Revista de Ciências Agroveterinárias
Universidade do Estado de Santa Catarina (UDESC)

Review Article

Intangible assets as drivers of innovation in the agricultural sector: A systematic review

Ativos intangíveis como impulsionadores da inovação no setor agrícola: Uma revisão sistemática

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Submission: June 10th, 2025 | Acceptance: September 15th, 2025

ABSTRACT

Intangible assets play a crucial role in fostering innovation and enhancing productivity across various industries, particularly due to their capacity to generate competitive advantages. In the agricultural sector, despite their slow adoption, these assets have a significant impact in the context of global challenges and the increasing need for sustainable practices. This systematic review investigates how the contribution of intangible assets to innovation has been studied in the agricultural sector. Using the PRISMA methodology, articles from the Scopus and Web of Science databases published between 1992 and 2024 were reviewed, identifying 46 studies that examine the relationship between intangible assets and innovation in this field. The findings reveal a growing interest in this area, underscoring the pivotal role of intangible assets in improving efficiency and competitiveness in the agricultural sector through innovation. Nonetheless, the review highlights the need for an integrative framework to provide a holistic understanding of how agricultural practices can be enhanced through the effective management of intangible assets.

KEYWORDS: Intellectual capital. Social Capital. Human Capital. Innovation

RESUMO

Os ativos intangíveis desempenham um papel crucial na promoção da inovação e no aumento da produtividade em diversos setores, principalmente devido à sua capacidade de gerar vantagens competitivas. No setor agrícola, apesar da adoção ainda limitada, esses ativos exercem um impacto significativo diante dos desafios globais e da crescente necessidade de práticas sustentáveis. Esta revisão sistemática investiga como a contribuição dos ativos intangíveis para a inovação tem sido estudada no setor agrícola. Utilizando a metodologia PRISMA, foram analisados artigos publicados entre 1992 e 2024 nas bases de dados Scopus e Web of Science, identificando-se 46 estudos que examinam a relação entre ativos intangíveis e inovação nesse campo. Os resultados revelam um interesse crescente pelo tema, ressaltando o papel fundamental dos ativos intangíveis na melhoria da eficiência e da competitividade do setor agrícola por meio da inovação. Ainda assim, a revisão destaca a necessidade de um marco integrador que permita uma compreensão holística de como as práticas agrícolas podem ser aprimoradas por meio da gestão eficaz desses ativos.

PALAVRAS-CHAVE: Capital intelectual. Capital social. Capital humano. Inovação.

INTRODUCTION

Intangible assets are fundamental elements of modern business dynamics, widely recognised for their significant contribution to the productive potential of organisations and characterised by their lack of physical form (BAGNA et al. 2024). Research, such as that by TSUI et al. (2014), highlights the pivotal role of intangible knowledge in driving innovation and sustaining long- term competitiveness. Similarly, BUCKLEY et al. (2022) describe these assets as inherently challenging for competitors to replicate—a unique trait that significantly enhances their value, particularly when integrated with other goods and services.

Intellectual capital (IC), recognized as an intangible asset, has garnered substantial and growing attention in both research and practice over the past three decades, firmly establishing itself as a strategic intangible asset within the global economic landscape (COSA et al. 2024). Its relevance becomes particularly pronounced in knowledge-based economies (HAZAN et al. 2021). According to BONTIS (1998) and EDVINSSON & MALONE (1997), IC equips organisations with the tools necessary to evaluate the value of their intangible assets more effectively and to make informed strategic decisions. Moreover, it enables organisations to identify and leverage their knowledge resources, thereby enhancing performance and fostering collaboration (SVEIBY 2001). This capability attracts investors who prioritise intellectual property and knowledge-based resources, providing organisations with a clear pathway to achieving sustainable competitive advantages (STEWART 1997).

Despite its critical importance across various economic sectors, the integration and adoption of IC within the agricultural sector have been relatively slow. KOZERA-KOWALSKA (2020) highlights that the incorporation of human and intellectual resources in agriculture often occurs through agribusiness, particularly in areas related to the food supply chain. Nevertheless, the application of IC in this sector is of paramount importance, especially in addressing the multifaceted challenges of sustainable development, where the effective management of knowledge and resources can enhance operational adaptability, resilience, and innovation capacity (KOZERA-KOWALSKA 2020, JANUŠKAITE & UŽIEN 2018).

IC is traditionally categorised into three core components: human capital, structural capital, and relational capital, which collectively contribute to the creation of organisational value (MARR et al. 2004). Human capital refers to the knowledge, skills, and expertise of an organisation's employees, which serve as essential drivers of collective growth (ZEGHAL & MAALOUL 2010). Structural capital includes organisational processes, databases, and information systems that enable efficient knowledge flow and operational effectiveness (BONTIS et al. 2000). Relational capital focuses on the organisation's relationships with external stakeholders, such as clients

and suppliers, delivering strategic value through these interactions (SVEIBY 1997).

Within the framework of IC, human capital specifically denotes the knowledge and skills that employees contribute to an organisation. This form of capital interacts closely with structural and relational components to generate substantial organisational value and deliver competitive advantages (ZEGHAL & MAALOUL 2010, MARR et al. 2004).

Classical theories of human capital, however, present a contrasting perspective. Pioneered by influential scholars such as SCHULTZ (1961) and BECKER (2002), these theories conceptualise human capital primarily as an individual economic resource. They argue that investments in education, training, and health directly increase employee productivity, thereby enhancing their value to organisations and the broader economy (GOLDIN 2016, BECKER 2002). Additionally, other authors frame human capital as a vital organisational asset that fosters competitive

advantages, improves performance, and drives success (CROOK et al. 2011, JIANG et al. 2012). Skilled employees, with their capacity for innovation, creativity, and adaptive problem-solving, play an instrumental role in addressing and overcoming complex organisational challenges (JIANG et al. 2012).

Social capital, another critical intangible asset, emerges from interpersonal relationships that facilitate resource access, promote cohesion, and mediate information flows (BOURDIEU 1986, COLEMAN 1988, PUTNAM 1993). Social capital is reflected in relationships that enable resource acquisition (BOURDIEU 1986) and provide social support (COLEMAN 1988, PUTNAM 2000). These connections represent a form of social power that, depending on their use and application, can have diverse and wide-ranging impacts on individuals and communities (ISHIHARA & PASCUAL 2009). Furthermore, social capital encompasses not only the relationships themselves but also the outcomes they generate, which often makes its measurement and evaluation particularly challenging (DURLAUF 2002). These relationships manifest across various contexts—such as families, communities, and organisations—contributing to collective engagement, shared benefits, and enhanced social cohesion (PUTNAM 2000).

Although the agricultural sector plays a strategic role in food security and sustainable development, it has historically lagged behind in the utilization of intangible assets, particularly in developing countries (WORLD BANK 2020, OECD 2019). Strengthening these assets is essential to address climate challenges, enhance sustainability, and promote the inclusion of small-scale producers (FAO 2022, IPCC 2022,KLERKX et al. 2012). However, research on intangible assets in agricultural contexts remains scarce and fragmented, underscoring the need for a systematic review that integrates their role in agricultural innovation processes.

