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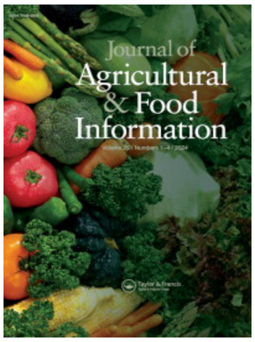

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Agrisemantics: The Current State of Adoption

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ABSTRACT

Agrisemantics promises improved interoperability, traceability and analytics in food and agriculture, yet adoption remains limited. This study reports 28 semi-structured interviews and a survey of 76 practitioners, analyzed thematically to identify organizational, financial, technical and cultural factors shaping uptake. Key barriers include decision-maker resistance, internal gatekeeping, limited tools, data heterogeneity and shortages of skilled personnel, with additional constraints in less developed countries. Drivers include provenance, traceability, digitalization, regulation and individual champions. The study contributes an empirically grounded account of adoption and recommends incentive alignment, stronger governance and enhanced tooling and training to support sustainable Agrisemantic infrastructure.

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agriculture; agrisemantics; information management

Introduction

Precision farming is becoming increasingly popular, (Addicott, 2020) given that it demonstrates higher yields than traditional agricultural practices. Precision farming, defined as the application of data science and related analytical techniques to agricultural problems (Neto et al., 2023), has been a major driver of the increase in agricultural data volumes (Neto et al., 2023).

Machine learning and related data-driven techniques rely on well-structured and integrated datasets. Siloed and poor-quality data have been estimated to cost organizations $12.9 million per year (Gartner & Inc, 2025). The data integration market is valued at $11.6 billion (MarketsandMarkets, 2025), underlining the monetary value of integrated data for downstream tasks.

Agricultural data is frequently fragmented, stored in distributed silos, and described using proprietary schemas (Jeedigunta & Goel, 2023), making integration difficult and costly. The consequences of poorly integrated

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or mismatched agricultural data are significant: they increase consumer costs through higher food prices and can contribute to increased risks of malnutrition and food insecurity (Headey & Ruel, 2023).

The scale of these costs is considerable. In India alone, the absence of agricultural data integration has been estimated at $65 billion (Khatoon & Ahmed, 2022). More broadly, the economic and social consequences of siloed agricultural data (Jeedigunta & Goel, 2023) are likely to intensify due to global population growth and the shrinking availability of cultivable land caused by climate change, biofuel competition, and desertification.

Effective data integration is essential for stakeholders, such as regulators and supermarkets, who need timely and accurate information to support informed decision making. Although initiatives such as Atlas Horizon Project and private sector solutions attempt to address this challenge, most remain fragmented and tied to specific technologies. Such approaches are inherently brittle, as they are vulnerable to concept drift and evolving uses of agricultural data.

Agrisemantics offers a more sustainable technology-agnostic approach (Khatoon & Ahmed, 2022). Agrisemantics provides universal definitions of agricultural concepts through semantic resources such as AGROVOC (Caracciolo et al., 2013; Food & Agriculture Organization of the United Nations, 2025) and the Crop Ontology (Matteis et al., 2013). Combining unambiguous concept definitions with Universal Resource Identifiers (URIs), drives Linked Data publishing (Bizer et al., 2023), graph databases (Abad-Navarro et al., 2020), Semantic APIs and discoverable Web Services, (Riazanov et al., 2013). Agrisemantics enables data sharing architectures for agri-food supply chains (Brewster et al., 2024) and interoperable frameworks that provide decision support for agronomists (Al Manir et al., 2018).

Agrisemantic resources have received substantial investment from organizations such as the Food and Agriculture Organization (FAO). Despite this investment and the availability of mature resources, the current state of agrisemantics adoption remains undocumented, and the return on investment thus far is uncertain or unquantifiable.

This article addresses this knowledge gap by presenting a qualitative study of academics and practitioners. Through interviews and a supporting questionnaire, we identify the barriers that have prevented agrisemantics from emerging as the default methodology for agricultural data integration, as well as the pressures that may encourage its wider adoption.

While U.N. organizations, such as the Food and Agriculture Organization (FAO) and initiatives such as the Global Open Data for Agriculture and Nutrition (GODAN) have published reports on the importance of agrisemantics (Food & Agriculture Organization of the United Nations (FAO)/AIMS, 2019; Pesce et al., 2018), these outputs are largely descriptive and focus on promoting best practices or highlighting technical resources. By contrast, this study provides an empirically grounded assessment of the current state of adoption, drawing directly on the perspectives of practitioners through semi-structured interviews and a targeted survey. In doing so, it offers evidence of both the barriers and pressures that influence adoption and highlights the disconnect between conceptual advocacy and practical adoption. This contribution extends beyond previous reports by systematically documenting real-world experiences, and motivational barriers, providing insights that can inform policy, training, and tool development to bridge the gap between aspiration and implementation.

Materials and methods

This study aims to address the current gap in knowledge concerning the adoption of agrisemantic resources, while also identifying barriers and drivers influencing their uptake. To achieve this, a qualitative research design was adopted, combining semi-structured interviews and a web-based questionnaire. This dual-method approach provided both depth (through interviews) and breadth (through a questionnaire), enabling a richer understanding of the current adoption landscape. The study was conducted from 2020 to 2025, with the majority of interviews taking place between 2020 and 2023, and the questionnaire being available to respondents for the full duration of the study. There were twenty-eight interviews and seventy-six respondents to the questionnaire.

Research design

The methodology was designed to elicit insights from a wide range of stakeholders, from academia, industry, and the broader set of practitioners engaged in the creation and use of agrisemantics, and agricultural data management. By incorporating multiple perspectives, the study sought to ensure that findings reflect both scholarly and applied contexts. Two main tools were used: semi-structured interviews and a web-based questionnaire.

Semi-structured interviews

Participants were selected based on demonstrable expertise in agrisemantics, defined by at least one of the following: authorship of peer-reviewed publications on semantic resources in agriculture, documented contributions to industry initiatives or standards, or nomination by peers already recognized in the field. We employed a modified form of snowball sampling (Goodman, 1961), where initial participants were identified through a structured review of recent publications and professional networks and were then invited to suggest additional experts. In total, sixty individuals were invited to participate, of whom twenty-eight agreed to hour-long interviews (46.70% response rate). To promote diversity, invitations were extended across multiple world regions and institutional types, including academia, government, NGOs, and the private sector. Although the sample size is modest, thematic saturation was observed, with no new codes or concepts emerging in the final two interviews. Thematic saturation is an indicator that the major concepts have been captured in the interviews. The interviews were conducted between 2020 and 2025, with most of the interviews being conducted between 2020 and 2023. See Appendix A for list of interview questions.

This provides confidence that the interviews captured the major perspectives present within the accessible expert community, while recognizing that the snowball sampling strategy may under-represent individuals outside established professional networks

The interviews followed a semi-structured format: while no rigid questionnaire was used, interviews were guided by thematic prompts to ensure comparability across participants while allowing flexibility for the elaboration of answers. Summaries of the interviews were produced, and the main themes were extracted through a process of manual thematic coding. All transcripts and notes were anonymized to encourage candid participation and protect reputational concerns.

The thematic classes were developed through an inductive approach (Fereday & Muir-Cochrane, 2006) where classes and the inclusion and exclusion criteria were inferred from the data through manual analysis, rather than imposing pre-set themes that may not have been suitable for the interviews. The resultant classes with the associated criteria are in Table 1.

The frequency of the thematic codes per interview, i.e. the number of quotes that were attributed to the theme, can be found in Table 2 which uses a heat-map to show the most frequently referred to terms. The most frequent themes across all interviews are shown in bold in the final row. The most frequent themes are Domain-Specific Drivers, Tool Limitations and Government/Policy Support, which is surprising as the overall sentiment of the interviews was not positive given the long history of failure of adopting semantics by industry in general.

Validation of interview encoding

A random subsample of five interviews was validated by an independent annotator, who used the inclusion and exclusion criteria in Table 1 as a guide. A Kappa Cohen Inter Annotator Agreement (Cohen, 1960) of 0.939 was computed. This score is almost perfect agreement on the Kappa Cohen scale. As there was little disagreement between the annotators, the encoding of the interviews can be seen as robust, and the inferences reliable.

Table 1. Granular coding schema for agrisemantics adoption barriers.

