are still able to grow new tillers, while optimal termination occurs between 50% anthesis and early milk stages for cereal rye.

2.4.1.1 Species-Specific Termination Requirements

Research validates significant variation in termination effectiveness across species. Broadleaf and legume cover crops are difficult to kill by rolling and crimping, with broadleaf plants requiring full flower for optimal mechanical termination (Southern Cover Crops Council, 2024). Critical findings include that rolling and crimping alone is not an effective termination method for crimson clover and other clovers, while the brassica mix formed a vegetative mat when crimped but required precise timing at least a week into flowering, with termination remaining effective through seed maturing stage (Sacramento Valley Orchards, 2025).

2.4.1.2 Equipment Design and Biomass Requirements

Technical specifications for effective termination are well-documented. Cover crops must be managed for high biomass production for this system to be successful—at least 9 tonnes/ha of dry matter, or about 1.2 to 1.5 metres of height (University of Nebraska CropWatch, 2024). Equipment design significantly affects outcomes, with roller/crimpers with a chevron or curved bar design helping prevent bouncing in the field compared to those with straight bars, although straight bars may be more effective for breaking plants' vascular structures (Southern Cover Crops Council, 2024).

2.4.1.3 Advanced Termination Technology Development

Recent innovations address traditional roller-crimper limitations. Advanced prototype development includes a new prototype machine provided with a roller crimper and an undercutting blade, allowing it to simultaneously crimp plant stems and cut root systems. Research demonstrates that the prototype can achieve a greater and faster weed devitalisation compared to the commercial roller crimper, with a lower plateau (0.23 vs. 5.35% of greenness of plant material, respectively) and higher constant of decay (1.45 vs. 0.39 day^{-1}, respectively) (Farinacci et al., 2023).

2.4.2 Alternative Mechanical Methods

Mowing effectiveness varies significantly by species and timing. Barley, cereal rye and hairy vetch can be effectively killed through timely mowing, though cover crops should be mowed as close to the ground surface as possible to encourage the plant to die, with flail mowers generally doing a better job than rotary mowers (Cover Crop Strategies, 2024). However, the plant stems detached from the roots will tend to bind or wrap around the equipment, with mowed stems facing in many different directions (Cover Crop Strategies, 2024).

2.4.3 Organic Termination Alternatives

Research on organic-approved termination methods reveals limited effectiveness of alternative approaches. Evaluation of OMRI-approved treatments showed that commercially available vinegar and cinnamon/clove oil solutions provided little predictable termination, and producers attempting to use these OMRI-approved products will likely resort to cover crop incorporation, or mowing, to terminate covers. More effective organic approaches include broadcast flame emitting 1100°C applied at 1.2 k/h or clear plastic for hairy vetch, winter peas, and cereal rye (Price et al., 2019).

2.4.4 Chemical Termination Considerations

Chemical termination remains the most reliable method for cover crop control, with **82% of surveyed New Zealand growers using herbicides or chemicals for cover crop termination**. However, species-specific effectiveness varies significantly and requires sophisticated management approaches.

2.4.4.1 Species-Specific Effectiveness

Grass cover crops (cereal rye, wheat, annual ryegrass) are effectively controlled with glyphosate alone or in combination with 2,4-D, dicamba, or clethodim. Contact herbicides like glufosinate and paraquat are less effective on grass species because of their inability to translocate and adequately terminate the growing point (Whalen et al., 2021).

Legume cover crops present greater challenges, with red clover and vetch requiring tank-mixtures for effective control. Research shows that >90% control of crimson clover was achieved with glyphosate plus 2,4-D, dicamba, or saflufenacil when applied to 10-19 cm plants, but control dropped to only 71-83% on 20-32 cm plants, demonstrating critical timing requirements (Whalen et al., 2021).

2.4.4.2 Critical Timing Factors

Cover crops that have started flowering may be difficult to control as photosynthate movement changes, altering herbicide translocation. Some cover crop species have natural tolerance to broad-spectrum herbicides, especially during stem elongation and late flowering periods. Termination treatments should be applied before the boot stage of grasses for optimal effectiveness (Michigan State University Extension, 2024).

2.4.4.3 New Zealand Resistance Concerns

Glyphosate resistance has been confirmed in annual ryegrass in Marlborough vineyards, marking New Zealand's first confirmed case (Foundation for Arable Research, 2024). Foundation for Arable Research warns this represents a significant threat given glyphosate's dominance in New Zealand agriculture (Foundation for Arable Research, 2024). Critically, **glyphosate-resistant ryegrass populations also show cross-resistance to glufosinate**, though higher rates (7.5 L/ha) can still provide effective control (New Zealand Plant Protection Society, 2024).

2.4.4.4 Multi-Species Management

Multi-species cover crop mixtures require sophisticated herbicide programs, as different species may be at different growth stages simultaneously. Tank-mixtures of glyphosate with synthetic auxins such as 2,4-D or dicamba prove most effective across diverse grass-legume combinations, though some selective herbicides can reduce effectiveness when mixed (Southern Cover Crops Council, 2024).

This research validates the survey findings that biological risk management (2.29-2.73 mean scores) and ease of termination (2.98 mean score) represent critical adoption barriers requiring species-specific knowledge and resistance management strategies.

2.4.5 System Integration Challenges

Recent research confirms that termination method affects subsequent crop establishment. Daily temperature fluctuation was higher in roller-crimped residue (17.3°C) compared to standing (15.0°C), though growers may not observe differences in soil moisture or temperature between mechanical or chemical termination methods in humid regions (Peterson et al., 2025). The challenge of equipment integration remains significant, with cover crop lodging making it difficult for planters to cut through the cover (Cover Crop Strategies, 2022).

This extensive international research validates termination reliability as a universal technical challenge requiring region-specific adaptation and sophisticated equipment development. The findings directly support survey results identifying ease of termination (2.98 mean score) as the third-highest barrier to cover crop adoption, demonstrating that even well-established technologies require continued refinement for reliable implementation.

2.5 Farmer-Led Knowledge Networks

2.5.1 Quorum Sense Network

Quorum Sense represents a significant farmer-led knowledge transfer mechanism, providing education and support for regenerative farming practices through webinars, case studies, and farmer exchange events. The network's MPI funding recognition validates farmer-to-farmer knowledge sharing as an effective extension model. Case studies from Canterbury seed crops, high diversity viticulture systems, and Central Otago pastoral systems demonstrate diverse implementation approaches across New Zealand agricultural sectors.

The network's emphasis on species selection across functional groups while managing seed cost budgets ($250/ha targets in viticulture) addresses practical economic constraints identified in adoption research. Their acknowledgment that diverse crop establishment requires patience and may show delayed results provides realistic expectations for implementation timelines.

2.6 Knowledge Gaps and Research Priorities

The synthesis of New Zealand and international literature reveals several critical knowledge gaps requiring targeted research investment:

2.6.1 Species-Climate Optimisation

Limited research exists on optimal cover crop species selection for New Zealand's diverse microclimates and soil types, particularly regarding establishment reliability under variable climatic conditions.

2.6.2 Economic Valuation Tools

Insufficient methodologies exist for quantifying long-term economic benefits of cover crops within New Zealand farming systems, hampering cost-benefit analysis and adoption decision-making.

2.6.3 System Integration Challenges

Research is needed on integrating cover crops with intensive horticultural production systems, particularly addressing operational timing conflicts and machinery compatibility requirements.

2.6.4 Termination Technology Identification

Limited identification of mechanical and biological termination methods specifically adapted to New Zealand species and conditions, representing a critical practical implementation barrier.

2.6.5 Soil Health Measurement

Identification of practical, farm-level soil health monitoring tools specific to New Zealand soil types and agricultural systems is essential for quantifying cover crop benefits and informing management decisions.

2.7 Literature Review Synthesis and Implications

The literature review reveals strong convergence between New Zealand research findings and international patterns, particularly regarding soil health as the primary adoption motivation and termination reliability as a critical technical barrier. However, New Zealand's unique agricultural diversity and institutional framework create distinct opportunities for cover crop integration.

2.7.1 Institutional Alignment

The alignment between MPI's research investment priorities (farmer-led applied research, soil health focus) and MfE's regulatory framework (freshwater management, nitrogen reduction) demonstrates unprecedented institutional convergence supporting cover crop adoption. This dual-agency focus addresses both production benefits and environmental compliance drivers, providing comprehensive policy backing for the three-tier implementation framework identified in this study.