The selection of the 1992–2024 period for this review is based on theoretical and empirical grounds related to the evolution of research on intangible assets. Since the

1990s, seminal works have been consolidated that defined and operationalized their main components. In the field of intellectual capital, scholars such as EDVINSSON & MALONE (1997), STEWART (1997), SVEIBY (1997), and BONTIS (1998) proposed conceptual frameworks and measurement models. In the area of social capital, COLEMAN (1988) and PUTNAM (1993) provided key contributions to understanding how social networks, trust, and cooperation generate collective value. The endpoint of 2024 corresponds to the time when the final literature search was conducted in Scopus and Web of Science.

This review differs from previous studies by proposing an integrative framework that articulates various intangible assets: intellectual capital, classical human capital theory, and social capital, offering a multidimensional perspective on their effects on agricultural innovation. It also provides a sector-specific synthesis focused on agriculture—a sector historically underexplored in the literature on intangible assets.

METHODOLOGY

To conduct this systematic literature review, the PRISMA methodology was employed (Figure 1), a robust framework that significantly reduces bias and subjectivity throughout the process, ensuring that the study is both comprehensive and reproducible (HADDAWAY et al. 2022). This methodology is particularly suitable for systematic reviews as it facilitates transparency and replicability in the research process, providing a clear structure for identifying, screening, and analysing relevant studies. The research question formulated for this review was: "How do intangible assets contribute to innovation in the agricultural sector?" This central question served as the foundation for defining the study's objective: analysing the complex relationship between intangible assets and innovation within this sector while identifying the various factors that influence and shape this connection.

For the selection of studies, the Scopus and Web of Science (WoS) databases were utilised due to their recognised high-quality standards, extensive coverage of peer-reviewed articles, and frequent use within the scientific community as reliable sources for academic research (PRANCKUTĖ 2021, ZHU & LIU 2020). These databases were chosen specifically to ensure the inclusion of studies with rigorous methodologies and robust findings. The search process was conducted using a comprehensive and carefully designed strategy, which included the following keywords: "intellectual capital" OR "structural capital" OR "relational capital" OR "social capital" AND "agriculture" OR "cattle raising" OR "farming" OR "husbandry" OR "breeding" OR "livestock" OR "aquaculture." This combination of terms aimed to capture a broad spectrum of relevant studies, covering various dimensions of intangible assets and their applications in diverse agricultural contexts. Although the search was defined to cover the period 1992–

2024 to ensure a comprehensive time horizon, the empirical evidence that met the inclusion criteria was only available from 2000 onwards.

Consequently, the effective temporal coverage of the reviewed studies begins in 2000. Regarding the exclusion criteria, the articles were discarded through three sequential selection phases (Figure 1). First, 110 duplicates were removed. Second, 151 articles were excluded for not explicitly addressing the agricultural sector, including those primarily focused on agro-industrial processes. Finally, 186 articles were excluded following a full-text review, based on one or more of the following criteria: (i) the study lacked empirical evidence, being conceptual or theoretical in nature; (ii) it did not establish a clear relationship between intangible assets and innovation; or (iii) it did not present findings directly applicable to agricultural production systems, despite referring to rural contexts. This selection process ensured that only studies offering concrete empirical contributions to understanding the role of intangible assets in agricultural innovation were retained for analysis.

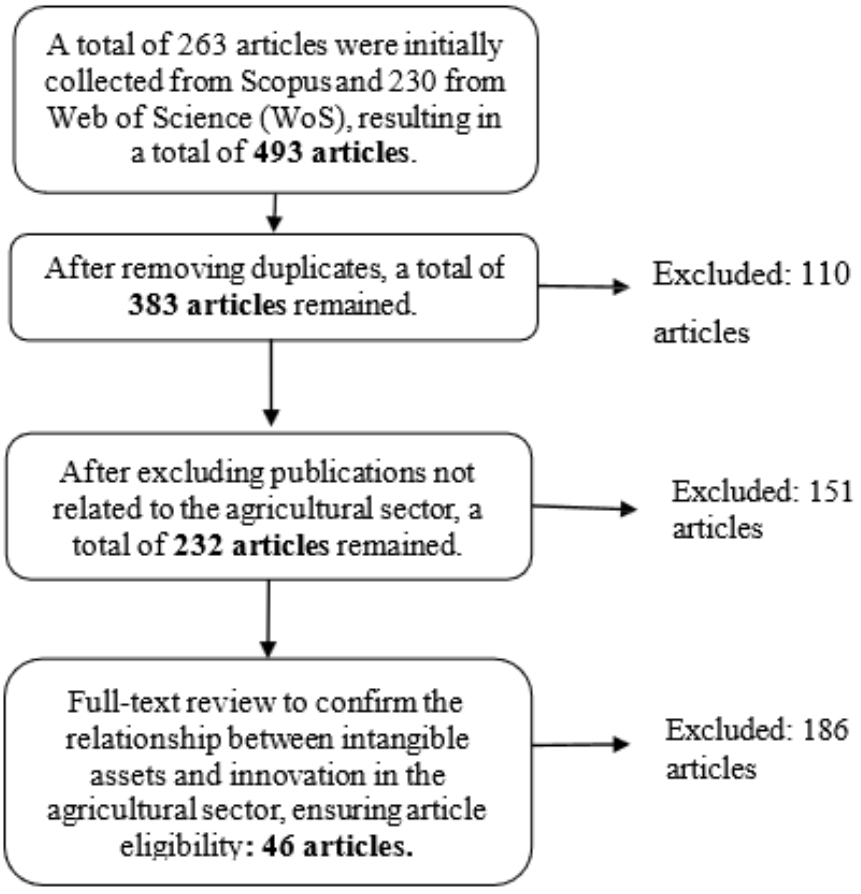

Figure 1. *PRISMA diagram.*

To ensure the quality of the studies included, PRISMA guidelines were followed (MOHER et al. 2009), starting with an initial review of the titles, abstracts, and keywords of each article. In cases of uncertainty, the review was extended to specific sections of the text. As the review process progressed, the need for a more thorough analysis became evident, leading to a full reading of the selected articles.

The essential data from each article were recorded in a synthesis matrix, including authors, publication year, objectives, sample, and main findings. As the review advanced, additional columns were added to capture specific information about intangible assets and their impact on agricultural innovation. When necessary for the analysis, additional sources cited in the articles were consulted to supplement the interpretation of key concepts.

Finally, the results were interpreted in alignment with the objectives of this research. Cross- synthesis enabled the identification of patterns, similarities, and differences among the selected studies (PETTICREW & ROBERTS 2006), providing a comprehensive overview of trends related to the relationship between intangible assets and innovation in the agricultural sector.

RESULTS

Overview of the review

A total of 46 articles were analysed, revealing a predominance of quantitative methodologies in 24 studies (52%), indicating a preference for statistical analyses that facilitate the quantification of variables and the generalisation of findings to broader populations. Qualitative methods, employed in 13 studies (28%), enabled the exploration of in-depth and contextual dimensions through techniques such as interviews and content analysis, offering valuable insights into processes and subjective meanings. Finally, mixed-methods approaches, utilised in 9 studies (20%), combined the strengths of both quantitative and qualitative methods, providing a more holistic and multifaceted understanding of the research questions by effectively correlating numerical data with interpretative analyses.

The quantitative studies included in this systematic review displayed significant variability in sample size and geographic scope, ranging from 50 participants in China (XU et al., 2020) to 2,697 in Germany (SAUER & LATACZ-LOHMANN, 2015). This broad variation, depicted in Figure 2, highlights not only differences in study scale but also methodological and population-focused approaches.