ID	Granular Code	Definition	Inclusion Criteria	Exclusion Criteria
1	Decision-Maker Resistance	Lack of understanding or buy-in from leadership.	Mentions of man-agers, boards, or executives rejecting or blocking adoption.	General references to cost/skills issues.
2	Client Cost Concerns	Perception that se-mantic web adds financial/ time burden.	Mentionsofover-head,extracost, slow implementation.	Broader"lackof value"claimsnot tied to cost.
3	Developer Skill Gap	Lack of trained staff to implement semantic tech.	References to learn-ing curve, lack of training, gaps in CS education.	Issueswith Tools /visualization (coded separately).
4	Tool Limitations	Weaknesses in current software for semantic adoption.	Mentions of Power BI not parsing, Protege limitations, poor us-ability.	Barriers linked tohuman knowledge / skills.
5	Ad-hoc Integration	Relianceonnon-standard, improvised integration methods.	Mentionsofdata lakes,connectors, piecemeal solutions.	Plannedadoption strategiesor standards.
6	Government/ Policy Support	References to external funding, regulation, or policy.	Mentions of Innovate UKcenters,FAO, EU mandates.	Company-driven adoptionwithout policy link.
7	Internal Gate-keeping	Individuals blocking progressinside organizations.	Mentions of project managers,internal politics.	Lack of adoption due to cost, not people.
8	Data Heterogeneity	Struggles with multiple formats and standards.	Mentions of many file types, legacy systems, fragmented ontologies.	General adoption issues not tied to for-mats.
9	Loss of Momen-tum	Decline of interest after initial enthusiasm.	References to semantic web being "popular years ago" but fading.	Currentongoing adoption barriers.
10	Individual Champions	Role of specific people driving adoption.	Mentions of "champions", "Evangelists", or single leaders.	Collective organizationalor policy-driven adoption.
11	Hybrid Architectures	Use of combined relational + semantic approaches.	Mentions of hybrid backends, ontology + RDBMS setups.	Puresemanticor purerelational approaches.
12	Domain – specific Drivers	Adoption varies by sector(e.g.retail, pharma, agriculture).	Mentions of organizations or technologies.	Generaladoption challenges.
13	Academic – Industry Divide	Gapsbetween research standards and industry practice.	Criticismof academia-driven initiatives,lackof enterprise adoption.	Internalcompany politics or technical challenges.

The categories are:

- Organizational and Cultural Barriers
  - o Theme Number. Merged Theme Categories (Theme Frequency)
    1. Decision-Maker Resistance (50)
    7. Internal Gatekeeping (51)
    9. Loss Of Momentum (53)
    13. Academic–Industry divide (39)

    Total: 193
  - o Rationale: These all relate to people and organizations rather than technical issues. Resistance from managers, siloed behavior, lack of

Table 2. Frequencies of themes across interviews.

	Themes												
Interviews	1	2	3	4	5	6	7	8	9	10	11	12	13
I.1	3	2	1	1	2	1	1	1	1	1	0	0	0
I.2	3	0	1	1	1	0	2	3	0	2	2	4	1
I.3	2	0	0	1	1	0	3	1	4	0	0	2	2
I.4	1	1	0	0	1	2	1	1	1	0	0	5	0
I.5	1	1	1	2	1	0	1	1	0	0	0	1	1
I.6	0	0	0	2	1	1	0	1	1	0	1	5	1
I.7	2	0	1	4	0	1	2	1	1	2	1	3	0
I.8	1	1	0	2	0	2	1	0	2	0	0	5	1
I.9	1	0	2	5	2	4	2	2	2	0	1	8	1
I.10	3	1	1	2	0	6	1	1	2	0	0	3	0
I.11	1	0	0	3	0	2	4	0	2	0	1	5	1
I.12	1	2	1	2	0	0	1	0	0	1	2	1	1
I.13	2	3	1	7	2	1	3	2	2	0	1	4	0
I.14	1	2	0	1	0	0	2	0	1	0	1	2	0
I.15	3	3	0	3	0	2	2	2	0	0	2	7	1
I.16	0	4	3	4	0	8	0	0	2	0	2	7	5
I.17	0	2	2	8	0	5	4	1	5	0	3	2	2
I.18	1	0	0	2	1	1	1	0	1	0	0	2	2
I.19	4	5	5	7	0	2	3	3	3	1	1	7	4
I.20	4	3	0	4	2	5	4	1	0	0	1	8	2
I.21	2	0	0	6	6	5	3	1	0	0	0	5	2
I.22	2	2	1	2	0	2	2	0	4	1	0	5	2
I.23	6	2	6	7	0	1	1	3	5	0	0	3	1
I.24	1	1	0	3	0	1	1	2	2	1	1	5	2
I.25	2	1	3	7	0	3	0	3	3	1	4	9	3
I.26	1	0	0	7	0	3	2	5	1	0	2	6	0
I.27	1	2	3	5	1	0	2	2	4	0	0	3	1
I.28	1	0	1	4	0	4	2	2	4	1	0	10	3
Total	50	38	33	**102**	21	**62**	51	39	53	11	26	**127**	39

trust between academia and industry, and projects losing steam are all manifestations of organizational culture and structural barriers.

- Economic and Resource Constraints
    - o Theme Number - Merged Theme (Theme Frequency)
      2. Client Cost Concerns (38)
      3. Developer Skill Gap (33)
      Total: 71
    - o Rationale: Both deal with lack of resources. One is financial (costs, lack of budget), the other is human capital (shortage of skilled workers, training gaps). They both ultimately come down to resource limitations that slow adoption.
- Technical and Infrastructure Challenges
    - o Theme Number - Merged Theme (Theme Frequency)
      4. Tool Limitations (102)
      5. Ad-hoc Integration (21)
      8. Data Heterogeneity (39)
      11. Hybrid Architecture (26)
      Total: 189
    - o Rationale: These are all technical in nature; poor tools, fragmented integration efforts, inconsistent data, and uncertainty about

technical stacks (triple stores, JSON-LD, KGs). Together they represent the infrastructure side of challenges

- Drivers of Adoption
  - o Theme Number - Merged Theme (Theme Frequency)
    6. Government/Policy Support (62)
    10. Individual Champions (11)
    12. Domain-Specific Drivers (127)
    Total: 200
  - o Rationale: These are all the forces pushing adoption forward. Regulation and public policy, specific sectoral needs (e.g., food safety, traceability), and key individuals who champion adoption all play a catalytic role.

Metadata of interviewees

The geographical distribution of interviewees is shown in Figure 1. Despite efforts to secure diversity, responses exhibited a strong Western skew: 51.85% of participants were based in Europe and 25.93% in North America, reflecting the main centers of agrisemantic resource production.

Occupational representation is shown in Figure 2. While attempts were made to balance employer types, the majority of interviewees were academics or employed in private, for-profit organizations.

Gender representation among interviewees was uneven, with 7 (25.00%) female and 21 (75.00%) male participants. Despite deliberate attempts to encourage female participation, the response rate skewed male.

Taken together, the average interview participant was a male, either an academic or an employee of a private for-profit organization and located in

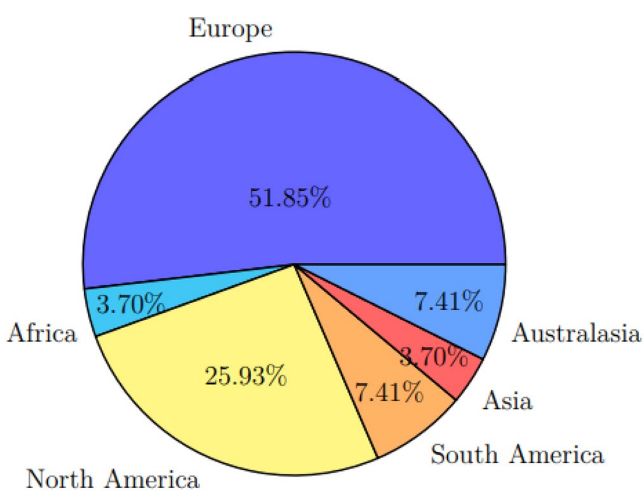

Figure 1. Breakdown of interviewees by geographic location, Europe, Australasia, Asia, South America, North America, Africa (percent).

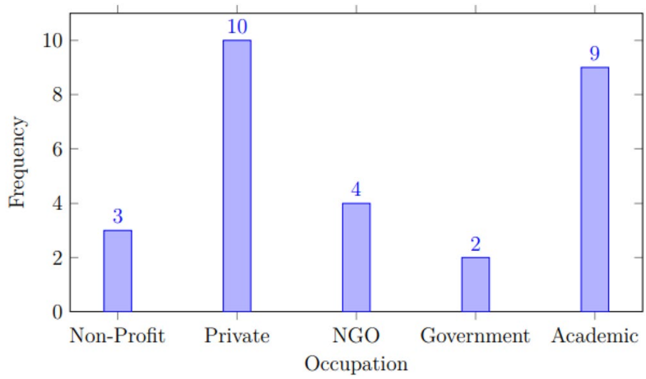

Figure 2. Frequency of interviewee occupations, academic, government, NGO, private, or nonprofit.