2.7.2 Implementation Pathways

New Zealand's institutional landscape offers multiple implementation mechanisms: MPI's Sustainable Farming Fund for practical research, MfE's regulatory requirements creating compliance drivers, existing monitoring systems (OverseerFM®, regional council soil quality programmes) for benefit quantification, and established farmer-led knowledge networks (Quorum Sense, LandWISE, FAR Growers Leading Change) for extension. This multi-pathway approach suggests that practical implementation support through integrated institutional mechanisms may be more effective than traditional single-agency research-extension models.

2.7.3 Research Priority Validation

The convergence between grower-identified priorities (establishment reliability, termination ease, soil health measurement) and institutional capabilities (SFF applied research funding, soil quality monitoring protocols, cross-agency coordination) validates the survey's three-tier framework and demonstrates that recommended research investments align with existing government priorities and funding mechanisms.

2.7.4 Unique New Zealand Context

New Zealand's combination of diverse crop rotations, virtual elimination of winter fallows, significant seed export industry concerns, and integrated agricultural-environmental policy framework creates implementation opportunities not available in other agricultural systems. This suggests that New Zealand could serve as a global model for institutional integration supporting cover crop adoption while addressing the practical implementation challenges identified as primary barriers in this study.

3 Methodology

This study employed a mixed-methods approach combining quantitative importance scoring with qualitative thematic analysis to understand cover crop adoption barriers and motivations among New Zealand horticultural growers.

3.1 Key Methodological Elements

Sample:
32 horticultural growers across five regions (Canterbury: 12, Hawke's Bay: 9, Pukekohe: 5, Manawatu: 4, Gisborne: 2), selected through purposive sampling by regional agronomists as "growers of interest."

Data Collection
Structured questionnaires administered by experienced regional agronomists using standardised 5-point importance scales (0=not a consideration to 4=make-or-break) plus open-ended qualitative responses.

Quantitative Analysis
Mean importance scores calculated for all factors with adequate sample sizes ($n \geq 5$), ranked to establish relative priority hierarchies. High importance defined as scores 3-4, with "make-or-break" representing score 4.

Qualitative Analysis
Systematic thematic analysis of open-ended responses across multiple survey sections, integrated with quantitative findings to validate patterns and identify nuanced insights.

Analytical Framework
Three-tier barrier classification system based on mean scores: Critical (>2.9), High Priority (2.5-2.9), and Moderate (2.0-2.5), reflecting practical implementation priorities.

3.2 Key Limitations

Selection bias
Growers were purposively selected by regional agronomists as "growers of interest" based on research relevance rather than representative sampling. This probably resulted in participants who are more experienced (average 23 years), better-resourced, and more engaged with cover crop practices than the broader farming population.

Generalisability limitations
The high experience level and purposive selection mean findings may not reflect barriers faced by typical farmers or those considering initial adoption. Infrastructure and information barriers may be artificially low due to sample characteristics.

Regional representation
Regional distribution reflects research priorities rather than adoption patterns, limiting ability to identify genuine regional differences in cover crop approaches.

See Appendix D for complete methodological details including statistical frameworks, sampling procedures, and data quality assurance protocols.

4 Results and Analysis

4.1 Current Adoption Patterns

Among surveyed growers:

- **75% (24/32) had cover crop experience** averaging 23.2 years (range: 4-60 years)
- 22% (7/32) had no experience
- 3% (1/32) unclear response

Most Common Species

Oats, annual ryegrass, barley, clover varieties, vetch, and brassicas (mustard, radish). Some growers use complex multi-species mixtures combining multiple species for different functional benefits, though experience levels show varied approaches to complexity.

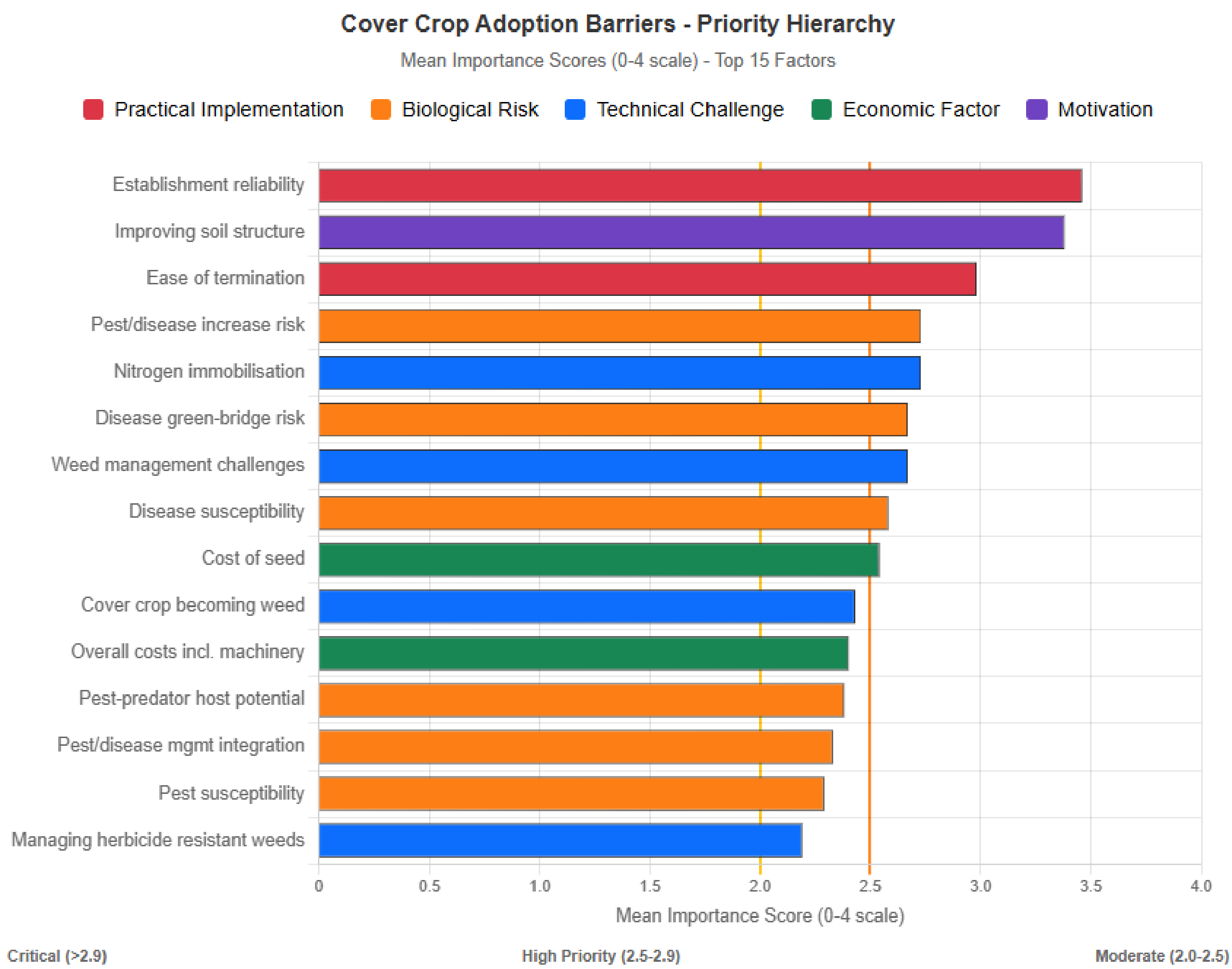

Figure 4-1 Priority hierarchy of cover crop adoption barriers by category, based on growers' ranked importance scores

4.2 Complete Factor Rankings

The following table presents all factors ranked by mean importance score, revealing the actual priority hierarchy for cover crop adoption decisions

Table 4-1Priority hierarchy of factors associated with cover crop adoption decisions