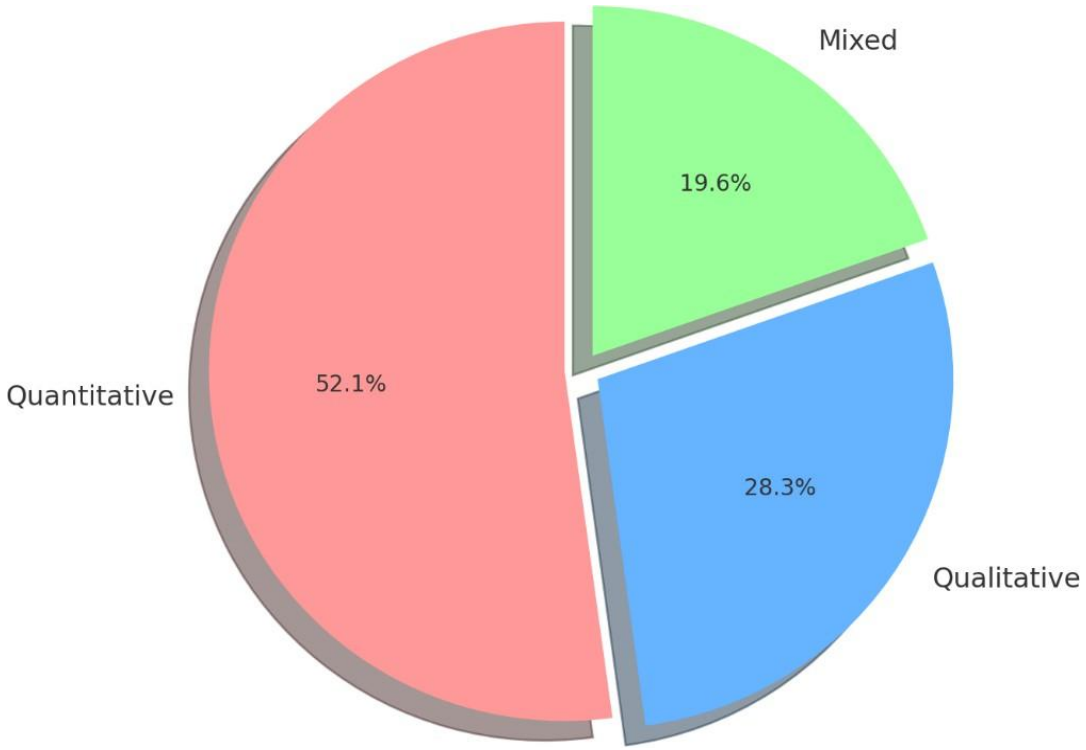

Figure 2. *Distribution of articles by methodology used.*

Regarding geographical distribution, the majority of studies focused on a single country, reflecting a tendency towards context-specific analyses. However, four studies expanded their scope to multiple countries. Notable examples include DAVIES et al. (2018), which covered five countries in West Africa, and VAN RIJN et al. (2012), which featured a substantial sample of 2,518 participants across Sub-Saharan African nations. Similarly, studies by KELLY (2022) and KELLY et al. (2021) jointly examined Northern Ireland and the Republic of Ireland, highlighting the significance of exploring cross-border phenomena in quantitative research.

The systematic review assessed 46 studies, with a predominant focus on agricultural producers: 34 studies concentrated exclusively on this group, emphasising the importance of understanding the practical applications and direct perceptions of intangible assets. Only two studies targeted sector experts, specifically in Brazil and Iran, conducted by DE MORAES et al. (2023) and KANIGOLZAR et al. (2013), respectively, providing specialised insights into intangible asset management.

Additionally, seven studies adopted an integrative approach by involving multiple actors within the agricultural sector, allowing for a more comprehensive exploration of intersectoral dynamics and their impact on innovation adoption. For instance, CULVER & CASTLE (2008) used government data to examine the influence of public policies in Canada. Meanwhile, studies such as KOZERA-KOWALSKA (2020) in YAKLAI et al. (2018) in Thailand analysed financial data and intellectual property management, respectively, demonstrating how intangible assets are managed and leveraged within diverse regulatory and economic contexts.

The geographical distribution of studies is presented in Figure 3. In North America—specifically the United States and Canada—four studies were identified, while South America recorded five, including research in Ecuador, Chile, Brazil, and

two in Peru, with notable works such as ALARCÓN & LEMA (2023), CAULFIELD et al. (2022), COFRÉ-BRAVO et al. (2019), DE MORAES et al. (2023), and JIMÉNEZ ALIAGA et al. (2023). Central America, while less represented with two studies, also contributes to understanding the influence of intangible assets on agricultural innovation.

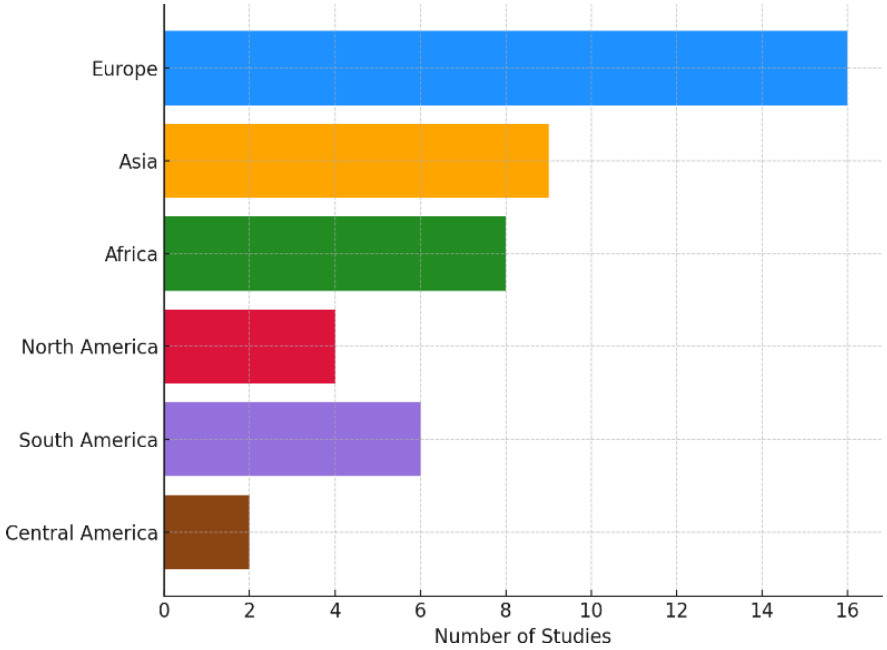

Figure 3. *Geographical distribution of articles.*

Although the search period spanned from 1992, the first empirical study included in this review was published in the year 2000, marking the starting point of scientific evidence on the relationship between intangible assets and innovation in the agricultural sector. This occurred despite the fact that conceptual and theoretical frameworks in this field had already begun to emerge during the 1990s.

In the following years, publication was sporadic, with only one article published in 2008 and another in 2011. As illustrated in Figure 4, the frequency then increased to two articles in 2012 and stabilized at three in 2015 and 2016. A rise was observed in 2018 with six studies, followed by steady output in 2019 and 2020 with three studies each year. The number of studies increased to five in 2021, peaked at nine in 2022, and remained consistent with seven publications in 2023, while only one study was identified in 2024.

