



Integrating agribusiness and climate-smart agriculture: A global bibliometric review

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ABSTRACT

This study presents a bibliometric analysis of global research on the integration of agribusiness practices and climate-smart agriculture (CSA) from 2010 to 2024. A total of 118 peer-reviewed articles indexed in Scopus were analyzed using VOSviewer, Biblioshiny, and Gephi to examine research trends, intellectual structure, and thematic evolution. The field progressed through three phases: conceptual emergence from 2014 to 2016, rapid expansion from 2017 to 2021, and consolidation from 2022 to 2024, with a compound annual growth rate of 40.7 percent during the expansion period. Six dominant thematic domains were identified: resilience and adaptation, adoption and implementation, value chains and markets, policy and governance, financing and investment, and technology and innovation. Despite growing scholarly attention, 66.9 percent of studies remain at early stages of integration, indicating a persistent implementation gap. Network analysis reveals fragmentation between technological innovation and financial and governance mechanisms. This study proposes a CSA Agribusiness Integration Maturity Model and a multidimensional framework grounded in resilience, innovation, governance, and sustainable finance. Comparative benchmarking demonstrates distinct thematic trajectories relative to the broader CSA literature. The findings emphasize the need to conduct regionally inclusive and equity-driven research, particularly in Latin America and Southeast Asia, and provide policy-relevant insights for accelerating CSA mainstreaming within agribusiness value chains.

Keywords: Agribusiness, Bibliometric Analysis, Climate-Smart Agriculture, Integration Maturity, Value Chains

I. INTRODUCTION

Climate change represents one of the most significant structural challenges confronting global agricultural systems. Rising temperatures, erratic rainfall patterns, prolonged droughts, flooding events, soil degradation, and increasing pest and disease pressures continue to reshape production environments across regions. These disruptions threaten agricultural productivity, rural livelihoods, and long-term food security, particularly in vulnerable contexts where adaptive capacity remains constrained (Kalele et al., 2021; Musafiri et al., 2022). In response to these pressures, Climate Smart Agriculture has emerged as an integrative framework that seeks to enhance productivity, strengthen resilience, and reduce greenhouse gas emissions while promoting sustainable development outcomes (Ma and Rahut, 2024; Okolie et al., 2022). Since its introduction in 2010, CSA has evolved into a widely adopted research and policy agenda that attracts sustained scholarly attention.

Although CSA scholarship has expanded rapidly, much of the literature has focused on farm level adaptation practices, technological uptake, and biophysical efficiency improvements. These contributions have generated valuable insights into adoption determinants, adaptive capacity, and mitigation potential. However, agricultural production operates within complex commercial systems that extend beyond individual farms. Contemporary food systems are structured through agribusiness networks that encompass input provision, aggregation, processing, logistics, certification, financing, and retail distribution. These actors influence production decisions, resource allocation, risk management strategies, and market access conditions. Agribusiness systems therefore play a central role in shaping incentives that determine whether climate smart practices are sustained and scaled.

Recent studies increasingly acknowledge the importance of market access, financial services, institutional arrangements, and knowledge systems in facilitating CSA uptake (Makamane et al., 2023; Erick et al., 2025). Nevertheless, the conceptual integration between agribusiness and CSA remains uneven. In many instances, climate smart principles and commercial agricultural systems have been examined in parallel rather than as structurally interconnected domains. Determinants of adoption have been identified, yet limited attention has been directed toward understanding how climate smart objectives become embedded within routine agribusiness operations, investment decisions, governance structures, and value chain coordination mechanisms. This separation constrains the ability of existing scholarship to inform systemic transformation across agricultural markets.

Furthermore, the rapid expansion of research at the intersection of agriculture, sustainability, and climate change has produced a dispersed body of literature. Bibliometric analyses of general CSA scholarship have documented increasing thematic diversification and accelerating publication trends (Okolie et al., 2022; Manyike et al., 2025). However, these reviews have not explicitly examined how agribusiness perspectives reshape thematic structures, institutional participation, or research maturity within the CSA domain. Consequently, limited clarity exists regarding whether agribusiness-oriented CSA research follows distinct growth trajectories, exhibits different collaboration patterns, or demonstrates deeper operational integration compared to the broader CSA field. Without systematic mapping of this interface, structural gaps and fragmentation are likely to persist.

This study addressed this limitation through a systematic bibliometric and thematic assessment of global research examining the integration of agribusiness practices and climate smart agriculture from 2010 to 2024. Rather than merely documenting publication trends, the study conceptualized the agribusiness and CSA nexus as an emerging intellectual domain whose structural coherence and integration depth required systematic evaluation. It advanced three principal contributions. First, it delineated substantive integration between agribusiness and CSA from superficial co-occurrence of climate and market terminology. Second, it introduced the CSA and Agribusiness Integration Maturity Model as a structured framework for evaluating integration depth within existing scholarship. Third, it conducted comparative benchmarking against general CSA literature to determine whether the inclusion of agribusiness perspectives generated distinct thematic complexity, institutional concentration, and maturity patterns.

The analytical lens guiding this assessment draws upon resilience theory, innovation diffusion perspectives, governance and institutional frameworks, and sustainable finance concepts (Chambers and Conway, 1992; Folke et al., 2016; Rogers, 2003; Gereffi et al., 2005). These theoretical domains provide complementary insights into how climate smart principles transition from conceptual recognition to operational integration and systemic transformation within commercial agricultural systems. Through this structured examination, the study provides an evidence-based foundation for strengthening research coherence, enhancing interdisciplinary engagement, and accelerating the mainstreaming of climate smart agriculture within agribusiness value chains.

The remainder of this paper is organized into five sections. Section II reviews the relevant literature and outlines the theoretical foundations that inform the analysis, including resilience, innovation, governance, and sustainable finance perspectives. Section III explains the methodological approach, detailing the data sources, search strategy, screening procedures, bibliometric techniques, and the operationalization of the CSA and Agribusiness Integration Maturity Model. Section IV presents the empirical findings and discusses publication trends, institutional contributions, thematic configurations, integration maturity distribution, network topology, and comparative benchmarking with the broader CSA literature. Section V concludes the paper and offers research and policy recommendations for advancing the integration of climate smart agriculture within agribusiness systems.

1.1 Research Questions

To support this analysis, this study adopted a multidisciplinary lens grounded in resilience, innovation, governance, and sustainable finance, as elaborated in the Theoretical Framework section below. These theoretical domains frame the conditions under which agribusiness systems engage with CSA to produce either incremental or transformative changes. Accordingly, this study is guided by four research questions: (1) How do growth patterns, institutional authorship, and geographic distribution in agribusiness and CSA research differ from general CSA literature? (2) Do incorporating agribusiness perspectives generate distinct thematic and conceptual structures? (3) At what stages of integration maturity do the current research cluster and what transitions are required for systemic transformation? (4) What research priorities, partnerships, and methodological innovations can accelerate the integration of CSA and agribusiness?

These research questions are addressed through specific analytical methods: RQ1 is addressed through publication trend analysis and geographic mapping; RQ2 through keyword co-occurrence analysis and thematic coding; RQ3 through the Integration Maturity Model classification; and RQ4 through structural gap analysis and comparative benchmarking with the general CSA literature.

II. LITERATURE REVIEW

2.1 Theoretical Review

A synthesis of the reviewed literature reveals that the nexus between agribusiness practices and climate smart agriculture (CSA) is underpinned by a convergent set of theoretical perspectives that frame how climate smart principles are conceptualized, operationalized, and scaled within commercial agricultural systems. Rather than emerging from a single disciplinary tradition, this body of scholarship draws on resilience and adaptive capacity theories, innovation diffusion theories, governance and institutional theories, and sustainable finance and systems transformation perspectives (Chambers and Conway, 1992; Folke et al., 2016; Rogers, 2003; Gereffi et al., 2005; Geels, 2002; Baker et al., 2018).