Rank	Factor	Mean Score	High Importance (3-4)	Make-or-Break (4)	Category
1	Establishment reliability	3.46	95.8%	50.0%	PRACTICAL
2	Improving soil structure	3.38	87.5%	50.0%	MOTIVATION
3	Ease of termination	2.98	79.2%	33.3%	PRACTICAL
4	Pest/disease increase risk	2.73	66.7%	33.3%	BIOLOGICAL
5	Nitrogen immobilisation	2.73	66.7%	13.3%	TECHNICAL
6	Disease green-bridge risk	2.67	66.7%	25.0%	BIOLOGICAL
7	Weed management challenges	2.67	66.7%	25.0%	TECHNICAL
8	Disease susceptibility	2.58	58.3%	20.8%	BIOLOGICAL
9	Cost of seed	2.54	45.8%	20.8%	ECONOMIC
10	Cover crop becoming weed	2.43	46.7%	13.3%	TECHNICAL
11	Overall costs including machinery	2.40	46.7%	20.0%	ECONOMIC
12	Pest-predator host potential	2.38	54.2%	4.2%	BIOLOGICAL
13	Pest/disease management integration	2.33	45.8%	12.5%	BIOLOGICAL
14	Pest susceptibility	2.29	45.8%	20.8%	BIOLOGICAL
15	Managing herbicide resistant weeds	2.19	56.3%	25.0%	TECHNICAL

Additional factors scoring below 2.0:

- Establishment cost (2.08)
- Soil moisture impact (1.87)
- Soil temperature impact (1.67)
- Information access (1.60)
- Machinery access (1.20)

4.3 Key Patterns Revealed

1. Practical Implementation Dominates
Establishment reliability (3.46) and ease of termination (2.98) rank #1 and #3 respectively, indicating that reliable, manageable systems are prerequisites for adoption.

2. Biological Risk Management Central
Six pest/disease factors appear in the top 15, revealing that risk assessment is integral to species selection and system design, not a peripheral concern.

3. Experience Filter Effect
Traditional barriers like machinery access (1.20) and information gaps (1.60) score lowest, reflecting the experienced nature of respondents who have overcome basic implementation hurdles.

4. Technical Challenges Secondary
While important, nitrogen management (2.73) and weed optimisation (2.67) rank below practical and biological considerations.

5. Economic Factors Moderate
Cost concerns (2.08-2.54) are real but secondary to operational functionality and risk management.

4.4 Qualitative Insights Integration

Establishment Challenges
Multiple growers emphasised reliability concerns validating the 3.46 quantitative score: "Cover crop establishment" and "establishment reliability" were recurring themes.

Termination Complexity
Growers provided specific examples supporting the 2.98 importance score: "Being organic the ease of cover crop destruction is important for example rye grass is too difficult to remove prior to planting main crop."

Operational Flexibility Constraints
A critical insight not fully captured quantitatively: "Once land is cover cropped it ties it up for a period of time and in a wet season it reduces options if we fall behind in our planting programme."

Seed Crop Industry Concerns
Sector-specific barriers emerged from qualitative data: "Contaminating small seed crops," "The risk of contamination to other seed crops," and "Brassicas due to the seed persistence and potential contamination of surrounding seed crops. Radish is a strict no-no."

4.5 Species Performance Insights

- **High performing:** Oats (most reliable), annual ryegrass (consistent), vetch (nitrogen fixation)
- **Problematic:** Rye (difficult termination, pest hosting), brassicas (contamination risks), complex mixes (management difficulty)

4.6 Three-Tier Barrier Framework

Analysis reveals three distinct barrier levels:

Tier 1: Critical Factors (Mean >2.9) - Immediate Priority

- Establishment reliability (3.46)
- Ease of termination (2.98)
- Foundation requirements for any cover crop system

Tier 2: High Priority Factors (Mean 2.5-2.9) - Strategic Focus

- Biological risk management (2.29-2.73)
- Technical challenges (2.67-2.73)
- Optimisation and integration challenges

Tier 3: Moderate Factors (Mean 2.0-2.5) - Support Systems

- Economic barriers (2.08-2.54)
- Support needed but not primary obstacles

5 Discussion

5.1 Why Growers Do or Do Not Use Cover Crops

The survey reveals that **75% of respondents (24/32) currently use cover crops**, with an average experience of 23.2 years, indicating that among this selected group of "growers of interest," cover crop adoption is well-established rather than emerging. However, the 22% of growers interviewed who do not use cover crops and the specific barriers identified provide insights into adoption constraints.

5.1.1 Primary Drivers for Adoption

The overwhelming consensus on **soil structure improvement (3.38 mean score, 87.5% high importance)** as the primary motivation indicates that growers adopt cover crops primarily for fundamental soil health benefits rather than secondary environmental or economic goals. This aligns with international research showing soil health as the universal primary driver across diverse agricultural systems.

5.1.2 Key Barriers Preventing Adoption

Non-adopters and hesitant adopters face **practical implementation challenges** rather than conceptual or informational barriers. The highest-ranked barrier—**establishment reliability (3.46)**—suggests that uncertainty about successful crop establishment prevents trial adoption. The second-highest barrier—**ease of termination (2.98)**—indicates concerns about operational control and system integration.

5.1.3 Experience Effect on Adoption Decisions

Notably, even experienced growers rate establishment reliability and termination ease as top concerns, suggesting these are **fundamental system requirements** rather than learning curve issues. The low scores for machinery access (1.20) and information gaps (1.60) among this experienced group indicate that basic infrastructure and knowledge barriers become minimal with experience, while practical implementation challenges remain critical.

5.2 Grower Experience Levels and Cover Crop Usage Patterns

5.2.1 Experience Distribution

Among cover crop users, experience ranges from 4-60 years (mean: 23.2 years), indicating both long-term practitioners and relatively recent adopters. This experience diversity reveals that **approach complexity is not determined by years of experience** but rather by individual farming system requirements and strategic choices.

5.2.2 Species Complexity vs. Experience - Actual Patterns

Contrary to expected linear progression, the data reveals highly variable approaches across all experience levels:

- **New adopters (4-10 years):** 75% use complex multi-species mixtures
  - Examples include combinations of "beans, linseed, peas, brassicas, oats" with both mixtures and monocultures
  - Some use 6+ species combinations from early adoption
- **Intermediate users (10-25 years):** 67% use complex approaches with high variation
  - Complex users employ diverse combinations: "annual ryegrass, barley, oats, triticale, phacelia, hairy vetch"
  - Others maintain simple 2-species approaches despite years of experience
- **Advanced practitioners (25+ years):** Only 43% use complex mixtures
  - Some highly experienced growers use only single species: "oats, baled or plough under. No mixtures"
  - Others maintain diverse approaches: "lupins, beans, green feed oats, buckwheat, phacelia, sunflowers"

5.2.3 Experience-Based Strategic Choices

Analysis reveals that experience correlates with **strategic decision-making confidence** rather than complexity adoption:

- **Simplification Strategy:** Some highly experienced growers have deliberately simplified approaches based on what works reliably on their specific farms
- **Experimentation Confidence:** Some newer adopters dive into complex systems, often guided by recent research or peer networks
- **System-Specific Optimisation:** Experienced growers make informed choices about complexity levels that suit their operational constraints and goals

5.2.4 Regional and System-Specific Patterns:

Analysis of cover crop species selection across the five regions reveals limited regional difference. While growers in all regions commonly use oats and annual ryegrass as reliable foundation species, individual farm requirements and management preferences appear to drive species selection more than regional factors.

The survey data does not reveal strong regional specialisations in cover crop approaches, suggesting that practical implementation factors (establishment reliability, termination ease) identified as top barriers may be more influential in species selection than regional or climatic considerations.

5.3 Current Cover Crop Species Selection and Usage

5.3.1 Most Successful Species (Based on Grower Satisfaction):

1. **Oats** - Most frequently mentioned positively, with consistent establishment reliability and termination ease
2. **Annual ryegrass** - Reliable ground cover with established management protocols
3. **Vetch** - Valued for nitrogen fixation when properly managed
4. **Barley** - Effective for wind protection and quick establishment

5.3.2 Complex Multi-Species Approaches

Some growers use sophisticated mixtures combining multiple species for different functional benefits. Examples include combinations of cereals (oats, barley), legumes (vetch, clover), brassicas (radish, mustard), and specialty species (phacelia, buckwheat, sunflowers). However, qualitative feedback reveals that **"multispecies mixes are hard to manage and control weeds,"** indicating a trade-off between functional diversity and management complexity.

Research supports strategic species combinations based on functional complementarity: cereals provide soil structure and carbon inputs, legumes fix nitrogen and improve phosphorus availability, while brassicas offer soil compaction relief and bio-fumigation benefits (Quintarelli et al., 2022). Effective mixtures balance C:N ratios - combining high C:N species (grasses) with low C:N species (legumes) to optimise nutrient cycling while maintaining soil organic matter accumulation.