This gradual increase likely reflects a growing academic interest in the topic, driven by technological advancements, the evolution of institutional frameworks, and global challenges that have underscored the strategic relevance of intangible assets in agricultural innovation.

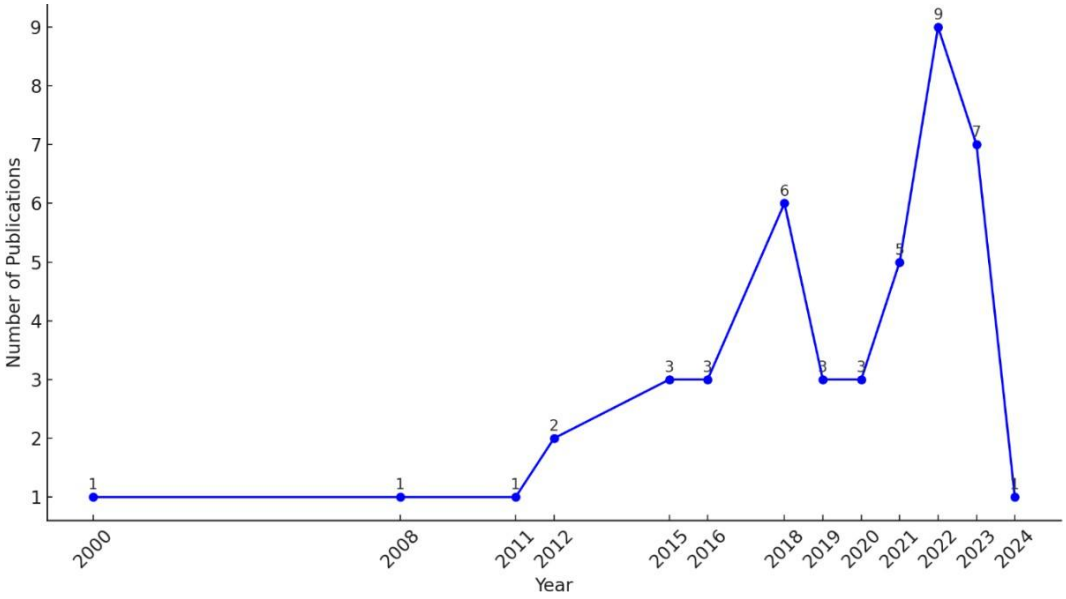

Figure 4. *Temporal evolution of publications on intangible assets in the agricultural sector (2000–2024).*

Intellectual capital and agricultural innovation

In our analysis of the literature in the agricultural sector, 11 studies were identified as incorporating the concept of intellectual capital. These studies primarily adopt the definitions and classifications proposed by EDVINSSON & SULLIVAN (1996) and BONTIS et al. (2000), emphasising the interaction among its three key components—human capital, structural capital, and relational capital—as fundamental for value creation and competitiveness (EDVINSSON & SULLIVAN 1996, BONTIS et al. 2000).

Human capital, reflected in the skills, knowledge, and abilities of workers, is consistently highlighted as a critical factor that enhances innovation and adaptability (EDVINSSON 2000). Structural capital, encompassing infrastructure, systems, policies, and internal procedures that enable operational efficiency and the implementation of innovations, is seen as essential. Here, process effectiveness is often as crucial as the quality of the final product (BONTIS et al. 2018).

Relational capital, which refers to managing relationships with stakeholders, is identified as a key determinant for accessing new markets and technologies, improving reputation, and building trust. The findings of our review reveal a geographical limitation in the coverage of IC studies, as they are exclusively conducted in Europe and Asia. Furthermore, of the 11 articles, only five studies comprehensively analyse all three components of intellectual capital.

Notable examples include CAVICCHI & VAGNONI (2018) and PAN et al. (2021), who highlight the synergistic interaction between human, relational, and structural capital. These studies demonstrate how the combination of technical skills and strategic collaborations, supported by adequate technological infrastructure, can enhance the adaptability and innovative capacity of agricultural organisations, particularly in the face of climate change and transitions towards sustainable agricultural practices.

The studies that integrate all three components also reflect how IC can serve as a foundation for tackling modern challenges, such as the Fourth Industrial Revolution and gender inclusion. These findings underline the necessity of a robust base of human and structural capital, complemented by relational capital, to thrive in rapidly evolving environments (SUGIARTO et al. 2019, MODAFFARI et al. 2023).

Human capital is consistently identified as a crucial pillar. Studies by CAVICCHI & VAGNONI (2018) and KOZERA-KOWALSKA (2020) underscore the importance of advanced technical skills and continuous training, particularly in areas such as precision agriculture. Human capital thus acts as a catalyst for adaptability to technological and regulatory changes, enhancing competitiveness and innovation. Structural capital is examined as a facilitator for knowledge management and efficient operations within agricultural enterprises.

KANIGOLZAR et al. (2013) and SUGIARTO et al. (2019) demonstrate that well-developed infrastructure enables better knowledge capture, storage, and transmission, leading to improved efficiency in agricultural knowledge management practices. Relational capital is highlighted in several studies, including those by PAN et al. (2021) and PAOLONI et al. (2022). These studies emphasise the role of relationships and networks in fostering knowledge exchange and resource access, facilitating innovation, and enhancing sustainability and resilience in agricultural enterprises. This component becomes particularly relevant during transitions towards more sustainable agricultural practices and the adoption of new technologies.

However, SÁENZ et al. (2023) point out that in organic agriculture, relational capital remains underdeveloped. It is important to note that while the components of intellectual capital significantly influence knowledge management, their direct impact on innovation may be conditioned by contextual and regulatory factors (YAKLAI et al. 2018).

Five studies (CAVICCHI & VAGNONI 2018, KANIGOLZAR et al. 2013, PAN et al. 2021, SUGIARTO et al. 2019, MODAFFARI et al. 2023) analyzed the joint interaction of the three components of intellectual capital in agricultural contexts. While CAVICCHI & VAGNONI (2018) and KANIGOLZAR et al. (2013) emphasize the articulating role of human capital in driving knowledge flows and strategically leveraging structural tools, PAN et al. (2021) demonstrate how these three assets converge in fostering green innovation through environmental commitment, relational cooperation around ecological practices, and the structural institutionalization of sustainable approaches.

SUGIARTO et al. (2019), in turn, highlight the mediating role of human capital between structural and relational capital, enabling the translation of organizational capabilities and collaborative ties into greater adaptability to technological challenges. Finally, MODAFFARI et al. (2023) underscore the synergy between human and relational capital to foster innovative ideas and reduce gender gaps, while structural capital acts as an enabler of business management.

Collectively, these studies show that the interaction among the three forms of capital is neither linear nor homogeneous, but rather manifests in complementary ways depending on organizational and territorial contexts, generating differentiated effects on innovation capacity—whether in terms of organizational resilience (SUGIARTO et

al. 2019), operational efficiency (KANIGOLZAR et al. 2013), environmental sustainability (PAN et al. 2021), or social inclusion (MODAFFARI et al. 2023).