Across the reviewed studies, resilience-oriented frameworks, most notably the Sustainable Livelihoods Framework (Chambers and Conway, 1992) and Climate Resilience Theory (Folke et al., 2016), are frequently used to explain how agribusiness actors manage climate risk, enhance adaptive capacity, and sustain productivity under environmental stress. Complementing this, innovation-focused theories such as the Diffusion of Innovations (Rogers, 2003) and the Agricultural Innovation Systems approach (Hall et al., 2006) dominate analyses of how CSA technologies and practices are generated, diffused, and adopted through agribusiness networks, often highlighting the intermediary role of firms, markets, and extension systems.

Governance and institutional theories further structure the literature by explaining how CSA principles are embedded within commercial value chains through standards, contracts, certification schemes, and regulatory environments (Gereffi et al., 2005; North, 1990; Scott, 2001). More recent studies have increasingly invoked Sustainable Finance Theory (Baker et al., 2018) and sustainability transition theory (Geels, 2002) to examine how ESG-aligned investments, blended finance mechanisms, and regime-level shifts enable CSA to move beyond isolated adoption toward system-wide transformation. Collectively, the literature demonstrates that these theories are complementary rather than competing, jointly shaping the scholarly understanding of how agribusiness systems engage with climate smart agriculture across multiple scales.

III. METHODOLOGY

3.1 Data Source and Search Strategy

This study employed a systematic bibliometric approach to map and synthesize global research addressing the nexus between agribusiness practices and climate-smart agriculture (CSA). The Scopus database was selected as the primary data source because of its extensive coverage of peer-reviewed journals, strong citation indexing capabilities, and broad representation of the agricultural, environmental, and social science literature (Baas et al., 2020). The search covered publications from 2010 to 2024, capturing the period from the introduction of the CSA concept by the Food and Agriculture Organization to the most recent available literature. An inclusive Boolean search string was applied to titles, abstracts, and keywords within Scopus:

TITLE-ABS-KEY ("climate-smart agriculture" OR "CSA") AND ("agribusiness" OR "value chain" OR "market" OR "private sector" OR "input supply" OR "agricultural finance" OR "food systems") AND PUBYEAR > 2009 AND PUBYEAR < 2025.

To ensure analytical consistency and quality, the search was restricted to peer-reviewed articles published in English. Non-article document types, including conference proceedings, book chapters, editorials, reviews, and gray literature, were excluded.

3.2 Inclusion and Exclusion Criteria

Study selection followed the PICOC framework (Population, Intervention, Comparison, Outcome, Context) to ensure transparency and methodological rigor. The included studies were required to explicitly address both agribusiness actors or systems and climate-smart agriculture practices or principles. Eligible articles presented empirical findings, conceptual frameworks, or systematic analyses, and were published as peer-reviewed journal articles in English with full-text availability. Studies were excluded if they focused solely on agribusiness without engaging with CSA, or exclusively on CSA without explicit reference to agribusiness or market-oriented dimensions. Grey literature, including policy briefs, technical reports, and working papers, as well as non-research formats, such as editorials and book chapters, were also excluded to maintain a consistent analytical scope.

3.3 Screening and Selection Process

The article identification and screening process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and reproducibility (Donthou et al., 2021). The initial database search yielded a total of 347 articles. After removing 41 duplicate records, an additional 91 articles were

excluded based on document type and language filters. The remaining 215 articles underwent title and abstract screening, of which 41 were excluded for failing to meet the inclusion criteria. Full-text screening was subsequently conducted on 174 articles, resulting in the exclusion of 56 that lacked substantive integration between agribusiness and CSA. This systematic process produced a final dataset of 118 articles that were included in the bibliometric and thematic analyses. The complete selection pathway is illustrated in the PRISMA flow diagram (Figure 1).

3.4 Data Extraction and Processing

Bibliographic data for the 118 selected articles were exported from Scopus in the BibTeX and CSV formats. The extracted information included author names and affiliations, institutional addresses and countries, publication year, source journal, article titles and abstracts, author keywords and indexed keywords, reference lists, and citation counts. Data cleaning and harmonization were performed using Microsoft Excel. Author names were standardized to resolve inconsistencies in spelling and initials, and institutional names were harmonized to ensure uniform representation; for example, by consolidating abbreviated and full institutional titles. Country affiliations were verified for multi-institutional publications and missing bibliographic fields were checked for completeness. Original author keywords were preserved, and a standardized keyword set was developed to support co-occurrence analysis.

3.5 Bibliometric Analysis Tools and Procedures

Bibliometric analysis combines performance analysis and science-mapping techniques, using multiple complementary tools. VOSviewer version 1.6.19, as well as keyword co-occurrence networks, was used to construct and visualize co-authorship networks at the author and institutional levels. Association strength normalization was applied with a resolution parameter of 1.0, and a minimum cluster size of five to balance analytical inclusiveness with visual clarity. The Bibliometrix R package version 4.1.4, accessed through the Biblioshiny interface, was employed to calculate publication trends, annual growth rates, author productivity indicators, and journal source distributions using Bradford's law. Network topology analysis was conducted using Gephi version 0.10 to compute structural metrics such as betweenness centrality, clustering coefficients, and structural holes, enabling deeper insight into collaboration patterns and knowledge integration dynamics (Burt, 1992). Microsoft Excel supported the descriptive statistics and custom visualizations.

3.6 Integration Maturity Classification

To operationalize the CSA–Agribusiness Integration Maturity Model, each of the 118 articles was classified according to the depth of integration between agribusiness and CSA. A structured coding protocol guided the classification into four stages. Stage 1 (Parallel Development) included articles that address CSA and agribusiness as conceptually separate domains with no explicit linkage between them. Stage 2 (Strategic Alignment) encompassed studies that recognize the relevance of integrating CSA and agribusiness but do not operationalize this integration in practice-oriented terms. Stage 3 (Operational Integration) captured research examining how climate smart principles are embedded within routine agribusiness operations, supply chains, or business processes. Stage 4 (Systemic Transformation) included studies that analyse or propose fundamental reconfigurations of value chains, governance systems, and investment models around climate smart objectives.

Two researchers independently coded all the articles using a standardized assessment sheet. Disagreements were resolved through discussion, and inter-rater reliability was assessed using Cohen's kappa coefficient, yielding a value of 0.78, which falls within the "substantial agreement" range (0.61–0.80) according to the widely used benchmark proposed by Landis and Koch (1977). Borderline cases, particularly those between Stages 2 and 3, were resolved through joint review of the article's methodology and findings sections, with classification determined by whether the study presented evidence of CSA practices embedded within agribusiness operations or merely acknowledged such potential. This procedure ensures consistency and reliability when applying the maturity framework to the dataset.

3.7 Comparative Benchmarking

To contextualize the findings within the broader CSA literature, this study conducted comparative benchmarking against three recent bibliometric reviews. These included Okolie et al. (2022), which analyzed 892 CSA-related publications; Manyike et al. (2025), which examined 1,247 articles; and Erick et al. (2025), which focused on CSA adoption research. This comparison enabled the assessment of whether agribusiness-integrated CSA research exhibited distinct patterns in thematic focus, geographic distribution, collaboration structures, and theoretical orientation.