Analysis shows that approach complexity is not determined by years of experience, with some highly experienced growers deliberately choosing simple single-species approaches.

5.4 Most and Least Important Decision-Making Factors

5.4.1 Most Critical Factors (Mean Score >2.9):

1. **Establishment reliability (3.46)** - The single most important consideration, with 95.8% rating it high importance
2. **Ease of termination (2.98)** - Critical operational requirement for system integration

5.4.2 High Priority Factors (Mean Score 2.5-2.9):

- **Biological risk management:** Six pest/disease factors rank in this range, indicating sophisticated risk assessment
- **Technical challenges:** Nitrogen immobilisation (2.73), weed management (2.67)
- **Species-specific risks:** Disease susceptibility (2.58), cover crop becoming weed (2.43)

5.4.3 Least Important Factors (Mean Score <2.0):

1. **Machinery access (1.20)** - Lowest-ranked barrier, indicating infrastructure is manageable
2. **Information access (1.60)** - Low priority among experienced growers
3. Soil temperature/moisture impacts (1.67-1.87) - Minor operational concerns

5.4.4 Barrier Hierarchy and Sample Characteristics

The survey reveals a clear hierarchy where infrastructure and information barriers rank lowest—machinery access (1.20) and information access (1.60)—while operational challenges rank highest—establishment reliability (3.46) and termination ease (2.98).

This pattern may reflect the high experience level of respondents (78% with 23.2 years average experience) and the purposive sampling methodology where agronomists selected "growers of interest." The findings suggest that operational timing constraints and technical implementation requirements remain significant even for experienced practitioners, indicating these challenges require system-level solutions rather than simply increased experience or information transfer.

Implications:
Traditional extension approaches focused on information provision may be less critical than developing reliable implementation protocols and addressing operational constraints, though this should be interpreted within the study's sample context.

5.5 Factors That Would Increase Cover Crop Consideration

5.5.1 For Non-Adopters

Based on barrier rankings, non-adopters would be most influenced by:

1. **Establishment reliability improvements** - Development of foolproof establishment protocols
2. **Termination technology access** - Reliable, accessible termination methods
3. **Risk management tools** - Clear guidance on pest/disease risk assessment and mitigation

5.5.2 For Current Users (Expansion/Optimisation)

Existing users would expand usage with:

1. **Technical optimisation solutions** - Better nitrogen management and weed suppression
2. **Economic valuation tools** - Methods to quantify and capture long-term benefits
3. **Advanced species selection guidance** - Sophisticated risk-benefit analysis tools

5.5.3 System-Level Improvements

Qualitative responses indicate that **operational flexibility** improvements would significantly increase adoption. As one grower noted: "Once land is cover cropped it ties it up for a period of time and in a wet season it reduces options." Solutions addressing this constraint could unlock broader adoption.

5.6 Primary Motivations for Cover Crop Adoption

5.6.1 Overwhelming Primary Driver

Soil structure improvement (3.38 mean, 87.5% high importance, 50% make-or-break) represents unprecedented consensus among surveyed growers. This universal agreement provides a clear foundation for promotion and policy messaging.

5.6.2 Secondary Motivations (Mean Score 2.5-2.7):

1. Biodiversity enhancement above ground (2.71) - Environmental stewardship motivation
2. **Soil moisture management (2.56)** - Practical water management benefits
3. **Input reduction (2.50)** - Economic sustainability through efficiency
4. **Weed suppression ability (2.50)** - Integrated management benefits

5.6.3 Motivation Hierarchy Insights

The clear prioritisation of soil structure over other benefits indicates that growers view cover crops primarily as a **soil health tool** rather than a pest management, economic, or environmental compliance strategy. Secondary motivations become relevant once soil benefits are achieved.

5.6.4 Long-term vs. Short-term Motivations

Qualitative responses reveal tension between long-term soil health benefits and short-term operational costs. Growers recognise soil structure improvements but struggle with economic valuation: "How to make them pay. How to put a value on them, especially longer term benefits."

5.7 Cover Crop Species Selection Decision-Making Process

5.7.1 Grower Decision Hierarchy (Derived from Combined Data):

1. **Establishment reliability filter (3.46)** - "Will it grow consistently under my conditions?"
2. **Termination feasibility check (2.98)** - "Can I control it when I need to?"
3. **Risk assessment (2.29-2.73)** - "What pest/disease risks am I accepting?"
4. **Benefit confirmation (3.38)** - "Will it deliver soil structure improvements?"
5. **Technical complexity evaluation (2.67-2.73)** - "Can I manage the nitrogen and weed issues?"
6. Economic feasibility (2.08-2.54) - "Are the costs reasonable?"

5.7.2 Species-Specific Selection Criteria

Growers apply sophisticated species-specific knowledge based on functional categories:

- **Oats:** Selected for reliability across establishment and termination criteria
- **Brassicas:** Avoided due to contamination risks in seed crop areas: "Radish is a strict no-no." However, research shows brassicas can provide unique benefits including soil compaction relief through taproot systems and bio-fumigation effects against soil-borne pathogens through glucosinolate release (Quintarelli et al., 2022)
- **Rye:** Rejected for termination difficulties: "host to pests and is difficult to remove." Research confirms rye's effectiveness for soil structure improvement and nitrogen scavenging but validates termination challenges
- **Vetch:** Chosen for nitrogen benefits but requires companion species for support. Leguminous cover crops can fix significant atmospheric nitrogen and acidify the rhizosphere to facilitate phosphorus uptake (Quintarelli et al., 2022)

5.7.3 Farm-Specific Adaptation in Selection

Species selection criteria vary primarily by individual farm requirements and management constraints rather than regional factors.

Key decision drivers include:

- **Operational constraints:** Available time windows between cash crops
- **Infrastructure capacity:** Existing termination equipment and methods
- **Risk tolerance:** Willingness to experiment with complex mixtures vs. proven single species
- **Production system:** Organic operations prioritise easily terminatable species; intensive vegetable systems favour quick-turnaround options

The survey data suggests that practical implementation factors outweigh regional climate considerations in species selection decisions.

Cover Crop Species Performance Matrix

Based on Grower Experience and Survey Data

Excellent/Reliable | Good | Moderate/Variable | Challenging | Avoid/High Risk

Species	Establishment Reliability	Termination Ease	Risk Level	Overall Recommendation
Oats *"Most frequently mentioned positive"*	Excellent	Excellent	Low	Highly Recommended
Annual Ryegrass *"Consistent ground cover"*	Good	Good	Low	Recommended
Vetch *"Valued for nitrogen fixation"*	Good	Moderate	Moderate	Recommended
Barley *"Good for wind protection"*	Good	Good	Low	Recommended
Clover *"Impossible to control with crimper"*	Variable	Challenging	Moderate	Use with Caution
Rye *"Host to pests, difficult to remove"*	Good	Very Difficult	High	Use with Caution
Brassicas (Radish/Mustard) *"Radish is a strict no-no"*	Variable	Moderate	Very High*	Avoid in Seed Areas
Complex Mixtures *"Hard to manage and control weeds"*	Variable	Difficult	High	Advanced Users Only

Figure 5-1 A decision support matrix developed from grower responses ranking main species against establishment reliability, termination ease and risk level, to give an overall recommendation.

5.8 Implementation Challenges Faced by Current Users

5.8.1 Persistent Operational Challenges:

Analysis of the dedicated "Challenges of growing cover crops" section reveals that **operational timing constraints represent the greatest challenge even for experienced growers**, with "Not enough time between crops" scoring 2.85 (the highest challenge score) and rated as high importance by 70% of growers.