Thus, innovation performance in agrarian systems does not rely on the isolated predominance of a single form of capital but on their contextualized interaction. This interaction adopts synergistic configurations that strengthen the dynamic capabilities of organizations: human capital operates as the articulating axis, mediating between organizational routines and external networks to translate knowledge into applied solutions (CAVICCHI & VAGNONI 2018); relational capital facilitates the mobilization and effective application of technical competencies through exchanges with key actors (PAN et al. 2021, SUGIARTO et al. 2019); and structural capital provides the organizational foundation that consolidates generated innovations (KANIGOLZAR et al. 2013, MODAFFARI et al. 2023). This integrative interpretation aligns with the systemic innovation approach, where effective responses in complex production systems emerge from dynamic combinations of intangible assets interacting with their organizational, institutional, and social environments (KLERKX et al. 2012).

Human Capital: Education and experience for agricultural innovation

In our review, 16 analysed articles apply the classical concepts of human capital, a theory developed by authors such as Schultz, Becker, and Mincer, who directly linked education and professional experience to improvements in individual productivity and economic growth.

SCHULTZ (1961) emphasised the importance of knowledge and health in worker productivity. Becker expanded on this idea, viewing education and training as economic investments that individuals assess against future costs and benefits.

The studies reviewed illustrate how formal education (O'DONOGHUE & HEANUE 2018), training in specific skills (JIMÉNEZ ALIAGA et al. 2023), and demographic characteristics influence the capacity of agricultural communities to adopt technologies and innovative practices. Human capital is recognised as an essential component for the acceptance of advanced agricultural technologies (KUVAEVA et al. 2019) and as a key catalyst for the adoption of innovations (XAYAVONG et al. 2016).

Investment in sector-specific training and development, as highlighted in the works of BAIYEGUNHI et al. (2023) and ALARCÓN & LEMA (2023), correlates positively with improvements in productivity and sustainability, underscoring education as a key tool for adopting new agricultural techniques. Specifically, formal education facilitates this process, with educated farmers often acting as pioneers in the adoption of innovations (O'DONOGHUE & HEANUE 2018).

Beyond technical training, the importance of soft skills and learning networks in fostering innovation is also emphasised. Research by GUNNARSSON (2021) and JIMÉNEZ ALIAGA et al. (2023) suggests that skills such as leadership, communication, and teamwork are crucial for effective management and for facilitating collaboration within agricultural value chains. These soft skills, combined with robust learning networks, allow farmers without formal education to actively participate in innovative processes, highlighting how informal learning and community support can complement formal education.

Additionally, access to resources, including financial resources, emerges as a determining factor for maximising the benefits of human capital in agriculture. As indicated by DE MORAES et al. (2023) and LI et al. (2022), without adequate investment in human capital and sufficient financial access, even the most skilled personnel may face significant limitations that hinder innovation and the effective implementation of new technologies.

Furthermore, factors such as language proficiency and organisational culture play a crucial role in the capacity to adopt advanced technologies. Findings by GODOY et al. (2000) and MICHEELS & GOW (2015) show how these variables can act as barriers or facilitators, depending on the specific context. They suggest that promoting bilingual education and fostering an inclusive organisational culture open to innovation could improve the adoption of modern agricultural practices.

Social Capital: Trust and cooperation as drivers of innovation in agriculture

The influence of social capital in the agricultural sector highlights its crucial role in the adoption of innovations and the improvement of cooperation and efficiency in agricultural practices. Robust social networks, trust, and reciprocity among farmers not only enhance creativity but also increase the propensity to take risks. HELIAWATY et al. (2020) and YILDIZTEKIN & EROL (2022) demonstrate that extensive social networks facilitate access to innovative information, while ALARCÓN & LEMA (2023) identify participation in associations as a positive predictor of adopting advanced agricultural techniques, underlining the role of social networks in fostering the dissemination of innovative knowledge.

Access to networks and the support of development agencies, as suggested by CAULFIELD et al. (2022), increase farmers' willingness to engage in participatory research, illustrating how social capital acts as a bridge between farmers and external resources. This finding is reinforced by studies like that of GONÇALVES et al. (2020), which show that social capital not only facilitates cooperation and knowledge exchange between producers and cooperatives but also promotes a mutual learning environment essential for rural development.

Authors like KELLY et al. (2021) and KOUTSOU & VOUNOUKI (2012) emphasise that network structures, trust, and reciprocity among farmers are essential for an environment that fosters continuous innovation. These dynamics not only enhance innovation within agri-food networks but also improve the efficiency and effectiveness of collective actions. In contrast, LEVY & LUBELL (2018) observe that, although well-connected networks and cooperation are fundamental for the rapid adoption of sustainable practices, excessive cohesion (CHARATSARI et al. 2020) or kinship among farmers (WOSSEN et al. 2015) can limit individual creativity and the adoption of innovative practices.

Additionally, DONKOR et al. (2018) argue that only the household head should be linked to social networks. Social capital has a significant impact on inclusion and equity in agricultural communities. DAVIES et al. (2018) document how strengthened social capital in innovation platforms has improved the inclusion of women in decision-making processes, fostering positive changes in cultural and gender norms. This outcome is complemented by GUNNARSSON (2021), who highlights how learning

networks, even among farmers without formal education, can overcome educational barriers and facilitate the adoption of new technologies.

Moreover, LANG et al. (2022) reinforce this perspective by noting that social capital also plays a crucial role in adaptation and resilience during times of crisis. Other studies, such as those by COFRÉ-BRAVO et al. (2019), MICHEELS & NOLAN (2016), and VECCHIO et al. (2022), discuss how different types of social capital, from family ties to connections with institutions, facilitate the adoption of technologies and innovative practices, underscoring the importance of a multifaceted approach to developing social capital. Social capital plays a crucial role in promoting agricultural innovation, especially among small-scale producers.

Increased social capital not only facilitates the dissemination of information but also fosters favourable attitudes toward innovation, accelerating its adoption (MUTYABA et al. 2024). In a similar context, SAINT VILLE et al. (2016) emphasise that for small producers, social capital is essential for enabling the flow of knowledge and innovation. This process is strengthened by mutual support among farmers, which, as noted by SHIBLI et al. (2021), plays a determining role in the adoption of technological innovations.

Furthermore, social capital enhances cooperation among farmers, facilitating the diffusion of advanced techniques (TEMPLE et al. 2011). However, to maximise its impact, relationships and networks must be strengthened, particularly in agricultural communities where these may be weak or underutilised (ZAINODDIN et al. 2018).

Table 1. Effects of social capital components on agricultural innovation.

Components of Social Capital	Impacts on Agricultural Innovation	Representative Studies
Trust	Facilitates the adoption of advanced technologies and promotes a collaborative environment	HELIAWATY et al. (2020), KELLY et al. (2021)
Social Networks	Drives knowledge dissemination and improves the efficiency of collective action	ALARCÓN & LEMA (2023), KOUTSOU & VOUNOUKI (2012)
Reciprocity	Fosters sustainability and resource exchange among key actors	DAVIES et al. (2018), GONÇALVES et al. (2020)

Interaction between intangible assets for agricultural innovation

An integrative framework is proposed that acknowledges the systemic, non-linear, and co-evolutionary nature of agricultural innovation, following the perspective developed by KLERKX et al. (2012). From this standpoint, innovation is not conceived as an individual or merely technological process, but rather as the outcome of dynamic interactions among multiple actors, structures, and forms of knowledge, all shaped by specific contextual conditions.