Europe or North America. This introduces a selection bias, which may limit the generalizability of the findings. Nonetheless, the data provides valuable insights into perspectives from the current centers of agrisemantic activity.

Web-based questionnaire

Recognizing the time-intensive nature of interviews, a web-based questionnaire was developed to complement them. The questionnaire was made available online (see Appendix B) and designed for rapid completion in order to minimize abandonment rates. The survey included both closed-ended multiple-choice questions (to allow comparability across responses) and open-ended questions (to capture nuanced experiences). The full text of the questionnaire is in Appendix C and the compliance checklist for the questionnaire is in Appendix D.

The questionnaire was disseminated *via* professional networks, mailing lists, and snowball sampling. An example of a recruitment attempt is shown by (Food & Agriculture Organization of the United Nations (FAO)/ AIMS, 2020). It is open to academics, industry practitioners, and researchers in agrisemantics. The only eligibility criteria were that the respondents had to self-identify as working in or with agricultural data/semantics.

A total of 76 respondents completed the questionnaire. Geographic distribution is shown in Figure 3. Compared to the interviews, the questionnaire attracted greater participation from Africa and Asia, partially balancing the Western skew observed earlier.

Employer status is shown in Figure 4. Most respondents were affiliated with either private (39.28%) or academic (35.71%) institutions, which is similar to the interview cohort. The breakdown of the affiliations by region are in Figure 5, and there are some clear differences between the regions with Africa having a higher percentage of respondents from NGOs, than the other regions, Australasia had the highest percentage of respondents

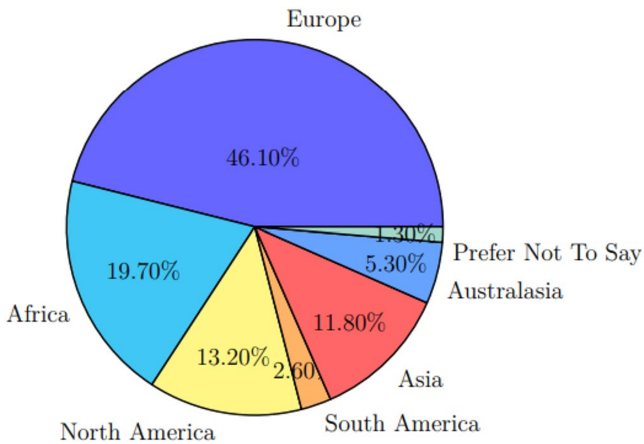

Figure 3. Overview of questionnaire respondents by geographic location: Europe, Australasia, Asia, South America, North America, Africa (percent).

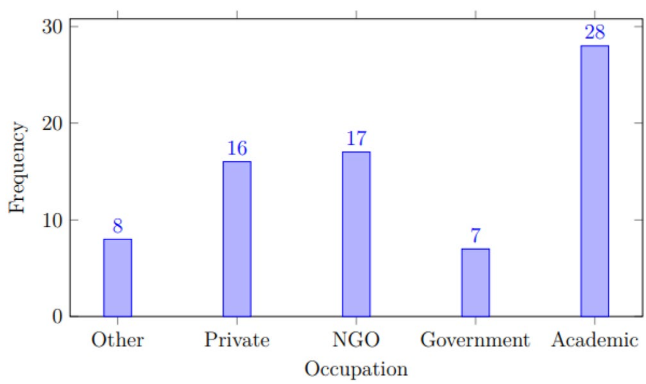

Figure 4. Overview of questionnaire respondents by occupation, academic, government, NGO, private, or other (number of respondents).

from Academia, although both regions had smaller number of respondents than North America and Europe. Both Europe and North America respondents had the highest response from Academia, with similar percentages from the Private Sector.

Unlike the interviews, the questionnaire did not record gender data. The rationale was that such questions might be perceived as intrusive and could reduce completion rates. However, this omission also limits the ability to analyze demographic factors shaping perspectives on agrisemantics.

Data analysis

All qualitative data from interviews and open-ended survey responses were analyzed using manual thematic coding (Ahmed et al., 2025). Codes were

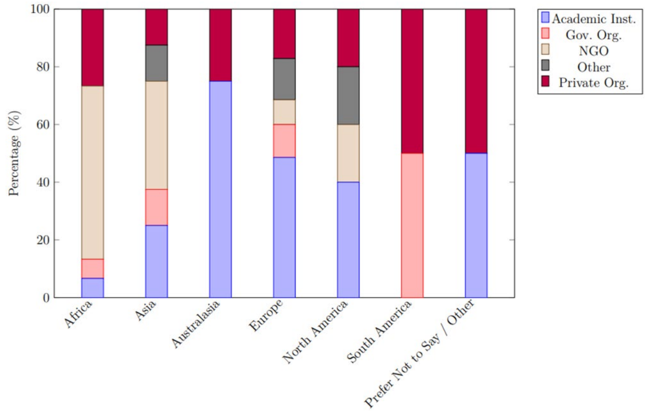

Figure 5. Breakdown of respondents by region and occupation, academic institution, government organization, non-government organization (NG), private organization or other (percent of total respondents).

developed inductively (Fereday & Muir-Cochrane, 2006) to allow key issues to emerge directly from the data, rather than being pre-determined by an ad-hoc basis. Manual coding was conducted by the lead researcher, with themes iteratively refined to ensure consistency and coherence across the dataset. Where appropriate, findings from interviews and questionnaires were triangulated to enhance validity and to cross-check emerging patterns.

Ethical considerations

All participants were informed of the purpose of the study, the voluntary nature of their involvement, and their right to withdraw at any time without penalty. Informed consent was obtained prior to participation in both interviews and the questionnaire. For the interviews, notes and summaries were anonymized to protect participant identities and to ensure that views could be expressed freely without reputational risk. No personally identifying information was collected in the questionnaire, and demographic questions were limited to non-sensitive categories to minimize privacy concerns.

All data was stored securely and were accessible only to the research team. The study design complied with applicable data protection regulations. By prioritizing confidentiality and minimizing data collection, the study sought to balance the need for meaningful insights with the ethical responsibility to safeguard participants' privacy and autonomy. This study received ethical approval from Liverpool Hope University (Ethical Approval Reference SEL-03092025-001). Authors assessed study compliance with qualitative reporting checklist (see Appendix E).

Representative Quotes

Decision-Maker Resistance
"Little customer demand for semantic web solutions" "Demand for Agrisemantics is simply not there"
Internal Gatekeeping
"Project managers blocking use of semantic web" "Business units and departments are siloed... politics that need to be played"
Academic–Industry Divide
"Academics must meet business on their terms" "Lack of trust between companies and universities"
Loss Of Momentum
"Adoption must be bottom-up, don't pick winners" "Projects stop when funding ends"

Figure 6. Representative quotes for four thematic codes, decision-maker resistance, internal gatekeeping, academic-industry divide, and loss of momentum.

Limitations

While this study provides valuable insights into the state of agrisemantic adoption, several methodological limitations must be acknowledged.

First, despite deliberate efforts to recruit globally, participation was skewed toward Europe and North America, which represent the current centers of agrisemantic development. As a result, perspectives from under-represented regions (e.g. Africa, Asia, and South America) are less prominent, potentially limiting the global generalizability of findings.

Second, although efforts were made to promote diversity in gender representation, most interview participants were male. The absence of gender data in the questionnaire further constrained analysis of demographic influences. Future work should incorporate optional demographic questions with "prefer not to say" responses to balance inclusivity and data utility.

Third, the selection of interviewees partly relied on personal recommendations, which introduces potential bias in participant recruitment. While this approach was effective in identifying knowledgeable individuals, it may have inadvertently reinforced existing professional networks.

Finally, the study employed manual thematic analysis of interviews and survey responses, while systematic, it may still be influenced by researcher interpretation. To strengthen reliability, future research could apply inter-coder checks or utilize qualitative analysis software to reduce subjectivity.

Despite these limitations, the combined use of semi-structured interviews and web-based questionnaires, along with triangulation across both datasets, provides a robust foundation for understanding the current state of agrisemantic adoption.

Interview results

The findings from the interviews are organized by the coarse categories, with discussion centerd around the related thematic codes within each category. The main findings are supported by direct quotes from the anonymized interviews which are associated with each thematic code.

Organizational and cultural barriers

This main category contained four thematic codes: Decision-maker resistance, Internal gatekeeping, Academic–Industry divide, and Loss of momentum. The frequency of each code was 50, 51, 39, and 53 respectively. None of the thematic codes were the most frequent across the interviews, but together they demonstrate important non-technical issues that impair the use, and by extension the demonstration of the "value proposition", of agrisemantics to industry.