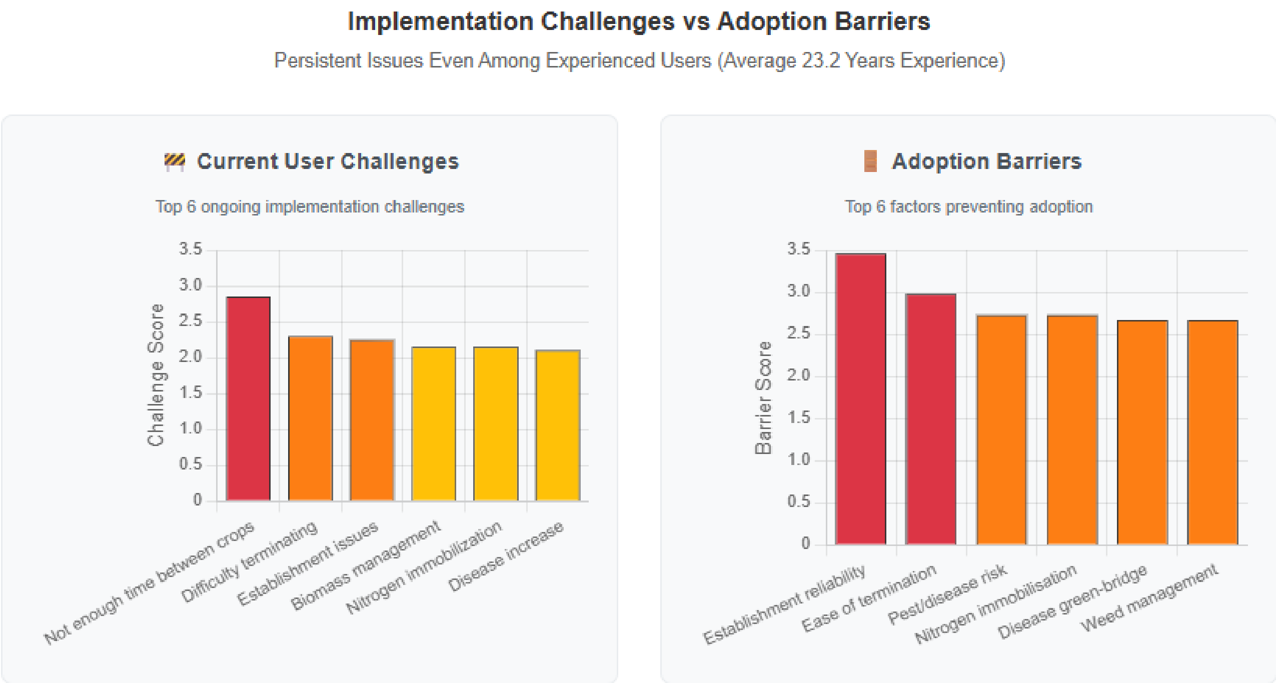

Figure 5-2 Implementation Challenges vs Adoption Barriers showing persistent issues even among experienced users.

5.8.2 Top Challenges Ranked by Severity:

1. **Not enough time between crops (2.85)** - Critical operational constraint
   - 70% rated as high importance, 45% as "make-or-break"
   - Grower feedback: "Mainly a timing factor - not enough time. And cost vs time in the ground"
2. **Difficulty terminating cover crop (2.30)** - Persistent practical challenge
   - 55% rated as high importance, 25% as "make-or-break"
   - Validates that termination remains challenging even for experienced users
3. **Cover crop establishment (2.25)** - Ongoing reliability concerns
   - 50% rated as high importance, 15% as "make-or-break"
   - Confirms establishment reliability as persistent rather than learning curve issue

5.8.3 Technical Management Challenges:

4. **Dealing with biomass following termination (2.15)** - Post-termination complexity
5. **Nitrogen immobilisation (2.15)** - Technical optimisation challenge
6. **Disease increase concerns (2.10)** - Biological risk management
7. **Slug population increases (2.10)** - Pest management integration

5.9 Validation of Barrier Analysis

The challenges section validates original findings while revealing lower overall scores, reflecting the difference between adoption barriers (original survey) and implementation challenges (current users).

Key validations:

- **Termination difficulties:** 2.30 (challenges) vs 2.98 (barriers)
- **Establishment concerns:** 2.25 (challenges) vs 3.46 (barriers)
- **Nitrogen immobilisation:** 2.15 (challenges) vs 2.73 (barriers)

5.9.1 Timing Coordination Complexity

"Cover crops can make management at spring cultivation difficult/slow as soil may stay waterlogged for longer and there's a large amount of biomass to breakdown." This reveals sophisticated soil management challenges that persist beyond basic establishment.

5.9.2 Operational Flexibility Constraints

"Once land is cover cropped it ties it up for a period of time and in a wet season it reduces options if we fall behind in our planting programme." This fundamental constraint affects farm-level flexibility and risk management, now validated as the #1 challenge (2.85 score).

5.9.3 Species-Specific Implementation Issues

- *"Clover was impossible to control with crimper"* - termination technology effectiveness varies significantly by species
- *"Multispecies mixes are hard to manage and control weeds"* - trade-offs between functional diversity and management simplicity
- Grower feedback: *"concerned about slug multiplication and timing of groundwork"*

5.9.4 Sector-Specific Constraints

1. **Seed Crop Contamination Risks:** *"Contaminating small seed crops"* and "*The risk of contamination to other seed crops"* represent critical barriers for New Zealand's significant seed export industry
2. **Land Tenure Complications:** *"If we lease the land then the owner will have a preference of what gets planted after our crop if they want to fatten lambs"* - structural barriers affecting adoption decisions

3. **Organic System Requirements:** *"Being organic the ease of cover crop destruction is important for example rye grass is too difficult to remove prior to planting main crop"*

5.9.5 Knowledge and Measurement Gaps

Despite high experience levels, growers identify specific technical knowledge needs:

- "*Defining common names vs scientific names, ie not all vetches are the same*"
- "*Ability to measure changes in soil health and structure*"
- "*How can we measure nitrogen release?"*
- Grower question: *"How to make them pay. How to put a value on them, especially longer term benefits"*

5.9.6 Economic Valuation Challenges

"Economic viability - substitutes for a cash crop" and the need for long-term economic analysis tools indicate sophisticated understanding of opportunity costs requiring dedicated economic frameworks.

5.9.7 Adaptive Management Solutions

Experienced growers develop innovative strategies: *"This season it was so wet that volunteers were enough. Many cropping weeds are palatable so get eaten off by stock or get frost kill. So take advantage of weeds as cover crops/fodder crops."* This demonstrates sophisticated integration of cover crop principles with opportunistic management.

5.9.8 Positive Implementation Experiences

- *"Cover crops planted as soon as possible after the cash crop is harvested*" - timing optimisation
- *"Rate cover crop of oats highly, cover crop reduces glyphosate usage by keeping ground clean"* - input reduction benefits
- *"With our light sandy soil wind erosion is important reason for cover crops"* - targeted benefit realisation

5.10 Major Themes from Qualitative Analysis

Qualitative analysis validated quantitative rankings while revealing critical gaps where numerical scores alone could not capture implementation complexity, particularly regarding operational flexibility constraints and sector-specific barriers not captured in the standardised importance scaling.

Thematic analysis of open-ended responses revealed seven major themes that provide crucial context for understanding cover crop adoption and implementation decisions:

5.10.1 Operational Flexibility Constraints

Growers repeatedly emphasised how cover crops reduce management options during variable weather conditions, with timing pressures creating fundamental system constraints rather than simple scheduling issues. This theme validates the quantitative finding that *"not enough time between crops"* (2.85) represents the highest implementation challenge.

5.10.2 Economic Valuation Challenges

Beyond direct costs, growers struggle with quantifying long-term benefits and opportunity costs, requiring sophisticated economic analysis tools rather than simple cost-sharing support. This explains why seed costs (2.54) rank as only moderate barriers while economic uncertainty remains a significant adoption constraint.

5.10.3 Seed Crop Industry-Specific Barriers

Critical contamination risks specific to New Zealand's seed export industry represent sector-specific barriers requiring targeted policy attention. These concerns were prominent in qualitative responses but not captured in standardised importance scaling, highlighting the value of mixed-methods analysis.

5.10.4 Land Tenure and Grazing Conflicts

Complex interactions between landlord-tenant relationships and cover crop management decisions reveal structural barriers affecting adoption that extend beyond individual farm management decisions.

5.10.5 Species-Specific Performance Insights

Detailed grower experiences with individual species performance, establishment reliability, and termination challenges provide practical implementation guidance that validates quantitative rankings while offering specific solutions.

5.10.6 Knowledge and Measurement Gaps

Specific technical knowledge needs including species identification, soil health measurement, and nitrogen dynamics quantification represent sophisticated information requirements beyond basic extension materials.

5.10.7 Adaptive Management Solutions

Innovative grower strategies for integrating cover crop principles with opportunistic management demonstrate sophisticated practical adaptation, suggesting that flexibility rather than rigid protocols may be key to successful implementation.