Within this framework, three distinct yet complementary conceptual dimensions are articulated: intellectual capital, classical human capital, and social capital. Intellectual capital is understood as an intangible asset of an organisational nature, comprising human, structural, and relational capital, whose integration enables the generation, systematisation, and mobilisation of knowledge. Meanwhile, the classical approach to human capital emphasises individuals' education, skills, and experience

as the foundation for productivity and learning. In turn, social capital encompasses networks of trust, shared norms, and relational structures that facilitate collective action, social learning, and serve as a foundation for collaborative innovation.

This approach enables the analysis of how these dimensions interact, giving rise to processes of organisational learning, local leadership, and participatory governance. The integrative framework summarises the key interactions among these components, highlighting their role in driving innovation.

The proposed integrative model allows for a visualisation of how these components interact, generating synergies aimed at fostering innovation and supporting its institutionalisation and scaling (Figure 5). This articulation is particularly relevant in the agricultural sector, where economic value has historically been linked to physical assets—such as land, water, and tools—while the development of intangible assets has been largely overlooked.

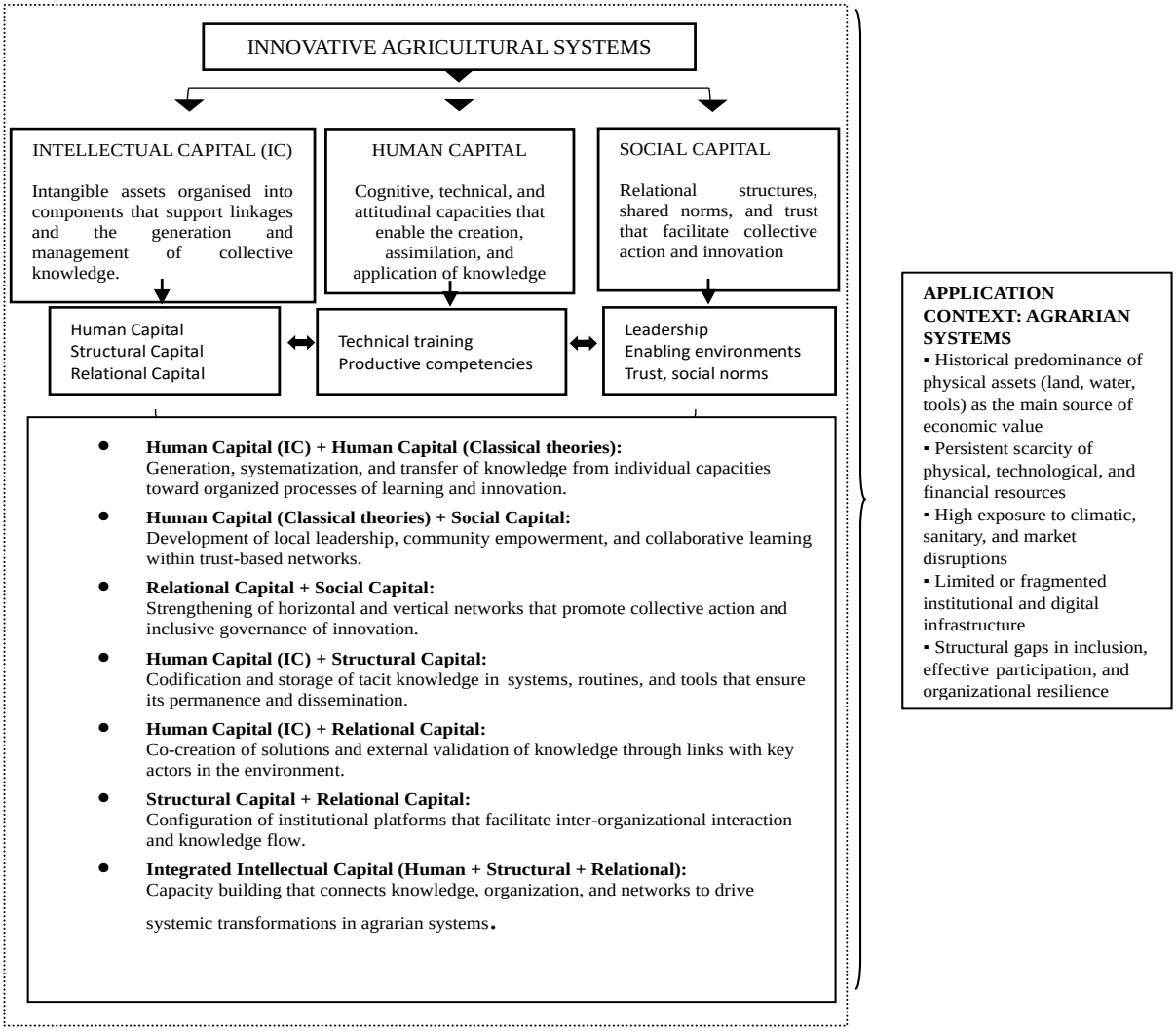

Figure 5. *Integrated framework.*

However, in the face of contemporary challenges—such as the scarcity of tangible resources, exposure to external shocks, and gaps in connectivity and inclusion—it is strategic to enhance intangible assets as key enablers of agricultural innovation.

DISCUSSION

The objective of this research was to analyse how intangible assets contribute to innovation in the agricultural sector. A systematic literature review spanning publications from 1992 to 2024 revealed an increasing interest in this topic over recent decades. While scientific output during the early years of the analysed period was relatively limited, a significant rise in studies addressing this subject has been observed in more recent years. This trend reflects a growing recognition of the critical role that intangible assets, particularly intellectual and social capital, play in addressing complex challenges within the agricultural sector, such as climate change, sustainability, and the need to meet the demands of a growing global population. This heightened attention underscores the importance of knowledge management and intangible assets as key drivers for fostering innovation and enhancing resilience in this vital industry.

The findings reaffirm the principles of classical theories of human capital, developed by SCHULTZ (1961) and BECKER (1964), which argue that investment in education and training increases individual productivity. Contemporary studies corroborate these principles, demonstrating that farmer training serves as a crucial catalyst for adopting agricultural innovations. Higher levels of education not only empower farmers to implement advanced techniques but also enhance the technical efficiency of their operations (MINVIEL et al. 2022). This dual benefit underscores the indispensable role of education in driving agricultural progress. Additionally, SAUER & LATACZ- LOHMANN (2015) contend that educational training fosters sustained efficiency gains derived from innovative agricultural processes. Evidence from developing countries further highlights the critical role of training and education as essential elements for adopting innovative technologies and practices (CAULFIELD et al. 2022, ALARCÓN & LEMA 2023).

The role of social capital in facilitating the diffusion and adoption of innovations is equally significant. Trust, networks, and collaboration among farmers serve as foundational mechanisms for exchanging knowledge and resources, fostering an environment conducive to collective action and shared learning. Social capital not only promotes the adoption of innovative practices but also supports the sustainable and collective management of natural resources, particularly in rural communities where mutual trust and support are essential (WESTERMANN et al. 2005). This dynamic underscores the importance of cohesive local networks in driving agricultural innovation, particularly in regions where community-based initiatives are the primary vehicles for implementing change.

However, the analysis reveals a critical gap: the absence of integrative frameworks that holistically address how the different components of intellectual capital—human, structural, and relational—interact to influence agricultural innovation. Most studies focus on individual components in isolation, overlooking the synergies that arise from their interconnection. This fragmented approach limits the development of comprehensive strategies capable of maximising the impact of intangible assets on the sector's innovation capacity. A systemic approach, as suggested by KLERKX et al. (2012), is essential for understanding the intricate interdependencies between these

components and fostering a more coordinated and impactful application of intellectual capital in agriculture.