Decision-maker resistance

Interviews revealed that the perceived benefits of standardization were often not recognized by decision-makers. Several respondents observed that "Most clients did not care about downstream data integration" (Interview One), that there was "Little customer demand for semantic web solutions" (Interview One), and that overall "Demand for agrisemantics is simply not there" (Interview Nineteen).

This lack of demand was not limited to external clients. Within organizations, respondents described widespread indifference or limited understanding among senior management. One interviewee reported that "Management did not understand the benefits… the board said no" (Interview Twelve). Successful initiatives were often attributed to sustained efforts to educate stakeholders or to actively promote the benefits of semantics. As one respondent noted, "There was some resistance, so a selling 'job' is required" (Interview Two). These efforts were further complicated by the priorities of data owners, who, according to one interviewee, "will only care about local issues and not global issues" (Interview Four). Even when awareness existed, organizational politics could present an additional barrier, since "Conflict is heavily embedded into private business" (Interview Eight). Furthermore, the global applicability of agrisemantics was questioned, as one respondent stated, "Half the world does not use food standards" (Interview Fifteen).

Respondents also highlighted resistance at the level of research funding. Duplication and fragmentation of resources were seen as persistent problems, with one interviewee observing that "Funders do not comprehend that [replication] is happening" (Interview Three).

In addition, concerns about ownership of data were widely reported. For instance, one respondent commented that "France is struggling with data ownership" (Interview Ten), reflecting broader tensions between data availability and commercial or institutional control.

Taken together, the findings suggest that the absence of a clear business case, combined with limited recognition of potential benefits among decision-makers and funders, constitutes a major barrier to adoption. This barrier is closely linked to Thematic Code 10 ("Individual champions"), since successful projects were consistently associated with strong leadership from committed individuals. A potential long-term solution is to embed semantics more firmly within higher education curricula, particularly within computer science, where modules on semantics and knowledge representation could help build a more informed generation of practitioners.

Internal gatekeeping

Whereas decision-maker resistance reflects barriers at senior levels, internal gatekeeping highlights obstacles created by individuals or units at lower levels who nevertheless exert significant influence over local data management or technology implementations. Such resistance was frequently attributed to "gatekeepers", as exemplified by comments such as: "Project managers blocking use of semantic web" (Interview One), "Motivation to protect knowledge which means it is unlikely data owners will share data voluntarily" (Interview Five), and "People protective of data, owners stop access" (Interview Fourteen).

In addition to these explicit barriers, participants also described implicit forms of gatekeeping, particularly the fragmentation of organizations into semi-autonomous groups working on local issues. This "Balkanization" was viewed as fundamentally at odds with the organization-wide perspective required for the effective adoption of agrisemantics. As one respondent noted, "Silos of activity within the company… IT battling with technical debt" (Interview Four), while another emphasized, "Business units and departments are siloed… politics that need to be played" (Interview Seven). These accounts highlight how organizational silos and internal politics, undermine efforts to achieve coordinated approaches to data standardization.

Politics and individual motivations were also cited as implicit forms of gatekeeping. For example, one respondent reflected on a culture of "not invented here", remarking: "In particular vanity where things not invented here are rejected" (Interview Eight), that is reminiscent of organizational defensiveness challenges, common in knowledge management projects.

Finally, the commercial value of data was repeatedly described as a key source of resistance to sharing. This economic dimension of gatekeeping was illustrated in statements such as: "IP is a big deal in commercial research environments, and companies will not want to release that either"

(Interview Twelve); "Sharing data is an issue because data has value" (Interview Fifteen); and "Data has value and companies will not share them, especially in poultry" (Interview Twenty-Four). The cumulative effect of such practices, according to respondents, is that publicly funded semantic resources remain incomplete, as one participant observed: "Private data [are] missing from public ontologies" (Interview Twenty-One).

Academic–industry divide

The aims of academia and industry are different, and because numerous semantic resources are produced in varying scales and dimensions across both domains, there can be mismatches that impair the adoption of agrisemantic resources.

This gap was recognized by interviewees, who noted that research projects often attempt to include both industry and academic participants. For example, one respondent observed a "Push for academic/industry partnerships in research" (Interview Twenty-Seven). Current research grant programmes such as Horizon (EU) mandate the participation of both sectors. However, interviewees were critical of the limited extent of industry participation in major Agrisemantic initiatives, as reflected in comments such as "More cooperation between FAO + industry than AGROVOC + industry" (Interview Twenty-Five).

Despite recognition of the importance of cooperation, several respondents argued that such collaboration is hindered by a lack of trust between the parties. The comment "Lack of trust between companies and universities" (Interview Twenty-Two) was typical. Given that industry produces the majority of food products, some interviewees suggested that academia must adapt more readily to industrial priorities, with one stating that "Academics must meet business on their terms" (Interview Twenty). At present, however, industry participation remains limited. As one respondent explained, "There is no formal interaction with private industry… companies like Syngenta and Bayer may share knowledge but there is no obligation" (Interview Eleven).

It is not only the sharing of standards between academics and industry, but the method of working with standards that can create barriers. Agrisemantics has a wide range of potential users, and any standard must be a compromise so that all potential users' interests are served. Depending upon who produced the standard there may be a bias in the standard, this is noted by an interviewee who stated, "Must work in a non-academic way, middle ground between Ontologist and Agronomist" (Interview Nine).

Finally, there is a direct connection between this theme, and the Decision Maker Resistance theme, as decision makers are simply ignorant of the advances in the research community. As one interviewee stated, "Business leaders are unaware of gains made in the research community" (Interview Five).

Loss of momentum

Agrisemantics has received significant support through funding from NGOs and government programmes. However, interviewees repeatedly observed that momentum tends to dissipate once the initial funds are exhausted.

The loss of momentum was often linked to the Academic–Industry Divide. One respondent argued that the prevailing funding model is flawed, since it is predominantly top-down rather than bottom-up: "Adoption must be bottom-up, don't pick winners" (Interview Six). As a result, many agrisemantic projects fail to achieve lasting impact, with another respondent noting that "Projects stop when funding ends" (Interview Thirteen). Because most funding is project-based, there is little incentive for organizations to embed tools or standards into day-to-day operations. This point was echoed in the observation: "Translating research into usable products, successful outputs?" (Interview Sixteen).

In addition to the funding model, interviewees highlighted the way in which standards are managed as a barrier to sustained adoption. Respondents pointed to the proliferation of competing bodies and redundant resources, combined with the absence of a central authority. As one participant explained, "[The] issue with standards is who will manage them" (Interview Nineteen). Another observed that "Agriculture [is] subject to inertia, major companies must agree on standards, needs global leader" (Interview Twenty). These concerns underscore how both financial and organizational structures contribute to the loss of momentum in agrisemantics initiatives.

Discussion of organizational and cultural barrier codes

The Organizational and Cultural Barriers category was frequently referenced across the interviews. These barriers are interconnected and together substantially impede the adoption of agrisemantics, because in part organizations will not share data internally. The value of agrisemantics is to enable interoperability, reuse, and integration across systems, organizations, and time through controlled vocabularies, or more structured representations such as ontologies. Controlled vocabularies and ontologies directly support FAIR data practices (Wilkinson et al., 2016), which are a set of guidelines that aim to ensure data is Findable, Accessible, Interoperable, and Reusable. When data is not intended to be shared, either externally or across internal organizational boundaries, the perceived value of semantic annotation is substantially reduced.

The current funding model, the absence of a clear business case, and the competitive nature of industry limit the feasibility of establishing a single set of standards. However, examples exist that show these obstacles can be overcome. The ADAPT standard, for instance, demonstrates how several agricultural machinery companies cooperated to address a shared business need. This case illustrates that organizational and cultural barriers can be mitigated when a strong financial incentive aligns the interests of multiple stakeholders.

Economic and resource constraints

This category encompasses barriers related to financial resources (implementation and integration costs as well as a lack of budget) and human capital (shortage of skilled workers and training gaps). Both constraints impede the implementation and adoption of agrisemantics.

These barriers should not be considered in isolation, as they complement those identified in the Organizational and Cultural Barriers category. The category contains two Thematic Codes: Client cost concerns and Developer skill gap, referenced 38 and 33 times respectively by interviewees. In comparative terms, this makes Financial and Human Capital Barriers a less frequently cited concern than other categories, although still significant in shaping adoption trajectories.