6 Strategic Recommendations

6.1 Research and Policy Priorities

6.1.1 Immediate Priority (0-12 months)

1. Establishment Reliability Research (Highest Priority)

- Develop comprehensive species-specific establishment protocols
- Research environmental factors affecting establishment success
- Create practical training programs for reliable establishment techniques
- **Funding allocation:** Should receive largest research investment given 3.46 importance score

2. Termination Technology Development (Critical Priority)

- Develop accessible mechanical termination equipment and methods
- Research optimal termination timing to balance benefits with operational needs
- Create non-chemical termination protocols for organic systems
- Support custom operator networks for equipment access
- **Consider termination method impacts:** Research shows that cover crop residues incorporated as green manure decompose faster than surface mulching, affecting nutrient release timing and greenhouse gas emissions. Surface mulching provides better long-term soil structure benefits while incorporation gives faster nutrient availability (Quintarelli et al., 2022)

3. Biological Risk Management (Integrated Approach)

- Develop disease-resistant cover crop varieties for New Zealand conditions
- Create comprehensive pest/disease risk assessment tools for species selection
- Research disease green-bridge risks and mitigation strategies
- Establish integrated pest management protocols incorporating cover crops
- **Leverage beneficial biological effects:** Certain brassicaceous cover crops release biofumigant compounds (isothiocyanates) during decomposition that can suppress soil-borne pathogens and nematodes. Strategic species selection can provide natural pest control benefits while managing disease risks (Quintarelli et al., 2022)

6.1.2 Medium-term Strategic Focus (1-3 years)

4. Technical Optimisation (Important but Secondary)

- Address nitrogen immobilisation through species selection and timing protocols and possible use of new biological products to enhance decomposition.
- Enhance weed suppression through improved variety selection and establishment techniques
- Identify measurement tools for soil health and nitrogen dynamics

5. Economic Support Systems (Targeted)

- Support cost-sharing programmes focused on establishment reliability and termination technology
- Develop economic valuation tools incorporating soil structure benefits
- Support equipment sharing programmes for termination technology access
- **Quantify input reduction benefits:** Research demonstrates that cover crops can reduce synthetic fertiliser requirements through biological nitrogen fixation and improved nutrient cycling, decrease pest management costs through biological suppression effects, and lower fuel consumption by reducing tillage operations. Strategic cover crop use can reduce farming operations and associated energy consumption by 43-51% (Quintarelli et al., 2022)

6. Information and Extension (Specialised)

- Create species selection frameworks incorporating practical, biological, and technical factors
- Develop sector-specific guidance addressing contamination risks for seed crops
- Establish demonstration sites showcasing reliable implementation methods

6.2 Implementation Framework

6.2.1 Phase 1: Foundation Building (Years 1-2)

Focus on practical implementation solutions that address the top-ranked barriers. Success in establishment reliability and termination ease creates the foundation for broader adoption.

6.2.2 Phase 2: Risk Management Integration (Years 2-4)

Develop sophisticated biological risk assessment and management tools that allow growers to confidently select appropriate species and manage system risks.

6.2.3 Phase 3: System Optimisation (Years 3-5)

Address technical challenges and economic optimisation opportunities that become relevant once basic systems are functioning reliably.

7 Policy Recommendations

7.1 Research Investment Allocation

1. **65% for practical implementation** (establishment, termination)
2. **25% for biological risk management** (disease resistance, risk assessment)
3. 10% for technical optimisation (nitrogen, weed management)

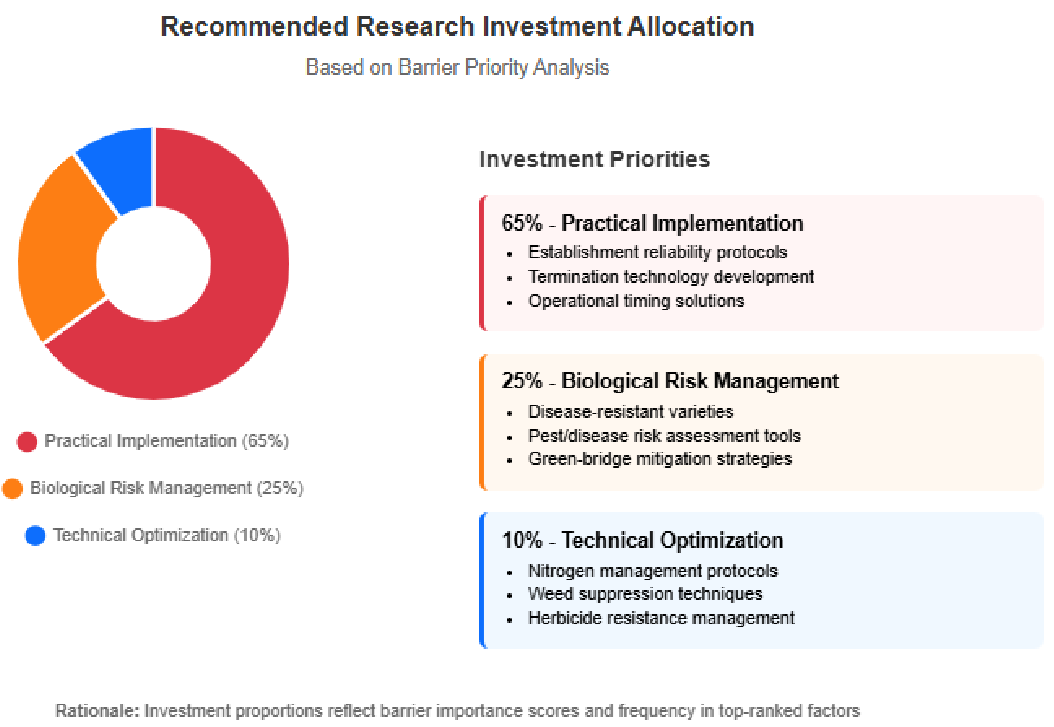

Figure 7-1 Recommended research investment allocation based on barrier priority analysis with investment proportions reflecting barrier importance scores and frequency in top ranked factors.

7.2 Extension Strategy Refocus

- Prioritise hands-on demonstration over theoretical content
- Emphasise risk management and reliable implementation
- Integrate biological and practical factors in all species selection guidance

7.3 Economic Support Targeting

- Focus support on practical barriers rather than general cost-sharing
- Support technology access initiatives for termination equipment
- Develop tools for quantifying long-term soil structure benefits

7.4 Expected Outcomes

Addressing the actual top-ranked practical factors through targeted research and extension should significantly expand adoption among both current and potential users. The clear consensus on establishment reliability (3.46) and soil structure benefits (3.38) provides a strong foundation for practical implementation programmes.

The moderate scoring of technical barriers suggests that practical solutions will be more effective than research-intensive agronomic optimisation alone. Once reliable systems are established, technical optimisation becomes relevant and valuable.

8 Conclusions

This importance-scoring analysis fundamentally reframes cover crop adoption barriers in New Zealand horticulture. Practical implementation factors, not technical agronomic challenges, represent the primary obstacles to expanded adoption.

8.1 Key Strategic Insights

8.1.1 Operational Timing First

The challenges analysis reveals that "Not enough time between crops" (2.85) represents the highest-scoring implementation challenge, indicating that **system-level timing solutions must be the primary policy focus** before technical optimisation.

8.1.2 Establishment First

Establishment reliability (3.46) is the single most important factor—more critical than any technical or economic consideration. This should be the #1 research and extension priority.

8.1.3 Operation Over Optimisation

Ease of termination (2.98) ranks higher than all cost factors and most technical challenges, indicating growers need reliable, manageable systems before engaging with optimisation.

8.1.4 Risk Management Central

Six pest/disease factors in the top 15 reveal that biological risk assessment is integral to species selection, requiring sophisticated risk management tools rather than simple species recommendations.

8.1.5 Persistent Implementation Challenges

Operational timing constraints and practical implementation challenges remain significant even among experienced growers in this study (average 23 years), suggesting these are fundamental system requirements. However, this finding should be interpreted within the context of the study's purposive sampling methodology.

8.1.6 Soil Structure Consensus

Overwhelming agreement on soil structure improvement (3.38) as primary motivation provides clear benefit messaging, but only when coupled with reliable implementation.

9 Bottom Line

The survey data clearly indicates that experienced growers need systems that work reliably first, then they will engage with technical optimisation.