The inherent characteristics of the agricultural sector further complicate the innovation process. Factors such as dependency on climatic conditions and market variability introduce significant uncertainty, necessitating not only technical innovations but also adaptive changes in management practices and social relationships. Resilience in agriculture, therefore, extends beyond technological advancements to include shifts in how knowledge is managed, shared, and applied within farming communities (DARNHOFER et al. 2016). This highlights the necessity of integrating social and relational dynamics into innovation strategies, recognising that the sector's unique challenges demand holistic solutions.

The results of the review highlight distinct yet complementary roles for social and relational capital in the adoption of innovations. Social capital, characterised by cohesion and reciprocity within local communities, is instrumental in facilitating knowledge exchange and fostering collaboration among farmers. This is particularly evident in geographically proximate regions, where trust and mutual support are readily established (COFRÉ-BRAVO et al. 2019). In contrast, relational capital operates on a broader scale, encompassing connections with external networks such as suppliers, distributors, and financial entities. These relationships provide farmers with access to resources and knowledge that extend beyond their immediate community, enabling the adoption of advanced technologies and the development of sustainable practices (PAOLONI & LOMBARDI 2022).

Relational capital is particularly relevant in contexts where integration into commercial networks expands opportunities for market access and financing. This facilitates the implementation of structured and scalable innovations, addressing challenges that require resources and expertise beyond those available locally. While social capital drives grassroots- level innovation and strengthens community cohesion, relational capital enables broader, market-oriented advancements.

CONCLUSION

The systematic review on the relationship between intangible assets and innovation in the agricultural sector demonstrates that these resources play a fundamental role in innovation and competitiveness. Although traditionally underutilised in this sector, intangible assets emerge as strategic elements to address sustainability challenges and meet increasing demands for productive efficiency.

Regarding intellectual capital, the analysed studies reveal that investment in human capital, , facilitates the adoption of advanced technologies and innovative agricultural practices, strengthening the sector's resilience to technological and market changes. Structural capital is also critical, as robust organisational infrastructure, with systems and knowledge management policies, enables efficient information transfer and improved operational performance. This not only drives individual productivity but also contributes to greater organisational cohesion, which is essential in the agricultural sector, where efficiency and adaptability are crucial. Additionally, relational capital highlights the importance of external networks and relationships, facilitating

access to markets and resources, and promoting effective collaboration among producers, suppliers, and other stakeholders.

Academic and technical training, combined with work experience and interpersonal skills, are essential for adopting agricultural innovations. These factors not only enhance the individual productivity of farmers but also contribute to the sector's sustained economic growth. Access to financial resources enhances the capacity of human capital to drive innovation, but barriers such as language and culture can limit human capital development. Therefore, promoting comprehensive training that encompasses both technical and soft skills can accelerate the adoption of agricultural innovations.

Social capital is an intangible asset that influences the adoption of innovations and improves cooperation in agricultural practices. Through social networks and trust among farmers, social capital not only fosters an environment conducive to creativity and risk-taking but also enhances access to and diffusion of innovation. Active participation in networks expands opportunities for farmers to engage in participatory research and adopt innovative technologies. Social capital also promotes a mutual learning and development environment. While network participation can be beneficial, it may also limit individual creativity. Moreover, it promotes equity by facilitating the participation of women in innovation processes.

However, the findings also suggest the need for an integrative framework that allows a holistic understanding of the role of these intangible assets in the agricultural sector. Implementing strategies that integrate the different components of intellectual and social capital could maximise their impact, improving not only the sector's competitiveness but also its long-term sustainability. This would provide a more comprehensive perspective on how these assets can foster innovation and development in the sector.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Cristian Sánchez and Marta Tostes; software and validation, Cristian Sánchez; investigation, Cristian Sánchez and Marta Tostes; resources and data curation, Cristian Sánchez; writing-original draft preparation, Cristian Sánchez; writing-review and editing, Marta Tostes; visualization, Cristian Sánchez; supervision, Marta Tostes; project administration, Cristian Sánchez; funding acquisition, none. All authors have read and agreed to the published version of the manuscript.

FUNDING

This work was not supported by any funding agency.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable for studies not involving humans or animals.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available under request.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the Pontificia Universidad Católica del Perú (PUCP) for providing the academic and institutional framework that made this research possible.

CONFLICTS OF INTEREST

There are no conflicts of interest to report.

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APPENDIX A

ID	Authors	Objectives	Continent	Human Capital	Relational Capital	Structural Capital	Human Capital (Classical theorie)	Social Capital
1	ALARCÓN & LEMA (2023)	This study analyzes how innovation adoption processes unfold in rice farming in Ecuador, focusing on four practices that enhance yields and improve natural resource manageme nt.	South America	Not mentioned	Not mentioned	Not mentioned	The study emphasizes that education, as a component of human capital, is essential to increase the adoption of innovative agricultural practices, enhancing productivity and sustainability.	The study finds that social capital, measured through association membership, positively influences the adoption of practices such as land leveling—highlighting the role of networks and social ties in facilitating innovation uptake.
2	HELIAWATY et al. (2020)	The paper investigates the extent to which social capital fosters innovative behavior among farmers in the Bantaeng region.	Asia	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Results indicate that strong social networks, mutual trust, and reciprocity among farmers significantly enhance creativity and risk-taking. Broad networks ease access to innovative information, while trust and reciprocity create a supportive context for trying out new practices.
3	BAIYEGUNHI et al. (2023)	An assessment is made of the causal relationship between human capital, innovation, and productivity on emerging sugarcane farms.	Africa	Not mentioned	Not mentioned	Not mentioned	On-the-job training expenditures are found to have a strong and positive effect on both innovation and productivity. This underscores the critical role of human capital development in improving	Not mentioned

							innovation capacity and farm performance.	
4	CAULFIELD et al. (2022)	Through a multi-site study, the research explores what drives or limits farmer participation in forage trials, emphasizing household and life-cycle factors to inform better participatory research design.	South America	Not mentioned	Not mentioned	Not mentioned	Families headed by younger individuals with higher education and more family members are more likely to participate, indicating that higher human capital improves readiness to adopt innovative techniques.	Farmers previously supported by development agencies and connected through social networks show greater engagement in participatory trials. These networks provide access to resources and build trust in collaborative innovation efforts.
5	CAVICCHI & VAGNONI (2018)	The aim is to understand how different forms of capital—human, structural, and relational—interact to support strategic management in agricultural firms under market and environmental uncertainty.	Europe	Skilled employees with expertise in precision agriculture and resource management contribute to competitiveness. Training in specialized skills enables adaptive responses to new technologies and regulations.	Collaboration with suppliers and participation in local/international networks foster knowledge exchange and innovation, strengthening firm resilience.	Technology infrastructure—particularly information systems and precision farming tools—supports decision-making and strategic adaptation.	Not mentioned	Not mentioned