Client cost concerns

This thematic code is closely related to the Academic–Industry Divide, as it reflects both the absence of a clear business case and the high cost of implementing agrisemantics projects. As one respondent observed, "Clients see semantic web as extra overhead, costs time and money with no perceived value" (Interview One). Consequently, the educational and advocacy processes identified in the previous category may also be necessary for external clients.

The need for a financial incentive was a consistent theme throughout the interviews. The "brand" of agrisemantics was not seen as sufficient to drive external projects. For example, one respondent noted that "Private org decisions are sales driven" (Interview Four), another stated that "Decision makers motivated by money, bonuses" (Interview Five), while a third remarked that "Private companies need a profit motive to participate in agrisemantics" (Interview Ten).

The financial burden of data acquisition was also emphasized. This challenge is particularly acute in lesser developed countries (LDCs), where smaller producers dominate and costs are proportionally higher. For instance, one interviewee stated that "In Africa data often has to be bought, bad for smallholders" (Interview Thirteen), while another commented "Struggled with small companies, no budget" (Interview Nineteen). However, concerns about costs were not confined to LDCs, as demonstrated by observations such as “Everyone is focused on the costs” (Interview Fourteen) and “Who is going to pay for agrisemantics” (Interview Fifteen). The issue was crystallized by the statement: “Level of investment at the start of a project is too high for companies” (Interview Twenty-Two). Combined with the absence of a compelling business case, these financial concerns constitute a significant barrier to the wider adoption of agrisemantics.

Developer skill gap

This thematic code relates to the shortage of trained staff capable of implementing agrisemantics. Skills required to integrate agrisemantics resources into software systems unique to an organization may include advanced expertise in mapping between ontologies and database schemas or knowledge of how to interrogate formal knowledge representations. The latter may require a robust understanding of complex axioms, such as cardinality or disjunction, along with expertise in the use of reasoning engines to perform inference tasks. The Developer Skill Gap is closely connected to the Tool Limitations thematic code, since effective tools could mitigate the skills shortage by shielding users from the underlying complexity of semantic languages such as RDF (Klyne, 2004) or OWL (McGuinness & Van Harmelen, 2004). The issue was often summarized in terms of a lack of in-house expertise, specifically a detailed understanding of Knowledge Representation and Modeling.

One respondent explained that “Companies lack expertise in-house to contribute to public resources” (Interview Twenty-Two), which implies limited capacity to complete internal agrisemantic projects. The problem is exacerbated by the Academic–Industry Divide, as industry actors often expressed skepticism about university training. As one interviewee put it: “Industry [is] not sure how to use the platform, lack of trust with universities…” (Interview Twenty-Two). Others pointed to the limited provision of formal training, with one remarking: “Training is an issue… academics won’t put on courses without demand” (Interview Sixteen). Even where training is available, the learning curve was described as prohibitive: “…steep learning curve for semantic technologies” (Interview Thirteen).

The lack of skilled staff in the broader labor market was also highlighted as a constraint. For instance, one respondent stated: “Barrier is education, most people are unaware of the semantic web” (Interview Nineteen). This issue extends beyond computing professionals. As agrisemantics has a diverse set of potential users, limited expertise in non-computing domains poses additional challenges. As one participant explained, “Food technologists do not know enough about semantics to implement it” (Interview Twelve).

Given these shortages, greater reliance is placed on tools to abstract away semantic complexity. Yet interviewees emphasized that tools remain inadequate: "Interface of current tools needs to be better so less skilled people can use them" (Interview Seven).

This thematic code illustrates a persistent structural challenge. A lack of demand for training limits university provision, while the steep learning curve makes it difficult to run private-sector training programmes or for developers to self-train. At the same time, non-computing staff may lack the predisposition to engage with semantics directly. As a result, much of the burden falls on tools, but current semantic tools are not yet fit for this purpose, as the barriers to entry for the average developer are too high due to the requirement of detailed semantics knowledge.

Discussion of economic and resource constraints

Economic and Resource Constraints were cited less frequently than other categories but nevertheless present important constraints on the adoption of agrisemantics. Client cost concerns highlight the absence of a clear business case and the prohibitive expense of implementation, especially in contexts dominated by smaller producers or limited budgets. The developer skill gap compounds these challenges, as both industry and academia struggle to provide sufficient training, leaving organizations without the necessary expertise. While improved tools may help to bridge the skills' shortage, current semantic technologies are not yet mature enough to remove the need for specialist knowledge. Taken together, these Economic and Resource Constraints act as significant but secondary barriers, reinforcing the difficulties identified in the Organizational and Cultural Barriers category.

Technical and infrastructure challenges

This category encompasses barriers that are primarily technical in nature. They include limitations of existing tools, fragmented and ad hoc integration efforts, inconsistent or poor-quality data, and uncertainty about which technical architectures and standards should be adopted.

This category contained the Tool limitations, Ad-hoc integration, Data heterogeneity and Hybrid architecture thematic codes, with frequencies of 102, 21, 39, and 26 respectively. The most frequently cited barrier is the lack of robust semantic tools and frustration with brittle prototypes.

Tool limitations

This was the most frequently cited barrier. A recurring theme was that the complexity of agrisemantics needs to be hidden from end-users. As one respondent remarked, “Ontology must be invisible to end-users” (Interview Nine), while another observed that “Current tools lack usability for non-experts” (Interview Seven). A successful semantics project was described in similar terms, with respondents emphasizing that “Users interact through dashboard, ignorant of semantics” (Interview Twenty-Five). Current tools such as Protégé are widely considered outdated, requiring at least a working knowledge of semantic technologies, which excludes many potential users. This point was reinforced by the observation: “Protégé is the only mature tool, 25 years old” (Interview Twenty-Three).

Agrisemantics also imposes formats such as RDF or OWL onto data. However, mature organizations often possess legacy data in diverse formats, including text files, PDFs, or proprietary systems. In some cases, there is no preexisting schema or metadata, which makes conversion into logically consistent representations especially challenging. Interviewees reported, for example: “Different formats: text, PDF, HTML… parse hazards, entities, food type” (Interview Twenty-Five); “4,000 spreadsheets with no metadata….no way forward” (Interview Twenty-Three); “Global orgs struggle to pull data together…lack IT understanding for integration” (Interview Twenty-One); and “Data is dirty, cleaning done manually” (Interview Thirteen). The lack of tools to facilitate integration compounds earlier issues of limited business cases and a shortage of skilled staff, together forming a substantial barrier. Without a clear return on investment, respondents noted private sector companies are unlikely to commit resources.

Another issue highlighted under this thematic code was the fragmentation and replication of agrisemantic resources. Examples included: “Disconnect between taxonomy across plants, lack of governance due to acquisitions, disparate farm management systems” (Interview Twenty); “Agricultural ontologies less rich than biomedical, not as joined up” (Interview Nineteen); and “Communicate info along supply chain… possibly 20 ontologies” (Interview Fifteen). The absence of a single authoritative standard, combined with limited cooperation from organizations directly involved in food production, effectively confines the use of agrisemantics to niche applications.

However, not all respondents were dismissive of existing tools. Some offered suggestions to improve adoption, primarily advocating a reduction in formality and greater reliance on more accessible technologies such as Knowledge Graphs (Hogan et al., 2022) or JSON-LD (Sporny et al., 2014). These, however, are not without drawbacks. One respondent remarked: “Knowledge Graphs entry point… but too flexible, messy, visualization issues” (Interview Seventeen), while another noted: “Knowledge Graphs popular, but not clearly better for companies” (Interview Twenty-Three). This underscores a key tension: funders and businesses face a dichotomy between reducing formality to broaden accessibility, thereby losing some of the rigor of agrisemantics, or maintaining formality, which restricts uptake among non-expert users.

Ad-hoc integration

This theme is concerned with the reliance on nonstandard or improvised integration methods. Such approaches often lack consistency, scalability, and robust documentation, leading to potential errors, high maintenance overheads, and difficulties in aligning with established data management practices. It is directly related to the previous theme of Tool Limitations, since both highlight the immaturity of technical infrastructures supporting agrisemantics.

Several respondents acknowledged that they do not use agrisemantic resources at all, instead depending on manual processes. Illustrative examples include: “Manual search to find different terms” (Interview Thirteen), “Querying many standalone databases” (Interview Thirteen), and “Field operations messy, grown in ad-hoc manner” (Interview Six). Although such inefficiencies might be expected to act as a driver for adoption, respondents emphasized that organizational inertia, coupled with limited awareness among decision-makers and the absence of a compelling business case, has frequently sustained the status quo.

Even where agrisemantic resources exist, they are often ignored or only partially used. One participant explained that “Ecologists create their own resources, takes a lot of time” (Interview Twenty-Seven), which was typical of the responses. This points to a lack of discoverability and coordination, further weakening the case for systematic adoption.