Research investment should prioritise building this foundation of reliable implementation before investing heavily in advanced agronomic research.

Policy makers should focus on:

1. **Practical implementation support** (primary investment)
2. **Risk management tools** (integrated approach)
3. **Technical optimisation** (important but secondary)
4. **Economic support** (targeted to practical barriers)

These evidence-based priorities provide a roadmap for research investment and policy development, though the findings reflect the perspectives of experienced, purposively selected growers and may not fully represent barriers faced by typical farmers or new adopters.

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11 Appendices

11.1 Appendix A: Complete Data Tables

Table 11-1 Complete Barrier Rankings by Mean Score

Rank	Barrier	Mean Score	High Importance (3-4)	Make-or-Break (4)	Sample Sise
1	Establishment reliability	3.46	95.8%	50.0%	24
2	Ease of termination	2.98	79.2%	33.3%	24
3	Pest/disease increase risk	2.73	66.7%	33.3%	15
4	Nitrogen immobilisation	2.73	66.7%	13.3%	15
5	Disease green-bridge risk	2.67	66.7%	25.0%	24
6	Weed management challenges	2.67	66.7%	25.0%	24
7	Disease susceptibility	2.58	58.3%	20.8%	24
8	Cost of seed	2.54	45.8%	20.8%	24
9	Cover crop becoming weed	2.43	46.7%	13.3%	15
10	Overall costs including machinery	2.40	46.7%	20.0%	15
11	Pest-predator host potential	2.38	54.2%	4.2%	24
12	Pest/disease management integration	2.33	45.8%	12.5%	24
13	Pest susceptibility	2.29	45.8%	20.8%	24
14	Managing herbicide resistant weeds	2.19	56.3%	25.0%	16
15	Establishment cost	2.08	37.5%	12.5%	24
16	Soil moisture impact	1.87	20.0%	20.0%	15
17	Soil temperature impact	1.67	6.7%	6.7%	15
18	Information access	1.60	26.7%	0.0%	15
19	Machinery access	1.20	20.0%	6.7%	15

Table 11-2 Implementation Challenges Rankings (Current Users)

Rank	Challenge	Mean Score	High Importance (3-4)	Make-or-Break (4)	Sample Sise
1	Not enough time between crops	2.85	70.0%	45.0%	20
2	Difficulty terminating cover crop	2.30	55.0%	25.0%	20
3	Cover crop establishment	2.25	50.0%	15.0%	20
4	Dealing with biomass following termination	2.15	50.0%	25.0%	20
5	Nitrogen immobilisation	2.15	55.0%	5.0%	20
6	Increase diseases	2.10	35.0%	25.0%	20
7	Increases slugs	2.10	40.0%	30.0%	20
8	Cost of establishment including seed	2.02	35.0%	20.0%	20
9	Yield reduction in following cash crops	2.00	50.0%	30.0%	20
10	Cover crop leaves soil too moist	1.75	35.0%	15.0%	20
11	Increases insect pests	1.75	35.0%	25.0%	20
12	Time and labour required	1.21	10.5%	0.0%	19
13	Cover crop uses too much soil moisture	0.85	10.0%	5.0%	20

Table 11-3 Complete Motivation Rankings by Mean Score

Rank	Motivation/Benefit	Mean Score	High Importance (3-4)	Make-or-Break (4)	Sample Sise
1	Improving soil structure	3.38	87.5%	50.0%	24
2	Improving biodiversity - above ground	2.71	62.5%	16.7%	24
3	Soil moisture management	2.56	50.0%	16.7%	24
4	Reducing inputs	2.50	45.8%	12.5%	24
5	Ability to suppress weeds	2.50	45.8%	20.8%	24

Table 11-4 Regional Distribution and Interviewer Details

Region	Number of Growers	Interviewer	Primary Crop Types
Canterbury	12	Charles Merfield	Mixed arable, vegetables
Hawke's Bay	9	Dan Bloomer	Vegetables, process crops
Pukekohe	5	Andrew Luxmoore	Vegetables, onions
Manawatu	4	Karen Coleman	Mixed farming
Gisborne	2	Chris Lambert	Vegetables, process crops

11.2 Appendix B: Species Performance Summary

Table 11-5 Current Cover Crop Species Usage

Most common species	
1	Ryegrass (multiple varieties)
2	Oats (most frequently mentioned)
3	Barley
4	Clover (annual and perennial)
5	Vetch
6	Brassicas (mustard, radish)

Complex Multi-Species Examples from Experienced Growers	
1	"Oats, barley, sorghum, mustard, smart radish, millet, vetch, phacelia, clover, annual ryegrass, winter/summer beneficial flower mix"
2	"Faba bean, Phacelia, annual clovers, buckwheat, sunflowers, oats, maise"
3	"Italian ryegrass, oats, vetch, tillage radish, rape, turnip, phacelia, linseed, buckwheat, sunflower"

Table 11-6 Recommended Species (High Establishment Reliability, Low Risk)

Species	Benefits	Grower Feedback	Considerations
Oats	• Highest grower satisfaction • Reliable establishment • Easy termination • Good biomass production	"Most frequently mentioned positive" "Rate cover crop of oats highly"	• Most successful across regions • Suitable for organic systems
Annual Ryegrass	• Consistent ground cover • Reliable performance • Grazing option available	"Consistent ground cover performance" "Well-understood management"	• Termination timing important • Established protocols exist
Vetch	• Nitrogen fixation benefits • Soil improvement • Good establishment when managed	"Valued for nitrogen fixation benefits"	• Mix with cereals for support • Requires proper inoculation
Barley	• Quick establishment • Wind protection benefits • Good winter performance	"Barley as stubble wind cover"	• Specific applications • Regional suitability varies

Table 11-7 Higher Risk Species (Require Careful Management)

Species	Issues	Grower Feedback	Risk Management
Rye	• Difficult termination • Pest hosting concerns • Can become weedy	"Potential to become a weed" "Host to pests and difficult to remove"	• Avoid in organic systems • Consider annual varieties only • Excellent for nutrient scavenging but requires proper termination timing
Brassicas	• Seed contamination risk • Establishment challenges • Persistence problems	"Radish is a strict no-no" "Contamination of surrounding seed crops"	• Avoid near seed crops • Monitor for persistence • Consider biofumigation benefits for pest management in appropriate situations
Complex Mixes	• Management difficulty • Weed control challenges • Termination complications	"Multispecies mixes are hard to manage"	• Focus on 2-3 compatible species with complementary functions • Balance C:N ratios • Require advanced skills
Clover	• Termination challenges • Variable establishment • Grazing conflicts	"Clover was impossible to control with crimper"	• Better for longer-term situations • Avoid where crimping planned • Provides nitrogen fixation benefits

11.2.1 Farm-Specific Selection Considerations

High-reliability species suitable for most operations**:**

- Oats: Most consistent performance across diverse conditions
- Annual ryegrass: Reliable establishment and management protocols
- Vetch: Effective nitrogen fixation when properly supported

Specialised applications:

- Wind protection: Barley, triticale for exposed sites
- Quick turnaround: Oats, mustard for intensive rotations
- Organic systems: Species with reliable non-chemical termination options
- Soil compaction relief: Deep-rooted brassicas where contamination risk is manageable

11.3 Appendix C: Detailed Methodology

11.3.1 Data Collection Framework

Regional agronomists conducted surveys using structured questionnaires across five key horticultural regions:

- **Canterbury:** 12 growers (Charles Merfield)
- **Hawke's Bay:** 9 growers (Dan Bloomer)
- **Pukekohe:** 5 growers (Andrew Luxmoore)
- **Manawatu:** 4 growers (Karen Coleman)
- **Gisborne:** 2 growers (Chris Lambert)

11.3.2 Quantitative Methodology

11.3.2.1 Importance Scoring System

Growers rated factors using a standardised 5-point scale:

- **0** = Not a consideration
- **1** = Only minor consideration
- **2** = Needs to be considered
- **3** = Very important in decision making
- **4** = Make-or-break consideration

Higher mean scores indicate greater importance as barriers or motivations.