Thematic Analysis: In addition to quantitative bibliometric mapping, qualitative thematic analysis was conducted across the entire dataset. An inductive coding approach was applied, based on the article's objectives, methodologies, and findings. This iterative process resulted in the identification of six major themes and 24 sub-themes that characterized research at the agribusiness–CSA interface. Each article was coded for both primary and secondary

themes using a structured excel-based matrix. A cross-theme analysis was then performed to identify thematic overlaps, complementarities, and emerging research fronts.

3.8 Quality Assurance and Limitations

Several measures were implemented to ensure analytical rigour and reproducibility. Ten percent of the articles were randomly selected for the verification of thematic coding consistency. The bibliometric indicators generated by VOSviewer and Bibliometrix were cross-validated, and all analytical parameters and decisions were documented. The raw data files and coding matrices were preserved to ensure transparency. Despite these measures, certain limitations should be acknowledged. Reliance on a single database (Scopus) may exclude relevant studies indexed in Web of Science, CABI, or regional databases. The English-language restriction limits the representation of regional scholarship published in other languages, and the exclusion of gray literature may omit practice-oriented insights. Importantly, geographic analyses in this study are based on author institutional affiliations rather than on the locations where research was conducted. This distinction is significant because research about a particular region may be published by authors based in institutions elsewhere, potentially overrepresenting countries with strong research infrastructure (such as the United States and the Netherlands) while underrepresenting regions where field research occurs but is published through externally affiliated authors. A dual analysis comparing authorship location with actual study location was not feasible with the available Scopus metadata, but future studies should consider this approach where possible. Nevertheless, the methodology provides a systematic and reproducible foundation for mapping knowledge at the intersection of agribusiness and climate smart agriculture.

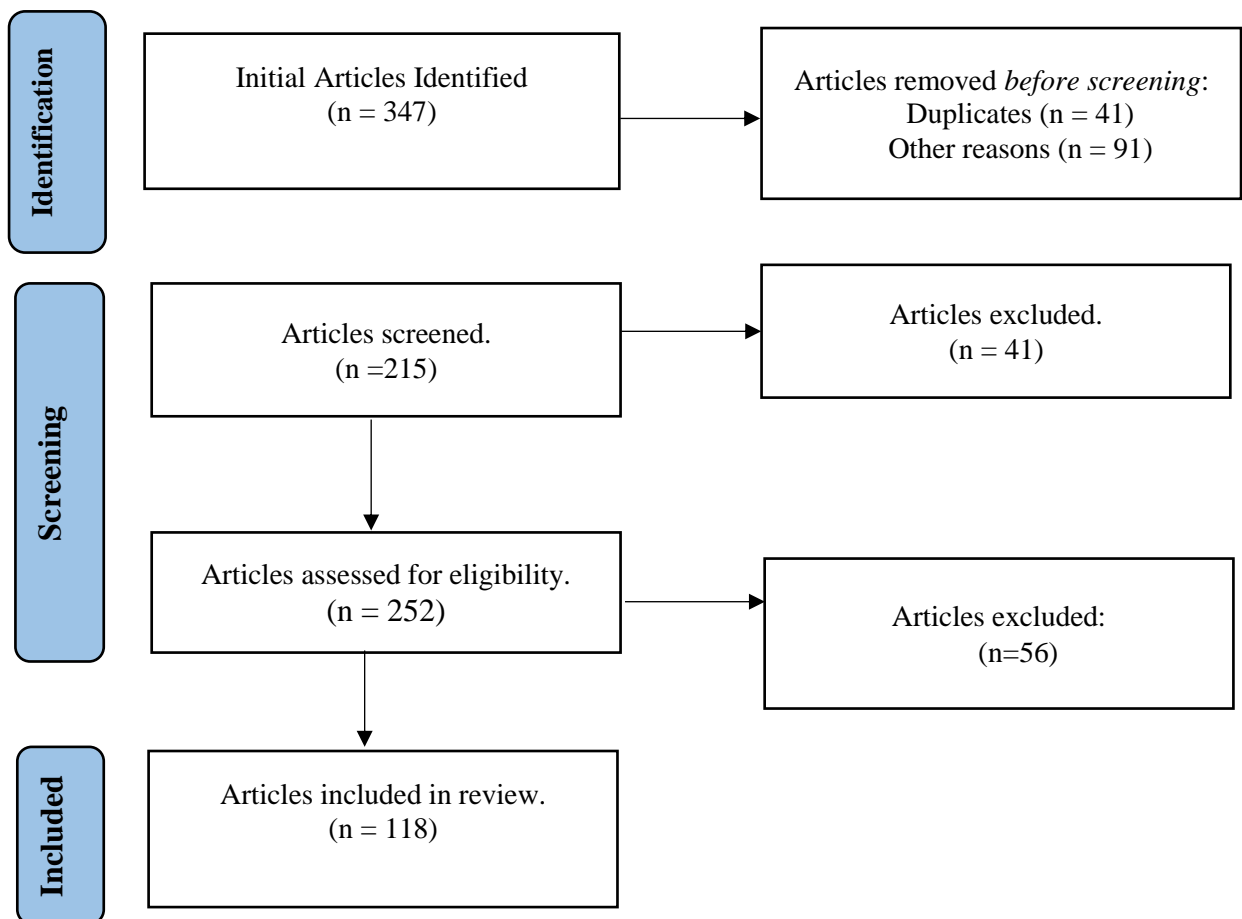


Figure 1
PRISMA Flow Diagram for Article's Selection Process



IV. FINDINGS & DISCUSSION

4.1 Findings

4.1.1 Dataset Overview

To characterize the knowledge structure underpinning global research on the nexus between agribusiness practices and climate-smart agriculture, a Sankey diagram (Figure 2) was generated, linking cited references (CR), authors (AU), and research keywords (DE). This mapping highlights how foundational studies addressing agribusiness, climate change, and agricultural adaptation connect to the most active authors and core thematic domains. Prominent research themes include agribusiness, climate-smart agriculture, food security, adaptation strategies, agricultural sustainability, and value chain resilience, along with more specialized areas such as small-scale farmers, supply chains, and greenhouse gas fluxes.