Overall, this theme was less frequently mentioned than others and frequently overlapped with issues captured under Tool Limitations and Data Heterogeneity, suggesting that ad-hoc integration is symptomatic of broader structural and technical shortcomings.

Data heterogeneity

This theme concerns the difficulties that arise when working with data stored in multiple formats and structured according to different standards. Respondents consistently reported that such heterogeneity complicates the process of integrating datasets, undermines interoperability, and increases the effort required to apply semantic methods effectively. This theme also overlaps with the Tool Limitations theme, since a lack of robust tools exacerbates the challenges of managing inconsistent data.

A recurring complaint was that tools themselves often generate incompatible outputs: “Wave of fashionable tech from vendors, differing formats”

(Interview Six). Similarly, the burden of legacy data was repeatedly raised, with one respondent noting that "Mature companies can't start from scratch…historical data hard to transform → bottleneck" (Interview Two). Even within active semantic projects, the proliferation of formats was evident, for example, in describing one project "where she is dealing with up to 40 different data formats" (Interview One).

Beyond technical incompatibility, respondents argued that the structural complexity of the food production supply chain presents additional obstacles. One observed that "Supply chain too large, rollout difficult" (Interview Five), while others pointed to the absence of a unified perspective: "Shared meaning. Different producers/growers have different ideas" (Interview Fifteen) and "Agriculture's semantic community is far more atomised… duplication of classes across ontologies" (Interview Nineteen).

In common with other themes, the lack of a single authoritative standard was emphasized as a major source of fragmentation: "Disparate collection of farm management systems…patchwork of standards" (Interview Twenty). Together, these issues illustrate how heterogeneity, both technical and organizational, continues to undermine the scalability of agrisemantics.

Hybrid architecture

This theme addresses the use of combined relational and semantic approaches within agrisemantics projects. Respondents highlighted that while semantic technologies provide expressive power and interoperability, many organizations continue to rely heavily on established relational database systems for core operations. As a result, hybrid architecture has emerged, in which semantic layers are introduced on top of, or alongside, relational systems.

There was some confusion about which technologies should be used in practice, given the wide range of available tools. For example, one interviewee asked, "When choosing an architecture stack do I choose a triple store, an ontology or a graph database?" (Interview Twelve). Another added, "Overriding issue…competing standards, and how to build an architecture stack…takes money, need commercial imperative" (Interview Twelve).

Performance concerns were also reported, with some respondents noting that semantic tools struggled in production environments and that hybrid approaches were therefore necessary. As one interviewee explained, "Hybrid back-end linking semantic technologies to relational database…performance at application-level poor" (Interview Two).

This theme overlaps with Tool Limitations, since both highlight confusion around technology selection and the performance challenges of semantic tools in production. More broadly, the reliance on hybrid approaches reflects the transitional stage of agrisemantics adoption, where organizations are reluctant to abandon established relational systems but experiment with semantic layers to meet interoperability needs.

Discussion of technical and infrastructure challenges

Technical and infrastructure challenges remain a major barrier to agrisemantics adoption. Tool limitations, including outdated or complex software and the need to manage legacy data in diverse formats, reduce accessibility for non-expert users. Ad-hoc integration practices persist, reflecting organizational inertia and limited awareness of semantic resources, and are symptomatic of broader structural deficiencies. Data heterogeneity across formats, standards, and supply chains impedes interoperability and contributes to duplication and inefficiency, while hybrid architectures illustrate a transitional adoption stage where semantic layers coexist with relational systems to balance performance and resource constraints. These findings suggest that adoption is constrained by interconnected technical and organizational factors, highlighting the need for improved tools, standardization, and alignment with institutional priorities to enhance scalability and uptake of agrisemantics.

Drivers of adoption

This coarse category brings together themes that describe the forces that encourage or accelerate the adoption of agrisemantics. It contains three themes: Government and Policy Support, Domain-specific Drivers, and Individual Champions, which were referenced 62, 127, and 11 times respectively. Among these, Domain-specific Drivers were most frequently cited, highlighting how specific sectoral needs such as food safety, traceability, and sustainability reporting can act as a counterbalance to the organizational, technical, and cultural barriers identified earlier.

Government and Policy Support was also noted as an important influence, particularly where regulation and public policy create mandatory requirements for interoperability, reporting, or compliance. Although less frequently cited, Individual Champions played a catalytic role in successful projects, particularly in cases where adoption relied on strong leadership or the advocacy of committed experts. Together, these themes suggest that while structural barriers to agrisemantics remain significant, targeted drivers can provide momentum and create opportunities for wider adoption.

Government/policy support

This theme was not among the most frequently mentioned in the interviews, which is unsurprising given that many respondents, as discussed in the Organizational and Cultural Barriers category, emphasized that adoption cannot be imposed from the top down and must instead be driven by pressing business needs.

Nevertheless, several interviewees acknowledged that government regulation and public policy can play an important role in encouraging adoption. Regulatory requirements were cited as drivers in cases where “Public authorities **(are)** demanding electronic submissions” (Interview Two), or where “Local agricultural data must conform to regulatory standards” (Interview Six). Others recognized that top-down enforcement is often ineffective, but that procurement policies or compliance obligations could provide leverage, as reflected in the observation: “Hard to enforce agrisemantics by top-down… procurement/regulation may work” (Interview Fifteen).

While most interviewees stressed the importance of a clear business case, some noted that regulation can create strong monetary incentives in specific contexts, particularly in relation to food safety reporting. One respondent cited “Monetary pressure for reporting… E. coli Spain 2011 case” (Interview Seventeen). The 2011 outbreak, which was falsely attributed to Spanish agricultural produce, led to sixteen deaths and cost Spanish producers an estimated £200 million per week (BBC News: Spain E. coli case, 2011). Accurate reporting, enabled by agrisemantic standards, could have mitigated these financial and reputational losses.

Interviewees also suggested that government-driven standardization initiatives can themselves create business cases. Illustrative comments included: “Semantics higher up supply chain… demanded by consumers and regulators (nutrition info, ingredients)” (Interview Twenty) and “Push for better labelling due to obesity costs” (Interview Twenty-Five). Respondents highlighted the need for improved nutritional information on food labeling to support consumer health, while others stressed the importance of semantics in regulatory contexts such as pesticide use in compound foods, with one participant noting: “Pesticide companies use semantics because regulators set limits” (Interview Twenty-Six).

Despite the broad agreement that adoption is most effective when driven by bottom-up business needs, a minority of respondents argued for the opposite, contending that adoption must be enforced through government intervention. This position was expressed in comments such as “Standards will have to be top-down” (Interview Twenty-One) and “Adoption must be top-down” (Interview Twenty).

Overall, while there is some evidence that regulatory pressure may influence adoption, the interviews provided little indication that such pressure is currently sufficient to drive widespread uptake of agrisemantics.

Domain-specific drivers

This was the most frequently mentioned theme, indicating that although senior decision-makers may not yet recognize clear business cases, there are strong bottom-up pressures for adoption within specific domains. These pressures arise from concrete operational needs rather than abstract arguments for standardization.

Several key drivers were consistently highlighted. Data provenance was cited as a central motivator, with one interviewee noting that "Data provenance is a driver" (Interview Twenty-Three). Regulatory compliance in food safety and traceability was also frequently mentioned, exemplified by the observation that "Main driver: FDA pushing standardization, traceability, chain of custody" (Interview Twenty-Five). The ongoing digitalization of agriculture was identified as a structural force shaping adoption, as reflected in the comment: "Driver in agriculture is digitalization" (Interview Two).

Interviewees also pointed to direct economic benefits. Reducing the time spent on data preparation was described as a major incentive: "Biggest economic driver: reducing data wrangling time" (Interview Four). Likewise, the role of semantics in enabling data integration was repeatedly emphasized, with one participant describing it as the "Main use case for semantics" (Interview Twenty-One). Finally, semantic search was seen as a practical and widely applicable function, described as a "Typical use case" (Interview Twenty-Two).

Regulatory compliance as a driver shares similarities with the food recall examples discussed in the Government and Policy Support theme, but here the emphasis is defensive rather than profit driven. This makes it a more difficult proposition for business leaders, as the economic value of loss avoidance is only visible in times of crisis and is rarely represented on balance sheets.

Moreover, there are competing technologies for search, data wrangling, and data integration that do not carry the steep learning curve of semantic approaches. Unless the highlighted limitations of Agrisemantic tools are addressed, it is likely that these domain-specific drivers will not be sufficient to translate into widespread adoption.