11.3.2.2 Statistical Analysis Approach

Descriptive Statistics Calculated:

- **Mean Score:** Primary metric for ranking importance (higher = more important)
- **Sample Sise (n):** Number of valid responses per question
- **Distribution:** Frequency count of each score (0-4)
- **High Importance Percentage:** Proportion scoring 3-4 (very important to make-or-break)
- **Make-or-Break Percentage:** Proportion scoring 4 (make-or-break consideration)

11.3.2.3 Inclusion Criteria:

Questions were included in the analysis if they had:

- At least 5 valid numeric responses ($n \geq 5$)
- Clear relevance to barriers or motivations
- Consistent use of the 0-4 importance scale

11.3.2.4 Ranking and Interpretation Methods

Barrier Analysis: Barriers were ranked by mean score in descending order, where higher scores indicate more significant barriers to adoption. The analysis focused on:

- Critical practical factors (mean >2.9) requiring immediate attention
- High priority biological risk factors (mean 2.5-2.9) needing targeted solutions
- Secondary technical factors (mean 2.5-2.9) for optimisation
- Moderate economic barriers (mean 2.0-2.5) for support programs
- Understanding minor barriers (mean <2.0) that are less problematic

Motivation Analysis: Benefits and motivations were similarly ranked by mean score, with higher scores indicating stronger drivers for adoption. Particular attention was paid to:

- Consensus motivations with high agreement (high percentage scoring 3-4)
- Make-or-break factors that could drive or prevent adoption
- Practical vs. environmental motivations

Implementation Challenges Analysis: The dedicated "Challenges of growing cover crops" section was analysed using the same statistical framework to understand ongoing difficulties faced by current users:

- Comparison with barrier rankings to validate findings
- Identification of persistent vs. experience-addressable challenges
- Assessment of operational vs. technical challenge priorities

11.3.3 Qualitative Methodology

11.3.3.1 Qualitative Data Sources

Open-ended text responses were extracted from multiple survey sections including species selection rationales, implementation challenges, adoption barriers, and comments re cover crop experiences.

11.3.3.2 Thematic Analysis Approach

A systematic thematic analysis was conducted following established qualitative research methods:

1. **Initial Coding:** All substantive text responses (>3 characters) were reviewed to identify recurring concepts, specific examples, and unique insights across grower responses
2. **Theme Development:** Related codes were grouped into broader themes representing common experiences, concerns, and strategic approaches
3. **Theme Refinement:** Themes were iteratively refined to ensure they captured distinct aspects of grower experience and decision-making processes
4. **Pattern Recognition:** Cross-cutting patterns were identified across different question types and grower responses to understand relationships between themes
5. **Integration with Quantitative Data:** Thematic findings were systematically compared with importance scores to identify convergent evidence, discrepancies, and nuanced understanding beyond numerical rankings

11.3.4 Mixed-Methods Integration

Data processing involved extracting numeric responses (0-4 scale) across all grower columns, calculating descriptive statistics, and ranking factors by mean importance scores. Qualitative responses were analysed thematically to validate and expand on quantitative findings.

11.3.4.1 Analytical Tools

The preparation of this report utilised Claude AI (Anthropic) to process and integrate quantitative and qualitative data. All reviews, substantive analysis, data interpretation, and recommendations were confirmed and curated by the authors.

11.3.5 Detailed Limitations

- **Selection bias:** Purposive sampling reflects experienced growers chosen by agronomists rather than representative populations
- **Experience filter:** High experience levels (average 23 years) mean basic barriers score low while advanced challenges remain prominent
- **Sample sise variation:** Different response rates (n=9 to n=24) affect reliability of factor comparisons
- **Temporal context:** Results represent perspectives at time of data collection
- **Scale interpretation:** While the 0-4 scale provides relative importance rankings, absolute threshold interpretations should be made cautiously
- **Regional representation:** Uneven regional distribution reflects agronomist research interests rather than regional adoption patterns

11.3.6 Data Quality Assurance

Data quality was ensured through:

- Cross-checking score distributions for logical consistency
- Verifying that responses aligned with the defined 0-4 scale
- Confirming that sample sizes met minimum thresholds for meaningful analysis ($n \geq 5$)
- Reviewing outlier responses and extreme scores for data entry errors
- Filtering out null values, empty strings, and non-numeric responses

This methodological approach allows for robust comparison of the relative importance of different factors while acknowledging the limitations inherent in the sampling and data collection approach.

11.4 Appendix D: Tabulated Summaries

Table 11-8 Qualitative Analysis Framework

Analysis Component	Method	Purpose
Primary Ranking Metric	Mean score calculation (0-4 scale)	Establish relative importance hierarchy
Consensus Assessment	High importance percentage (scores 3-4)	Identify factors with broad agreement
Critical Factor Identification	Make-or-break percentage (score 4)	Determine system-critical requirements
Sample Reliability	Minimum n≥5 responses per factor	Ensure statistical meaningfulness
Threshold Classification	Mean score ranges: >2.9 (critical), 2.5-2.9 (high), 2.0-2.5 (moderate), <2.0 (minor)	Guide priority setting

Table 11-9 Survey Implementation Details

Aspect	Details
Data Collection Period	2025
Survey Method	Structured questionnaire administered by regional agronomists
Sampling Approach	Purposive sampling - "growers of interest" selected by agronomists
Response Format	5-point importance scale (0-4) plus open-ended responses
Data Processing	CSV format with 177 rows (factors) and 37 columns (growers + metadata)
Quality Assurance	Cross-checking for logical consistency, outlier review, null value filtering
Inclusion Criteria	n≥5 valid responses, 0-4 scale consistency, barrier/motivation relevance

Table 11-10 Major Qualitative Themes with Representative Quotes

Theme	Representative Quotes	Frequency	Implications
Establishment Reliability	"Cover crop establishment concerns" "Establishment reliability"	High	Validates quantitative ranking
Termination Complexity	"Being organic the ease of cover crop destruction is important" "Difficulty terminating cover crop"	High	Supports termination technology priority
Operational Flexibility	"Once land is cover cropped it ties it up for a period of time"	Medium	Critical barrier not fully captured quantitatively
Economic Valuation	"How to make them pay. How to put a value on them" "Economic viability - substitutes for a cash crop"	Medium	Need for economic analysis tools
Seed Crop Contamination	"Contaminating small seed crops" "Radish is a strict no-no"	Medium	Sector-specific barrier
Land Tenure Issues	"If we lease the land then the owner will have preference" "Short term leases"	Low	Structural barrier

Table 11-11 Information Source Preferences

Source Type	Specific Sources Mentioned	Grower Preference Level
Peer Networks	"Word of mouth," "fellow farmers"	High
Digital Resources	Internet, overseas podcasts, UK media	High
Commercial Sources	Seed suppliers, resellers	Medium
Organisations	FAR, industry bodies	Medium
International	UK sources, overseas information	Medium

Table 11-12 Species Selection Decision Framework (From Grower Experience)

Priority Order	Decision Factor	Grower Approach	Supporting Evidence
1	Will it establish reliably?	Primary filter - eliminates unreliable options	3.46 mean score, 95.8% high importance
2	Can I terminate it when needed?	Operational requirement	2.98 mean score, 79.2% high importance
3	What are pest/disease risks?	Risk assessment for farm integration	6 factors in top 15 rankings
4	Will it improve soil structure?	Benefit confirmation	3.38 mean score, 87.5% high importance
5	Are technical challenges manageable?	Complexity assessment	2.67-2.73 range for technical factors
6	Are costs reasonable?	Economic feasibility check	2.08-2.54 range for cost factors

Table 11-13 Knowledge and Information Gaps Identified

Gap Category	Specific Needs Mentioned	Priority Level
Species Identification	"Defining common names vs scientific names, i.e. not all vetches are the same"	High
Performance Measurement	"Ability to measure changes in soil health and structure" "How can we measure nitrogen release?"	High
Pathogen Knowledge	"Knowledge of reduced or increased pathogens such as clubroot"	Medium
Weed Management	"Knowledge of reduced weed seed bank with some cover crops"	Medium
Technical Resources	"Fact sheets/online info would be helpful"	Medium

Table 11-14 Economic Analysis Framework Components

Component	Description	Measurement Needs
Direct Costs	Seed, establishment, termination	Cost tracking systems
Opportunity Costs	Land use, timing constraints	Alternative crop revenue analysis
Direct Benefits	Reduced inputs, yield improvements	Input reduction quantification
Indirect Benefits	Soil health, pest management, compliance	Long-term benefit valuation tools
Long-term Benefits	Sustainability, resilience, carbon storage	Economic valuation methodologies

LandWISE