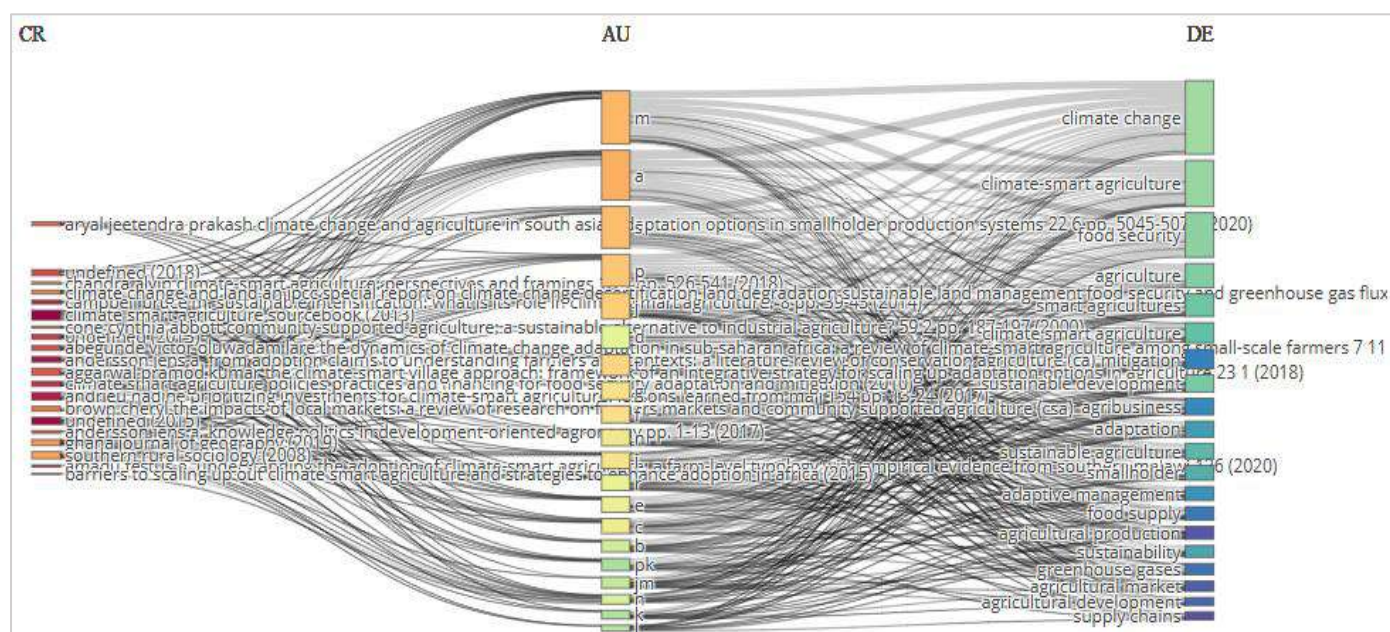


Figure 2
Sankey diagram linking cited references (CR), authors (AU), and research keywords (DE) in agribusiness and climate smart agriculture research.

4.1.2 Trends in Publication Output

The annual distribution of publications examining the nexus between agribusiness practices and climate-smart agriculture from 2014 to 2024 revealed three observable phases of research activity, with phase boundaries defined descriptively based on observed publication patterns rather than statistical breakpoints (Figure 3). The first phase (2014–2016) was characterized by low and fluctuating publication output, beginning with four documents in 2014, increasing to eight in 2015, and declining to two in 2016. The second phase (2017–2021) reflected a period of steady growth, with annual publications increasing from six in 2017 to a peak of 21 in 2021, representing a compound annual growth rate of 40.7 percent. However, this growth rate should be interpreted in the context of the field’s small publication base, rising from 6 to 21 publications annually. The third phase (2022–2024) showed a temporary decline, with 15 publications in 2022 and 10 in 2023, followed by a recovery to 20 publications in 2024, nearly matching the 2021 peak. Overall, the dataset produced an average of 10.8 publications per year (standard deviation = 5.7), with a median of 10 and a range of 2–21 publications. The average annual growth rate is 23.5 percent.

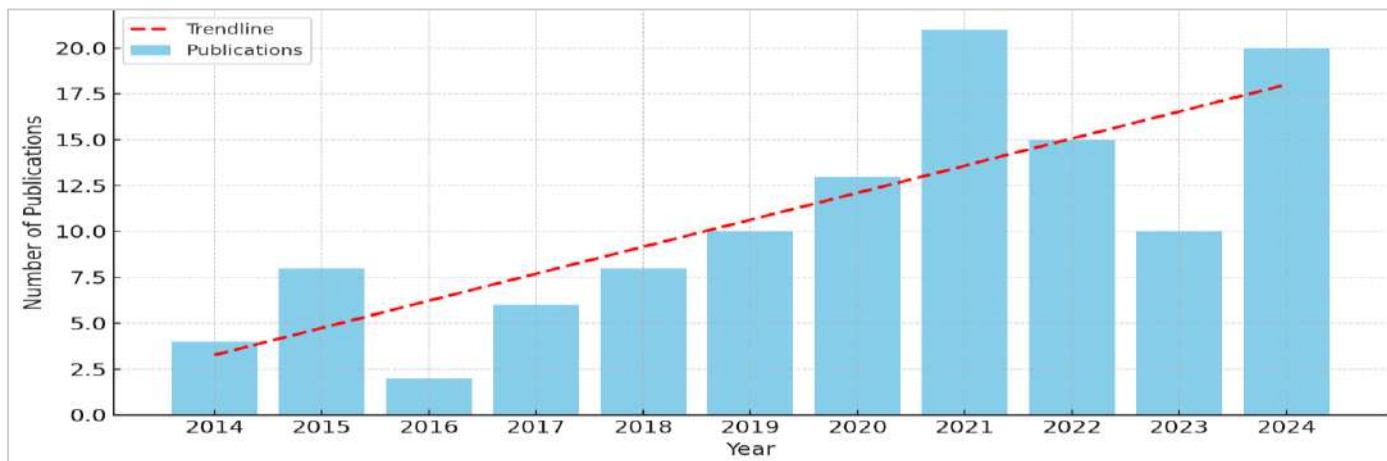


Figure 3
Annual Distribution of Publications on the Agribusiness–Climate Smart Agriculture Nexus (2014–2024).

4.1.3 Institutional Contributions

The distribution of publications by leading research institutions contributing to global scholarship on the nexus between agribusiness practices and climate-smart agriculture showed clear institutional leadership patterns (Figure 4). Across the 118-article dataset, contributions originated from a total of 87 unique institutions. The International Livestock Research Institute (ILRI, Nairobi, Kenya) ranked highest with 17 publications, representing 14.4 percent of the total dataset, followed by Wageningen University and Research (Netherlands) with 12 publications, and the Centro Internacional de Agricultura Tropical (Colombia) with 11 publications. Kwame Nkrumah University of Science and Technology (Ghana) and the University of Leeds (United Kingdom) contributed ten publications each. Other notable contributors include CIRAD, the World Agroforestry Centre, Bioversity International, Københavns Universitet, the International Crops Research Institute, and the World Bank, all with fewer but significant contributions. This concentration underscores the pivotal role of international research centers and globally networked universities in advancing agribusiness and climate-smart agriculture scholarship.

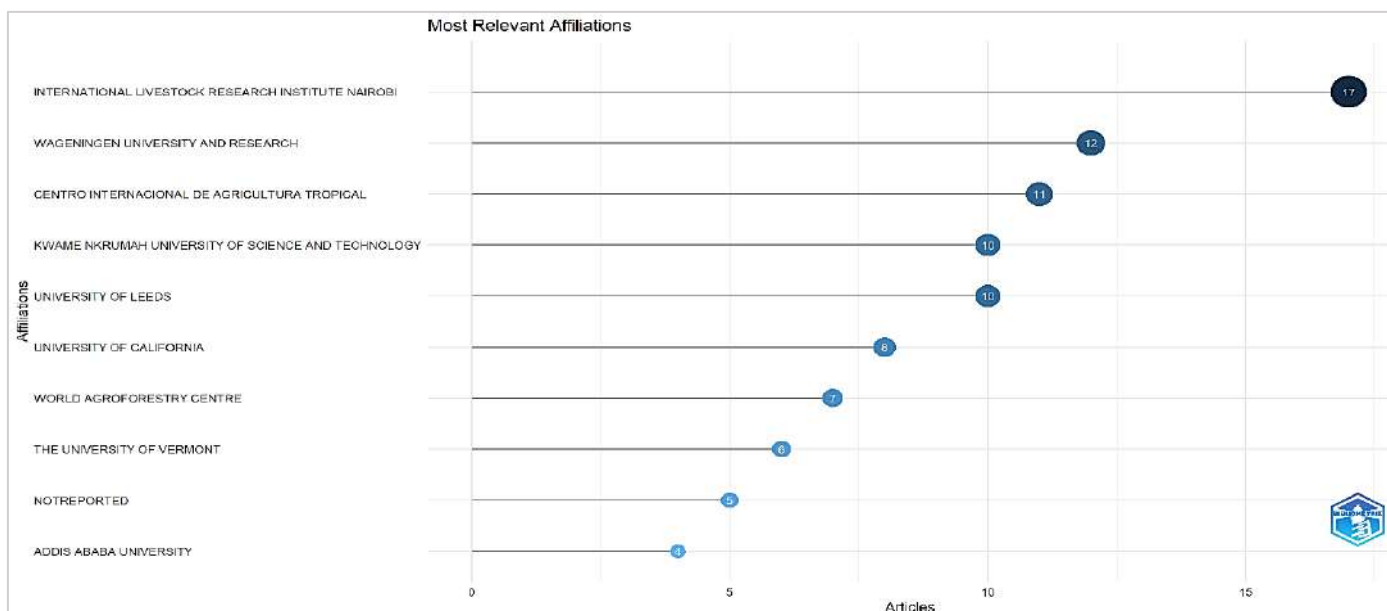


Figure 4
Top Contributing Institutions Publishing on Agribusiness and Climate Smart Agriculture (2014–2024).