Individual champions

This was the least frequently mentioned theme, yet it underscores an important dynamic in the adoption of agrisemantics: the role of committed individuals or organizations acting as champions. In many cases, successful projects were attributed to the influence of a single advocate who was able to drive adoption within their organization. As one interviewee noted, "Adoption due to one person" (Interview Two).

These champions were often required to simplify technical arguments and secure executive buy-in, as illustrated by the observation that "Adoption requires corporate sponsor, simplified arguments" (Interview Seven). In some cases, individual expertise was directly linked to organizational outcomes, as in the comment that "Business units siloed, hired the interviewee for interoperability" (Interview Seven).

However, despite these examples, interest from large corporate sponsors appeared limited. While there were isolated signs of engagement, such as "Some interest from large players such as Tesco" (Interview One), respondents generally reported that such support remained sporadic and insufficient to drive systemic change.

Overall, the evidence suggests that individual champions can play a catalytic role in initiating projects, but without clear repudiation of the tall poppy syndrome and broader institutional support their influence is fragile and unlikely to sustain large-scale adoption.

Discussion of drivers of adoption

The analysis of drivers of adoption highlights that agrisemantics uptake is primarily influenced by domain-specific needs, government or policy support, and individual champions. Domain-specific drivers, such as food safety, traceability, data provenance, and digitalization, create strong bottom-up pressures, providing clear operational incentives for adoption. Government and policy support can reinforce these pressures, particularly where regulatory compliance or public reporting requirements generate financial or reputational stakes, although top-down enforcement alone appears insufficient to achieve widespread uptake. Individual champions play a catalytic role by simplifying technical arguments and securing executive buy-in, yet their influence is limited without broader institutional support. Together, these drivers indicate that adoption is most likely when concrete operational needs align with regulatory or policy incentives and are championed by committed individuals, suggesting that successful implementation relies on a combination of technical, organizational, and sector-specific factors.

Although Generative Artificial Intelligence was not highlighted in the interviews, it is arguable that the role of agrisemantics will be enhanced through the use Neuro-symbolic methodologies (Meghraoui et al., 2025) because of the tight definition of concepts and relationships that provide a basis for reasoning about agricultural issues. There is some informal evidence that Neuro-symbolic techniques are being adopted by industry (Shai Sela, 2025), but currently this avenue of research is not common.

Furthermore, agrisemantics can be employed in conjunction with Generative Large Language Models (LLMs) to enhance both prompt formulation and response quality. This configuration is referred to as Retrieval-Augmented Generation (RAG) (Arslan et al., 2024). In this context, agrisemantics functions as a structured knowledge representation framework that supports the refinement of user inputs and improves the accuracy and relevance of generated outputs (Barzdins & Gruzitis, 2025).

Synthesis of interview findings

Agrisemantics adoption is constrained by intertwined organizational, economic, and technical barriers, but can be enabled through domain-driven incentives, policy support, and committed individual champions operating within supportive institutional structures. The interview findings indicate that agrisemantics adoption is shaped by interrelated organizational, economic, technical, and sector-specific factors. Organizational and cultural barriers, including decision-maker resistance, internal gatekeeping, academic–industry misalignment, and loss of momentum, limit uptake by reducing awareness, trust, and long-term commitment. Economic and resource constraints, particularly high implementation costs and shortages of skilled personnel, reinforce these barriers, constraining both initial adoption and sustained engagement. Technical challenges, such as tool limitations, data heterogeneity, ad-hoc integration, and hybrid architectures, further impede scalability and usability, particularly for non-expert users. Despite these obstacles, targeted drivers can facilitate adoption. Domain-specific pressures, including food safety, traceability, and digitalization, provide operational incentives, while government and policy support can create regulatory or financial leverage. Individual champions can catalyze projects by securing buy-in and simplifying technical arguments, although their impact is limited without institutional backing. Overall, successful agrisemantics implementation requires alignment across technical, organizational, economic, and policy dimensions, with bottom-up operational needs and committed advocates complementing regulatory or financial incentives to overcome structural constraints.

Questionnaire results

The interviews provided in-depth insights from a small pool of experts. To complement these qualitative findings, the questionnaire was designed to elicit further information from a broader group of respondents. The survey items were derived from both the coarse categories and selected thematic codes identified during the interview analysis. The subsections below follow the closest matching coarse categories, with some refinements to capture the emphasis of the questionnaire responses.

Conceptual understanding and framing

This subsection reflects respondents' conceptualization of agrisemantics and their perceived scope of application. Almost half (48.70%) reported that their work required agrisemantics, though this is likely an overestimate given the targeted nature of the sample.

The breakdown of the use of agrisemantics in projects by organization type is in Table 3. The "Other" category is a collection of individuals without a common employer type and has the highest use of agrisemantics. The highest use of agrisemantics of recognized employer category was NGO at 52.94%, but this was not much higher than Private Industry and Academics.

The breakdown of the use of agrisemantics by region is shown in Table 4, and the region with more than two responses with the highest use of agrisemantics is Europe, and the lowest use of agrisemantics is Africa. Africa having the lowest rate of use of agrisemantics is not surprising, because the interviewees raised issue with the major agrisemantic resources not representing African agriculture and native species of crops.

Table 5 shows that most participants associated agrisemantics primarily with a shared vocabulary, while fewer recognized more complex applications such as reasoning or nanopublications. This finding suggests that agrisemantics is still largely understood in limited, terminology-focused terms rather than as a broader infrastructure for interoperability, data integration, knowledge discovery and decision support.

Organizational and cultural barriers

Barriers to adoption reported in the questionnaire closely mirrored the interview results, confirming the prominence of organizational and cultural

Table 3. Use of agrisemantics by organization type showing percentage and number of questionnaire respondents in parentheses.

Organization Type	Use of agrisemantics
Academic Inst.	42.85 % (28)
Gov. Org.	14.28% (7)
NGO	52.94% (17)
Other	87.50 % (8)
Private Industry	50.00% (16)

Table 4. Use of agrisemantics by region showing percentage and number of questionnaire respondents in parentheses.

Region	Use of agrisemantics
Africa	33.33 % (15)
Asia	55.00 % (9)
Australasia	50.00 % (4)
Europe	57.14 % (35)
North America	40.00 % (10)
South America	0.00 % (2)
Prefer Not To Say Other	100.00 % (1)

Table 5. Questionnaire respondents' understanding of agrisemantics.

Explanation of agrisemantics	Understanding Response
A shared common vocabulary of terms about agriculture	75.00%
Use of ontologies for annotation of field data	61.80%
Creation or use of formal ontologies in a KR standard	46.10%
Use of ontologies for text mining tasks	43.40%
Creation or use of agricultural knowledge graphs	35.50%
Reasoning over ontologies to infer new knowledge	36.80%
Creation or use of nanopublications from agricultural data	15.80%
Annotation of Web services with semantic metadata	34.20%

Table 6. General barriers to adoption of agrisemantics identified by questionnaire respondents (percent of total responses).

General barrier	Response
Management not aware of benefits	41.00%
Lack of technical expertise	48.70%
No motivation for adoption	41.00%
Lack of tools	30.80%
Learning curve too steep	28.20%
Cannot find skilled staff	15.40%

Table 7. Organization-specific barriers to adoption of agrisemantics identified by questionnaire respondents (percent of total responses).

Organization-specific barriers	Response
Lack of knowledge in the organization	54.90%
Resistance from data owners	31.00%
Resistance from decision makers	25.40%
Lack of understanding of semantic technologies	56.30%
Benefits and ROI difficult to quantify	19.70%
Existing technologies are sufficient	12.70%
Agrisemantic technologies not available for domain	16.90%

challenges Respondents identified general barriers to adoption (Table 6) and organization-specific barriers to adoption (Table 7). Knowledge and skills gaps were most widely cited, alongside limited managerial awareness and a lack of motivation for adoption. These results resonate with the themes of decision-maker resistance and internal gatekeeping, showing that many obstacles are less about technical feasibility than about organizational priorities and capacity.

External pressures and incentives

Some respondents reported adoption pressures linked to external demands, including high data generation costs, compliance mandates from larger partners, and reporting requirements related to sustainability, trade, traceability, or risk management. These factors correspond with the "Drivers of Adoption" category from the interviews. However, they were mentioned by relatively few participants, suggesting that such pressures are not yet widespread or systematically enforced across the agricultural sector.

Table 8. Reasons for not contributing to agrisemantic resources identified by questionnaire respondents (percent of total responses).

Response	Percent Response
No formal process to contribute	40.00%
Lack of time	25.70%
Prohibited by organization	11.40%
Did not consider contributing	22.90%
Insufficient motivation	40.00%

Engagement with standards and resources

Among those using agrisemantics, AGROVOC and the Crop Ontology were the most widely adopted resources. Other tools, such as FoodOn and the Agronomy Ontology, were reported but with lower uptake. A majority (61.30%) of respondents stated that they contributed to public resources. For those who did not, the main reasons were insufficient motivation and the absence of a clear contribution process (Table 8). These findings align with the "Contribution and Sustainability" challenges observed in the interviews, where limited incentives and fragmented governance hinder sustained development of shared resources.

Discussion of questionnaire results

The questionnaire results reinforce the interview findings by highlighting the limited and uneven adoption of agrisemantics. Respondents most frequently cited knowledge and skills shortages, managerial resistance, and lack of incentives as barriers. External drivers such as regulation and compliance requirements were only rarely mentioned, suggesting that agrisemantics remains a marginal concern for most organizations. are Contribution patterns indicate that while some resources are widely used and maintained, the broader ecosystem suffers from limited motivation and fragmented governance. Overall, the survey suggests that agrisemantics adoption is still at an early stage, and its expansion will likely depend on clearer business cases, stronger institutional leadership, and more inclusive engagement strategies.

Outlook

The findings of this study were derived through a mixed-methods approach that combines expert interviews with a complementary questionnaire. The web questionnaire was publicly accessible; however, its dissemination through specific networks and the inclusion of a knowledge declaration reduced the likelihood of responses from outside the intended audience.

While the interviews provided in-depth perspectives, the questionnaire helped validate and extend these insights across a wider sample. The results from both instruments can be interpreted through the same set of coarse categories, ensuring a coherent view of adoption challenges and opportunities for agrisemantics.

Conceptual understanding and framing

Both interviews and questionnaire responses indicate that agrisemantics is most often conceived as a shared vocabulary, with fewer stakeholders recognizing its wider potential for interoperability, reasoning, or advanced data integration. This limited framing suggests that much of the current discourse is focused on terminology management rather than broader infrastructures for agricultural knowledge or decision support. The implication is that educational efforts need to expand beyond terminology to emphasize how semantics underpins interoperability, automation, and decision support.

Organizational and cultural barriers

The strongest barriers remain organizational in nature. Interviews revealed persistent resistance from decision-makers and data owners, while the questionnaire confirmed widespread gaps in knowledge, skills, and managerial awareness. These cultural and institutional barriers are particularly visible in Less Developed Countries (LDCs), where respondents highlighted weak data infrastructures, corruption in funding agencies, and lack of trust in standards developed in Western contexts. Unless these barriers are addressed, agrisemantics will remain marginal in both global North and South, albeit for different reasons. More inclusive approaches are required, especially those that prioritize crops and livestock indigenous to LDCs.

Technical and infrastructure challenges

Technological barriers also persist. Respondents highlighted fragmented standards, immature tools, and competing technology stacks. These issues are compounded by limited integration of agrisemantics into day-to-day operations, particularly when projects are funded on a short-term basis without clear sustainability plans. Emerging innovations such as agricultural digital twins underscore the importance of sustainability and semantic interoperability for right-time modeling and forecasting. However, unless tool usability and integration frameworks improve, such technologies and their benefits will remain accessible only to a limited subset of organizations.

External pressures and incentives

Adoption pressures were reported only in isolated cases, often tied to regulatory compliance, sustainability reporting, or food safety concerns. These findings suggest that agrisemantics adoption is unlikely to accelerate without stronger external imperatives. Government interventions, such as the H2020-funded ATLAS project, (European Commission, 2019–2023) which incentivises third-party integration, offer promising models but remain the exception. More systematic regulatory or market-driven incentives will be necessary to generate sustained momentum.

Contribution and sustainability

Both data sources emphasized the fragility of contribution and sustainability mechanisms. While resources such as AGROVOC and the Crop Ontology are relatively well maintained, participation remains inconsistent, with many respondents citing lack of formal contribution processes or insufficient motivation. The absence of strong governance structures leads to redundancy and fragmentation, which in turn undermine user trust and long-term adoption. Greater coordination, potentially led by intergovernmental organizations or large industry actors, will be needed to sustain agrisemantics resources in the long term.

Synthesis of interview and survey findings

Overall, the findings suggest that agrisemantics adoption remains at an early stage, with progress constrained less by technical feasibility than by cultural, organizational, and economic factors, commonly identified in digital transformation initiatives (Table 9). Adoption is most likely to accelerate when external incentives align with organizational priorities, as seen in cases driven by agricultural machinery sales, food safety or traceability requirements. Broader adoption will require not only stronger technological foundations but also new governance models, sustained funding, and a clearer articulation of business cases that can appeal to both public and private stakeholders.

Conclusion

This study has provided an empirically grounded account of the current state of agrisemantics adoption, combining insights from expert interviews and a broader questionnaire survey. The results demonstrate that adoption remains limited and fragmented, shaped by the interplay of technical, organizational, cultural and financial barriers. Technological obstacles such as steep learning curves, immature tools and heterogeneous data infrastructures are compounded by social and institutional constraints including limited awareness, resistance from decision makers and data owners, and weak industry engagement. Financial concerns and shortages of skilled personnel further inhibit progress, while adoption pressures from regulation and reputational risk are present but inconsistent. At present, agrisemantics persists largely in niche projects, with limited evidence of mainstream integration.

Nevertheless, the analysis also points to clear opportunities. Domain-specific drivers such as food safety, provenance and digitalization offer concrete business cases, while regulatory and policy interventions can provide additional leverage. Successful projects were consistently associated with strong individual champions and, in some cases, collaboration between academia and industry, suggesting that adoption is possible when incentives and leadership align. Respondents from Less Developed Countries also emphasized the importance of inclusivity, highlighting that without addressing data sovereignty, infrastructural weaknesses and the high relative cost of data, global uptake will remain uneven.

To shift agrisemantics from peripheral experimentation to sustainable infrastructure, three measures are particularly important. First, funders and governments should embed semantic adoption criteria within grants, procurement, and regulatory frameworks, ensuring that outputs are reusable across domains and sectors. Second, tool development must move beyond research prototypes to provide robust, user-friendly solutions that integrate seamlessly with mainstream analytics environments, thereby lowering entry barriers for practitioners and non-specialists. Third, stronger engagement with industry and underrepresented regions is essential, both to reduce reliance on Europe-centered models of development and to ensure that semantic resources reflect global agricultural realities, including crops and livestock central to the Global South. A summary of the main and secondary recommendations for grant funders are listed (Table 10).

Table 9. Synthesis of interview findings on agrisemantics adoption showing key barriers and enablers or drivers for four themes.

Theme	Key Barriers	Enablers / Drivers
Organizational	Decision-maker resistance; internal gatekeeping; misalignment between academic and industry priorities; loss of project momentum	Individual champions; alignment with operational needs; cross-sector collaboration
Economic	Highimplementationcosts; limitedfunding continuity; shortage of skilled personnel	Targeted funding; long-term efficiency gains; externally imposed requirements
Technical	Immature tools; steep learning curves; heterogeneous data infrastructures; ad-hoc integration	Incremental tool maturation; reuse of existing infrastructures; standardization pressures
Sector/Policy	Fragmented incentives; lack of mandate; weak industry engagement	Food safety and traceability requirements; policy and regulatory support

Table 10. Summary of recommendations.

Area	Opportunity	Implication
Funding and policy	Embed semantic interoperability and reuse criteria within public funding, procurement, and regulatory frameworks	Incentivizes sustainable infrastructure and reduces duplication of semantic resources
Tooling and infrastructure	Prioritize usability-focused tools that integrate semantic layers into existing analytics and business intelligence work-flows	Lowers the skills barrier and enables adoption by non-expert practitioners
Governance and coordination	Strengthen intergovernmental and cross-sector governance of core agrisemantic resources	Reduces fragmentation and improves trust, stability, and long-term maintenance
Industry engagement	Focus adoption efforts on high-risk, high-value domains such as food safety, traceability, and recall management	Establishes clear business cases linked to compliance, reputational risk, and operational efficiency
Skills and education	Support semantics education in universities with targeted funding	Addresses skills shortages and aligns education with industry practice

By combining these measures, agrisemantics can progress beyond niche deployments to form the backbone of transparent, efficient and resilient agricultural data ecosystems. Without such interventions, however, the field risks continued fragmentation and limited impact, leaving its potential to transform agricultural knowledge and practice unrealized.

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Generative AI declaration

GPT-5 was used in the preparation of this article. It was used to edit and organize the text produced by the authors.

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Data availability statement

The qualitative interview summaries and raw survey responses are not publicly available in order to protect participant confidentiality. De-identified materials supporting the findings of this study may be made available from the corresponding author upon reasonable request. The questionnaire instrument and coding framework are provided in the Appendices to this article.

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