4.1.4 Geographical Distribution

The bibliometric analysis identified research outputs originating from 15 countries worldwide (Figure 5). The United States had the highest number of publications (n = 21, 15.0 percent), followed by Kenya (n = 18, 12.9 percent), India (n = 16, 11.4 percent), the Netherlands (n = 14, 10.0 percent), and the United Kingdom (n = 11, 7.9 percent). These five countries collectively account for 57.1 percent of the total research output. European countries contributed 53

publications (37.9 percent), with notable representations from Italy (n = 9, 6.4 percent), France (n = 8, 5.7 percent), and Germany (n = 7, 5.0 percent). Africa produced 39 publications (27.9 percent), followed by Kenya, Ghana (n = 7, 5.0 percent), South Africa (n = 6, 4.3 percent), Ethiopia (n = 4, 2.9 percent), and Nigeria (n = 4, 2.9 percent). The Asian countries generated 25 publications (17.9 percent), primarily from India and Sri Lanka (n = 5, 3.6 percent). South America was represented by Colombia (n = 6, 4.3 percent), whereas Oceania contributed through Australia (n = 4, 2.9 percent).

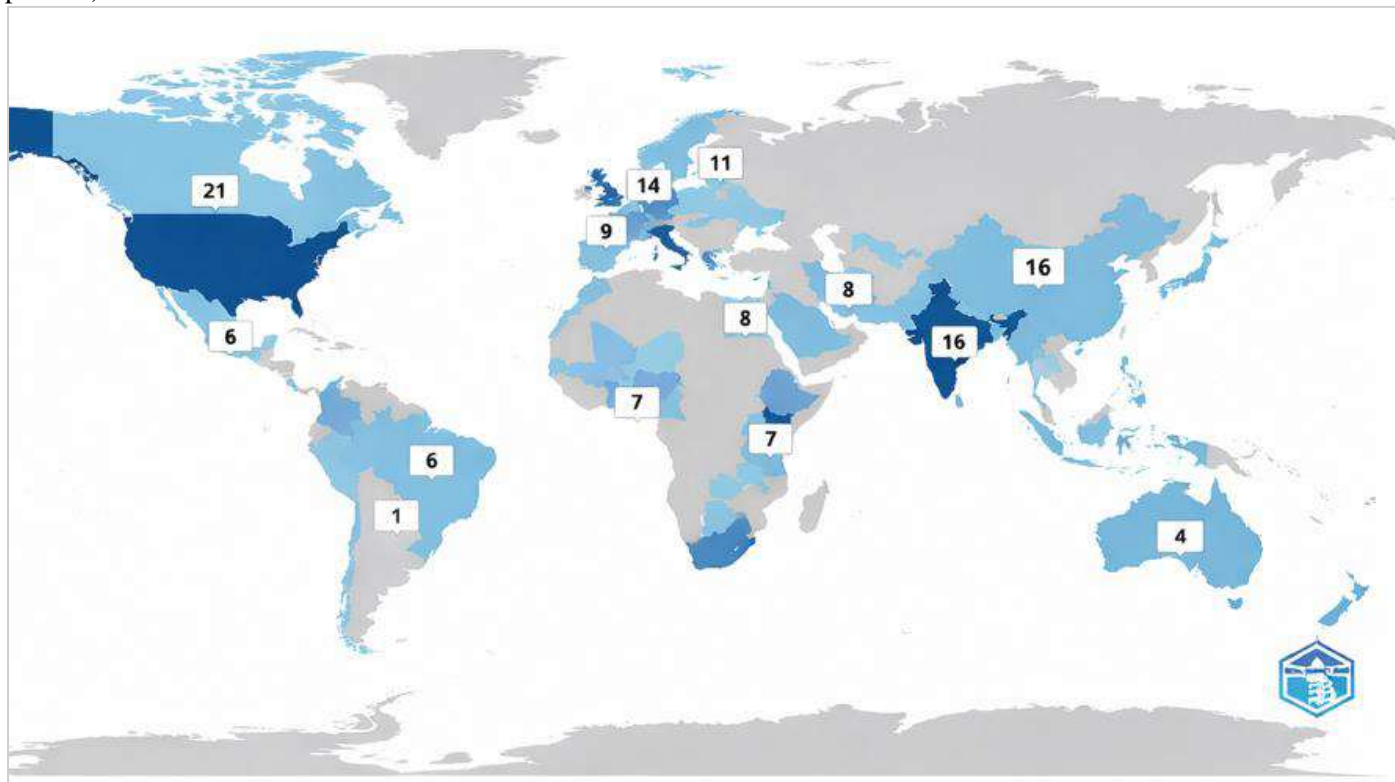


Figure 5
Geographical Distribution of Publications on the nexus between Agribusiness Practices and Climate Smart Agriculture.

4.1.5 Conceptual Linkages and Keyword Co-occurrence

Keyword co-occurrence analysis was performed to examine the conceptual structure of research on the nexus between agribusiness practices and climate-smart agriculture (Figure 6). Each node in the network represents a keyword, with node size reflecting its frequency of occurrence, and links indicating the strength of co-occurrence between terms. The mapping produces five major clusters, each representing a distinct research domain.

Cluster 1 (red) focused on adaptation and mitigation strategies, including adaptation, mitigation, farming systems, and value chains. Cluster 2 (blue) emphasizes risk management and resource efficiency with keywords such as food supply, economics, risk management, irrigation, and sustainability transition. Cluster 3 (green) centers on agricultural technology and innovation, including agricultural finance, technology adoption, and agricultural technology. Cluster 4 (yellow) addressed sustainable agriculture and agribusiness, incorporating terms such as sustainable agriculture, agribusiness, smart agriculture, and climate change adaptation. Cluster 5 (purple) highlights the local food systems and institutional dimensions, including rural development, extension services, innovation, and agricultural economics. Together, these clusters illustrate how research on agribusiness and climate-smart agriculture connects climate-change mitigation and adaptation to market systems, technological solutions, and value-chain sustainability.

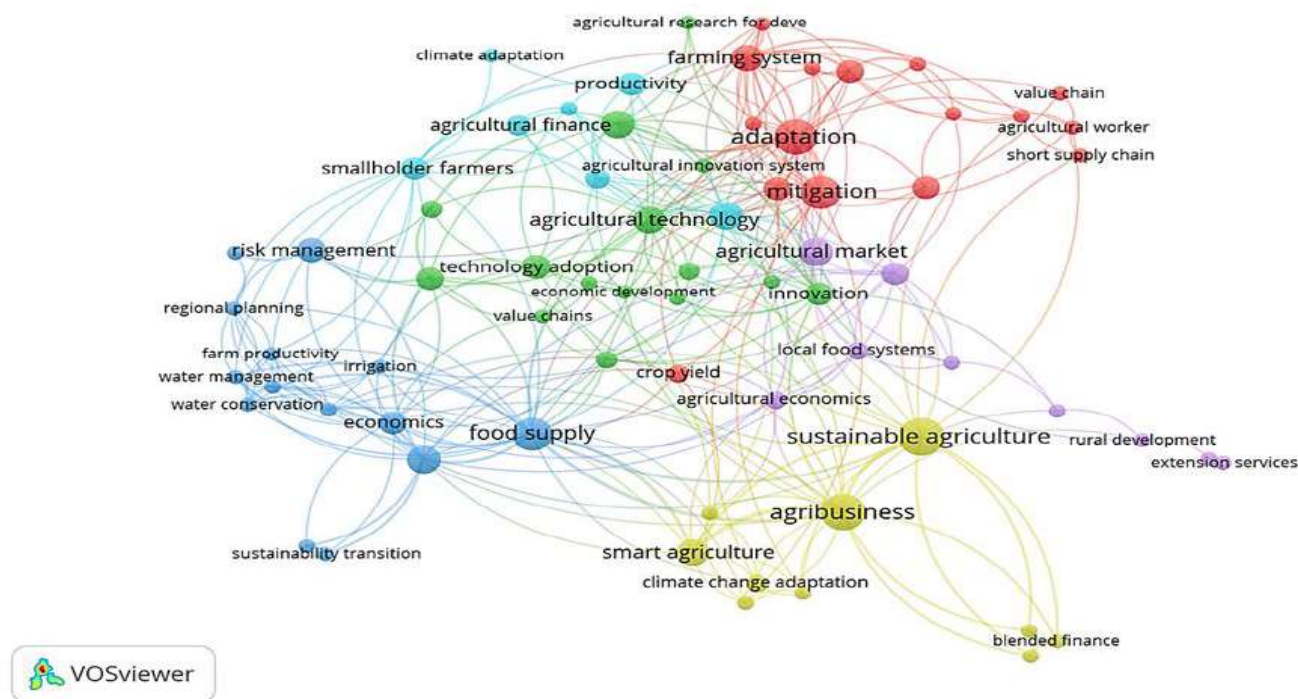


Figure 6
Keyword Co-Occurrence Network Generated using VOSviewer, Showing Thematic Clusters and Conceptual Linkages.

4.1.6 Thematic Landscape of Agribusiness–CSA Literature

A comprehensive thematic analysis of 118 peer-reviewed articles published between 2014 and 2024 revealed six major themes with twenty-four associated subthemes that characterized research at the intersection of agribusiness practices and climate smart agriculture (CSA). The six core themes were resilience and adaptation, adoption and implementation, value chains and markets, policy and governance, financing and investment, and technology and innovation. These themes frequently overlapped, reflecting the interdisciplinary nature of agribusiness and CSA scholarship. Resilience and adaptation emerged as the most dominant themes, addressed in 106 articles, representing 89.8 per cent of the reviewed literature. Studies on this theme focus on how agribusiness systems anticipate, absorb, and reorganize in response to climate-related challenges. The main subthemes include risk management (42 articles), adaptive capacity (38), climate mitigation (35), and food security (41). Collectively, these studies highlight the role of agribusiness systems in building climate-resilient value chains that sustain production and livelihood.

Closely related, adoption and implementation appeared in 101 articles, accounting for 85.6 per cent of the dataset, and examined the mechanisms through which CSA practices are integrated into agribusiness operations. Subthemes within this category included knowledge transfer (51 articles), barriers to adoption (45), decision-making processes (38), and extension services (29). This body of work emphasizes the importance of institutional capacity, information flows, and socioeconomic factors in shaping the uptake of CSA practices. The theme of value chains and markets is featured in 99 articles or 83.9 per cent of the literature and explores the commercial integration of CSA across agricultural systems. Research under this theme addressed supply chain integration (18 articles), market access (15), input supply (12), and value addition (8). These studies reveal how interactions among producers, suppliers, and buyers influence the integration of the CSA principles.

The policy and governance themes were represented in 86 articles (72.9 per cent of the sample), highlighting the regulatory and institutional architecture influencing CSA adoption. The subthemes included institutional support (45 articles), incentive mechanisms (22), regulatory frameworks (18), and certification systems (11). These studies illustrate how governance structures and policy instruments enable or constrain CSA practices in agribusiness systems. The financing and investment theme appeared in 85 articles, comprising 72.0 per cent of the literature, and focused on the economic and financial mechanisms for CSA implementation. The subthemes include economic viability (48 articles), investment models (25), insurance schemes (12), and climate finance (8). Research in this area investigates how agribusinesses mobilize capital and adopt financial innovations to support climate smart investments over the long term.

Lastly, the technology and innovation themes were featured in 71 articles, or 60.2 per cent of the dataset, and explored technological advances that support CSA adoption. The subthemes included digital agriculture (23 articles),



smart technologies (19), remote sensing (15), and precision farming (11). These studies highlight the ways in which technological solutions and digital tools enhance efficiency, monitoring, and data-driven decision making across agribusiness systems.

Table 1
Distribution of CSA – Agribusiness Literature by Theme and Subthemes

Theme	Subthemes (Number of Publications)	Total Articles (%)
Resilience and Adaptation	Risk Management (42), Adaptive Capacity (38), Climate Mitigation (35), Food Security (41)	106 (89.8)
Adoption and Implementation	Knowledge Transfer (51), Barriers (45), Decision Making (38), Extension (29)	101 (85.6)
Value Chains and Markets	Supply Chain Integration (18), Market Access (15), Input Supply (12), Value Addition (8)	99 (83.9)
Policy and Governance	Institutional Support (45), Incentives (22), Regulatory Frameworks (18), Certification (11)	86 (72.9)
Financing and Investment	Economic Viability (48), Investment Models (25), Insurance (12), Climate Finance (8)	85 (72.0)
Technology and Innovation	Digital Agriculture (23), Smart Tech (19), Remote Sensing (15), Precision Farming (11)	71 (60.2)

4.1.7 Comparative Benchmarking with General CSA Literature

To position these findings within the broader climate smart agriculture literature, we conducted a systematic comparison using three benchmark bibliometric reviews: Okolie et al. (2022), Manyike et al. (2025), and Erick et al. (2025). While general CSA literature typically clusters into three broad themes, this review of the agribusiness–CSA nexus revealed six themes, indicating greater thematic complexity.

Resilience was more prevalent in agribusiness-oriented research, appearing in 89.8 per cent of articles, compared to approximately 65 per cent in general CSA studies. In contrast, technology and innovation topics were slightly less common in the nexus literature (60.2 per cent) relative to approximately 78 per cent in the wider field. Publication growth between 2017 and 2021 showed a compound annual growth rate of 40.7 per cent in nexus literature, outpacing the 25 per cent CAGR observed in general CSA publications. Institutional output was also more concentrated in agribusiness–CSA literature, with a Gini coefficient of 0.72 compared to approximately 0.58 in general CSA literature.

Table 2
Benchmark Comparison: Agribusiness – CSA Nexus and General CSA Literature

Indicator	This Study (Nexus)	General CSA Literature
Thematic Complexity	Six themes	Three themes
Resilience Emphasis	89.8	≈ 65
Technology Emphasis	60.2	≈ 78
Publication Growth (CAGR)	40.7 (2017–2021)	25
Institutional Concentration	Gini = 0.72	Gini ≈ 0.58

4.1.8 Integration Maturity Distribution

Applying the CSA–Agribusiness Integration Maturity Model developed in this study, 118 articles were classified into four stages of integration depth. Stage 1, representing parallel development in which CSA and agribusiness are conceptually disconnected, accounted for 38 articles or 32.2 per cent of the total. Stage 2, representing strategic alignment where integration is recognized but not deeply operationalized, included 41 articles or 34.7 per cent. Together, these early stages comprise 66.9 per cent of the reviewed literature, suggesting that most research remains at the foundational level of integration. More advanced stages, including Stage 3 operational integration and Stage 4 systemic transformation, were represented by 25 articles (21.2 per cent) and 14 articles (11.9 per cent), respectively. These stages reflect research that examines how climate smart principles are embedded in routine agribusiness operations or how entire systems reorganize around CSA objectives. The smaller representation of these stages suggests a relative need for more research focusing on the operational mechanisms and institutional changes necessary to scale CSA through agribusiness systems.

Table 3*Representative Articles by Integration Maturity Stage*

Stage	Classification Criteria	Representative Example	Rationale
Stage 1: Parallel Development	CSA and agribusiness addressed as separate domains	Kalele et al. (2021)	Examines climate change impacts on smallholders without linking to agribusiness systems or value chains
Stage 2: Strategic Alignment	Integration recognized but not operationalized	Makamane et al. (2023)	Identifies determinants of CSA adoption including market access but does not analyse embedded business processes
Stage 3: Operational Integration	CSA principles embedded in agribusiness operations	Senyolo et al. (2021)	Analyses public-private partnerships as operational mechanisms for technology adoption within commercial agriculture
Stage 4: Systemic Transformation	Fundamental reconfiguration of value chains around CSA	Ng'ang'a et al. (2021)	Evaluates cost-benefit structures of CSA investments, proposing systemic changes to financing and value chain models

4.1.9 Network Topology and Structural Gap Analysis

Network topology analysis revealed the key structural features of the agribusiness – CSA knowledge domain. Concepts with high betweenness centrality, such as climate change adaptation (0.42), food security (0.38), and sustainable agriculture (0.35), served as conceptual bridges connecting multiple thematic clusters. The term value chain also held a central position with a betweenness score of 0.31 and a clustering coefficient of 0.67, indicating its importance despite some conceptual isolation from other clusters. The structural hole analysis highlighted gaps in integration across thematic areas. The largest structural gap occurred between the technology and innovation and financing and governance clusters, with an index of 0.73, indicating limited cross-domain engagement. Additional structural holes were found between resilience and adaptation and value chains and markets (0.61) and between policy and governance and technology and innovation (0.54). These structural gaps suggest fruitful areas for future research to enhance the connectivity across knowledge domains.

4.1.10 Regional Variation in Integration Maturity

Geographic analysis based on institutional affiliations has revealed meaningful differences in integration maturity across the world. African institutions demonstrate the highest average integration maturity score of 2.4, driven by active research hubs in Kenya and South Africa. European institutions followed an average score of 2.1, while North American and Asian institutions had lower average scores of 1.9 and 2.0, respectively. These patterns may reflect differences in research priorities, policy environments, and funding landscapes, which shape regional engagement with agribusiness – CSA integration.

4.2 Discussion**4.2.1 Evolution and Growth of the Agribusiness and Climate Smart Agriculture Nexus**

The bibliometric evidence suggests that the development of scholarship at the intersection of agribusiness and climate smart agriculture has followed a discernible progression, beginning with conceptual framing and gradually expanding into market-oriented applications. Between 2017 and 2021, the literature exhibited a compound annual growth rate of 40.7 percent, which appears to outpace the 25 percent growth observed in general climate smart agriculture literature (Manyike et al., 2025). This pattern may indicate heightened scholarly interest in the nexus, as market mechanisms and agribusiness strategies gain prominence in climate adaptation discourse (Okolie et al., 2022). It is important to note, however, that these bibliometric patterns reflect trends in the published scholarship and require empirical validation through primary field studies to confirm whether they correspond to real-world developments in agribusiness practice.

Bibliometric trends and science mapping indicate that the literature has evolved from early emphases on resilience and adaptation toward more complex socioeconomic and institutional dimensions, including value chain integration and climate finance (Kishore et al., 2024). This trajectory aligns with the theoretical progression from resilience-oriented frameworks (Folke et al., 2016) toward sustainability transition theory (Geels, 2002), suggesting that the field is moving beyond adaptation toward systemic transformation perspectives. The post-2024 recovery in publication volume may underscore the resilience of the field despite global disruptions such as economic volatility and climate-induced shocks (Chitakira and Ngcobo, 2021). However, the observed fluctuations also highlight the sensitivity of this research area to external funding and policy shifts, underscoring the need for agile and context-responsive research frameworks (Senyolo et al., 2021; Geetha et al., 2023).

4.2.2 Integration Maturity and the Implementation Gap

The maturity distribution analysis provides new insights into the persistent implementation gap in climate smart agriculture research and practice. While earlier studies have attributed this gap to constraints such as limited finance and inadequate policy support (Thornton et al., 2018), the current review suggests an additional dimension: the knowledge base itself may remain insufficiently integrated to support systemic change. Of the 118 articles reviewed, 66.9 percent were classified within the two lowest stages of integration, Parallel Development and Strategic Alignment, indicating that most studies appear to address climate smart agriculture and agribusiness separately or only conceptually link them (Erick et al., 2025).

In contrast, only 21.2 percent of the studies reached the Operational Integration stage, and only 11.9 percent demonstrated the characteristics of Systemic Transformation. Viewed through the lens of Innovation Diffusion Theory (Rogers, 2003), this distribution suggests that CSA integration within agribusiness may still be in the early adoption phase, with most scholarship describing the innovation rather than documenting its diffusion through commercial networks. Similarly, from a Governance Theory perspective (Gereffi et al., 2005; North, 1990), the limited prevalence of Stage 3 and 4 studies implies that institutional mechanisms for embedding CSA within value chain operations remain underdeveloped in the literature. Addressing this gap requires frameworks that move beyond coordination and toward embedded integration, focusing on how agribusinesses internalize climate smart agriculture objectives across value chains (Makamane et al., 2023).

4.2.3 Thematic Patterns and Structural Fragmentation

The review identified six major themes, but significant fragmentation remained across research domains. For example, the structural hole analysis revealed a notable gap between technology and innovation and financing and governance clusters, with a structural hole index of 0.73. From a theoretical standpoint, this gap reflects the disconnect between Innovation Diffusion Theory, which emphasizes technology generation and uptake (Rogers, 2003; Hall et al., 2006), and Sustainable Finance Theory, which addresses the capital and investment conditions for scaling innovations (Baker et al., 2018). The bibliometric evidence suggests that technological advances may often be developed in isolation from the institutional mechanisms that enable adoption, such as financial services or regulatory frameworks (Burt, 1992; Wang et al., 2024). Such disconnects could constrain the real-world scalability of climate smart innovation. Bridging these gaps may require interdisciplinary designs, such as studies examining how digital platforms can reduce financing asymmetries or how regulatory innovations support the adoption of precision agriculture (Jew et al., 2020; Raj et al., 2022). Additionally, the relatively low representation of technology and innovation themes (60.2 percent) suggests an underexplored area, particularly in relation to data analytics, remote sensing, and other tools essential for monitoring performance (Bertoglio et al., 2021).

4.2.4 Institutional Landscape and Geographic Disparities

The institutional landscape remains concentrated, with leading contributions from CGIAR centers, such as the International Livestock Research Institute, the International Center for Tropical Agriculture, and the World Agroforestry Center, alongside select universities (Makate, 2020; García Agüero et al., 2023). While this concentration supports high-quality methodological development, it limits the diversity of contextual perspectives. Geographic analysis revealed that most publications originated from a small group of countries, primarily the United States and Kenya, with limited representation in Latin America and Southeast Asia (Afinjuomo and Muyali, 2024). Interestingly, institutions based in Africa demonstrated the highest average maturity score of 2.4, compared to 2.1 in Europe, 2.0 for Asia, and 1.9 for North America. Viewed through the Sustainable Livelihoods Framework (Chambers and Conway, 1992), this pattern may suggest that African researchers, who often work in environments in which climate and market pressures converge, adopt more integrative analytical approaches precisely because resilience is an immediate operational concern rather than an abstract concept (Makamane et al., 2023). These findings challenge the assumptions that northern institutions lead in analytical sophistication and point to the potential of South–South learning and collaboration.

4.2.5 Knowledge Gaps and Research Priorities

However, several important gaps remain to be explored. While much of the literature addresses technical adoption and economic viability, few studies have examined equity, institutional power dynamics, and inclusive business models. These dimensions are essential for understanding the benefits of climate smart agriculture integration and promoting sustainable and equitable agricultural transformation (Dobkowitz et al., 2020; Njoya et al., 2022). The absence of research in regions such as Latin America further limits its generalizability (Autio et al., 2021). To address these gaps, future studies should incorporate mixed-method designs that validate bibliometric patterns through in-depth empirical inquiry (Makamane et al., 2023). Research on inclusive agribusiness models, particularly those that balance commercial viability with equity, is urgently required. This also includes greater attention to gender dynamics, land tenure, and the role of small and medium agribusinesses in driving climate smart transitions (Raj et al., 2022).



4.2.6 Methodological and Network Considerations

The study’s reliance on Scopus and English language sources may have excluded regionally significant literature, particularly non-English publications and gray literature, which often contain practitioner insights and policy innovations (Öztürk et al., 2024). Broader reviews using multilingual and multidatabase strategies tend to show more diverse geographic and thematic coverage. Incorporating patent data and altmetrics could further enrich the analysis of innovation and real-world impact (Kanire et al., 2024). Moreover, collaboration patterns reveal persistent power asymmetries, with most partnerships occurring in the North–South constellations rather than through South–South cooperation (Ali et al., 2025). Strengthening underrepresented institutions will require intentional strategies, such as regional research grants, mentorship schemes, and open access platforms that lower barriers to participation (Senyolo et al., 2021; Raj et al., 2022).

Table 4
Mapping of Thematic Findings to Theoretical Foundations

Theme	Theoretical Foundation	How Findings Relate	Implication
Resilience & Adaptation (89.8%)	Sustainable Livelihoods Framework; Climate Resilience Theory (Folke et al., 2016)	Dominance of this theme confirms resilience as the foundational concern driving agribusiness–CSA scholarship	Suggests resilience is the entry point for most integration efforts
Adoption & Implementation (85.6%)	Diffusion of Innovations (Rogers, 2003); Agricultural Innovation Systems (Hall et al., 2006)	High prevalence indicates focus on how CSA practices spread through agribusiness networks	Literature remains focused on early diffusion stages rather than scaled adoption
Value Chains & Markets (83.9%)	Global Value Chain Theory (Gereffi et al., 2005)	Reflects scholarly attention to commercial structures as vehicles for CSA integration	Value chain governance is recognized but operational embedding remains limited
Policy & Governance (72.9%)	Institutional Theory (North, 1990; Scott, 2001)	Governance arrangements shape CSA adoption through rules, standards, and certification	Structural holes between governance and technology clusters indicate fragmentation
Financing & Investment (72.0%)	Sustainable Finance Theory (Baker et al., 2018)	Growing attention to financial mechanisms, but structural gap with technology cluster (0.73)	Finance and technology research streams need greater cross-domain engagement
Technology & Innovation (60.2%)	Sustainability Transitions Theory (Geels, 2002)	Lowest representation despite importance; limited connection to finance and governance	Underexplored area requiring interdisciplinary research designs

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

This study provides a comprehensive bibliometric mapping of 118 publications examining the intersection of agribusiness and climate-smart agriculture (CSA). It reveals a rapidly evolving research domain structured around six interconnected thematic areas with a growing emphasis on value chain integration, financial innovation, and governance reform. The compound annual growth rate of 40.7% between 2017 and 2021, though based on small absolute numbers, underscores the increasing relevance of market-oriented approaches for scaling CSA practices.

Despite this growth, the analysis revealed a notable gap between operational and systemic integration. The finding that 66.9 percent of the reviewed literature remains at the Parallel Development or Strategic Alignment stages indicates that the knowledge base has yet to mature sufficiently to guide systemic transformation. This implementation gap points to a need for research that focuses not only on CSA adoption, but also on institutional mechanisms, financing models, and business processes that enable its mainstreaming. The introduction of the CSA–Agribusiness Integration Maturity Model offers a novel diagnostic tool to classify and evaluate integration depth, supporting both scholarly analysis and policy design.

Geographic and institutional disparities further highlight the concentration of research output among a small number of institutions and regions. African institutions, despite their limited resources, demonstrate higher integration maturity (average score of 2.4) than their counterparts in North America (1.9) and Asia (2.0), suggesting valuable opportunities for South–South collaboration. However, the limited representation in Latin America and Southeast Asia indicates critical blind spots that need to be addressed.

Drawing directly from the empirical findings, this study recommends three priority actions to advance this field. First, the predominance of early-stage integration (66.9% at Stages 1–2) calls for mixed-method research designs that

move beyond bibliometric mapping to validate integration patterns through in-depth case studies of agribusiness operations embedding CSA principles. Second, the structural hole between technology and innovation and financing and governance clusters (index = 0.73) underscores the need for interdisciplinary research that bridges digital agricultural tools with financial mechanisms and regulatory frameworks. Third, the underrepresentation of equity, gender, and inclusive business model research, coupled with the geographic concentration of outputs, demands equity-focused research agendas that prioritize marginalized regions and smallholder perspectives. Ultimately, this study lays the groundwork for a more coherent, inclusive, and action-oriented body of knowledge capable of guiding systemic CSA integration across agribusiness systems.

5.2 Recommendations

The findings indicate that most studies remain at early stages of integration between agribusiness and climate smart agriculture, with 66.9 percent classified within Parallel Development and Strategic Alignment stages. Future research should therefore prioritize empirical investigations that examine how climate smart principles become embedded within routine agribusiness operations, supply chain coordination systems, and investment decision frameworks. Mixed method designs that combine bibliometric mapping with case-based analysis would strengthen understanding of operational integration and support the transition toward systemic transformation.

The structural gap identified between technology and innovation and financing and governance domains highlights the need for stronger interdisciplinary engagement. Future scholarship should explore how digital agriculture, precision technologies, and data driven monitoring systems connect with climate finance instruments, insurance mechanisms, regulatory incentives, and value chain governance arrangements. Bridging these domains would enhance scalability, improve investment confidence, and support long term sustainability of climate smart strategies within commercial agricultural systems.

Finally, greater attention is required to address geographic concentration and limited focus on equity dimensions. Research efforts should expand into underrepresented regions such as Latin America and parts of Southeast Asia, while incorporating perspectives related to gender, land tenure, small and medium enterprise participation, and inclusive business models. Policymakers and agribusiness actors should align institutional frameworks, financing mechanisms, and performance metrics with measurable resilience and mitigation outcomes to ensure that climate smart integration moves from conceptual recognition toward practical and equitable transformation.

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