6	CHARATSARI et al. 2020	Examine how social capital influences the co-creation of knowledge and innovation in farmer field schools	Europe	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital plays a critical role in the effectiveness of FFSs by enhancing communication, community cohesion, and collective engagement. Bonding and interpersonal ties positively influence knowledge and innovation co-creation, though excessive cohesion may hinder individual creativity and limit active involvement.
7	COFRÉ-BRAVO et al. 2019	Explore how farmers build support networks using bonding, bridging, and linking social capital for agricultural innovation	South America	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Farmers utilize bonding, bridging, and linking social capital to access knowledge, resources, and institutional support. A balanced use of these forms enhances their capacity to innovate.
8	DAVIES et al. 2018	Identify factors that contribute to the effectiveness of innovation platforms in relation to agricultural performance in West and Central Africa. The study analyzes variables in four categories (context, structure, conduct, and process) that interact	Africa	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital strengthens trust and collaboration within innovation platforms, facilitating value co-creation, conflict resolution, and inclusive decision-making. It also empowers members to access information and engage confidently in new production initiatives.

		to affect innovation platform performance and sustainability.						
9	DE MORAES et al. 2023	This study seeks to identify and analyze key barriers and enablers of innovation in alternative proteins in Brazil, aiming to inform public policies and industry practices that foster the development of innovative products and technologies in the context of circular economy and food sustainability.	South America	Not mentioned	Not mentioned	Not mentioned	Innovation in the alternative protein sector relies on both technical and soft skills, sector-specific knowledge, and an understanding of consumer behavior. While motivated and capable staff enhance product and process innovation, financial limitations remain a major barrier even for skilled teams.	Social capital facilitates innovation by fostering trust-based associations and collaborative networks that ease market barriers and promote knowledge exchange. While strong relationships among stakeholders drive innovation, trust deficits may impede effective collaboration.
10	DONKOR et al. (2018)	Examine the influence of different dimensions of social capital on farmers' adoption of agricultural innovations in Ghana.	Africa	Not mentioned	Not mentioned	Not mentioned	Not mentioned	The study reveals that bridging and linking social capital significantly promote innovation adoption among farmers, especially through access to extension services and external networks. Bonding capital, while strengthening trust within groups, may inhibit innovation if

								group norms discourage change.
11	GODOY et al. 2000	This study analyzes the determinants of agricultural technology adoption among the Tawahka people in Honduras, examining how human capital, wealth, and land tenure security affect adoption decisions, with the goal of designing policies that promote sustainable innovation and environmental conservation in rural areas.	Central America	Not mentioned	Not mentioned	Not mentioned	Formal education and Spanish fluency significantly enhance the adoption of modern agricultural technologies by improving farmers' ability to access, evaluate, and apply relevant information. Bilingual education emerges as a potential strategy to strengthen technology uptake and input use.	Not mentioned
12	GONÇALVES et al. 2020	Analyzes how rural enterprises and organizations foster innovation and smart development through the mobilization of local resources, the creation of collaborative networks, and the implementation of effective governance models aimed at	Europe	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital underpins innovation strategies and rural development by facilitating cooperation, knowledge exchange, and mutual learning among local actors. Trust-based networks enhance coordination and access to resources, serving as a key catalyst for innovation in rural contexts.

		revitalizing territorial production systems and promoting sustainable economic growth.						
13	GUNNARSSON 2021	Examines the role of supply contracts in fostering agricultural innovation among farmers in Gambia, emphasizing how these mechanisms, combined with social learning contexts, contribute to poverty reduction and the development of innovative capacities, while also assessing the conditions that influence the adoption of new agricultural technologies.	Africa	Not mentioned	Not mentioned	Not mentioned	Education and training are essential for enabling farmers to adopt new technologies and improve practices. Farmers who receive project-based training are more likely to innovate. Even those without formal education can benefit from integration into learning networks that provide access to knowledge and peer support.	Learning networks, as expressions of social capital, facilitate knowledge exchange and training access among farmers, accelerating innovation diffusion and supporting those with limited formal education. Trust-based collaboration with agribusinesses further enhances access to resources and technical assistance.
14	JIMÉNEZ ALIAGA et al. 2023	Evaluates the competencies and capacities of stakeholders involved in the guinea pig value chain in Jauja, Peru, with the purpose of identifying critical gaps in project management skills and designing innovative	South America	Not mentioned	Not mentioned	Not mentioned	Stakeholders demonstrated moderate project management skills, particularly in communication, leadership, and teamwork, underscoring the need for capacity-building to strengthen human capital and support rural initiative sustainability.	Not mentioned

		training strategies to support sustainable rural development.						
15	KANIGOLZAR et al. 2013	Investigates the impact of intellectual capital components—human, structural, and relational—on knowledge management among agricultural experts in Kurdistan, aiming to determine how each dimension influences the effectiveness of organizational knowledge practices.	Asia	Human capital demonstrates a strong positive association with knowledge management. The expertise and skills of agricultural professionals significantly enhance the organization's ability to manage and apply knowledge, contributing to innovation and competitiveness.	Relational capital facilitates collaboration and external networking, playing a crucial role in knowledge transfer and in securing resources that enhance innovation and organizational efficiency.	Structural capital—comprising systems, technologies, and organizational infrastructure—has a significant effect on knowledge practices, enabling effective knowledge capture, storage, and dissemination throughout the organization.	Not mentioned	Not mentioned

16	KELLY 2022	Examines the role of business support programs in enhancing social capital and promoting collaborative approaches in the agri-food and agricultural sectors, with a focus on how these initiatives can increase innovation capacity and knowledge exchange among farmers.	Europe	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital plays a vital role in agri-food support programs by facilitating trust, collaboration, and access to new knowledge and resources. Its bonding, bridging, and linking dimensions collectively strengthen support networks that enhance innovation capacity in the sector.
17	KELLY et al. 2021	Explores how business support programs and network-based interventions foster social capital and collaborative strategies within agri-food enterprises in Ireland, particularly within the context of Agricultural Knowledge and Innovation Systems (AKIS).	Europe	Not mentioned	Not mentioned	Not mentioned	Not mentioned	The study shows that social capital—particularly trust, reciprocity, and network structures—enhances innovation in agri-food networks by improving knowledge exchange, resource access, and collaborative capacity.

18	KOUTSOU & VOUNOUKI 2012	Seeks to understand the interplay between collective action and innovation in rural Greece, identifying whether the need for innovation drives farmers toward cooperation or if collective dynamics lead to innovation, while also analyzing the factors that influence farmers' willingness to engage in collective initiatives.	Europe	Not mentioned	Not mentioned	Not mentioned	Not mentioned	The study emphasizes that social capital—through trust-based networks and shared norms—plays a pivotal role in facilitating cooperation among farmers and driving innovation. It enhances the efficiency and impact of collective action by reducing complexity and uncertainty in agricultural settings.
19	KOZERA-KOWALSKA 2020	Aims to develop and validate the ISVA indicator as an alternative tool to assess the contribution of intellectual and physical capital to value creation in agricultural enterprises, while also demonstrating the role of intellectual capital in enhancing productivity and competitiveness.	Europe	Human capital is identified as the most efficient component of intellectual capital in Polish farms, significantly contributing to value creation. Despite a decline in physical capital efficiency, human capital showed an increase, reflecting the adaptability and skills of workers in transformi	Not mentioned	Structural capital efficiency in Polish agricultural enterprises remains low, despite investments in physical infrastructure and ICTs. This suggests underutilization of resources, highlighting the need to improve structural capital management to enhance its contribution to value generation.	Not mentioned	Not mentioned

				ng resources into measurable financial benefits for agricultural businesses.				
20	KUVAEVA et al. 2019	Investigates changes in perceptions of investment in agriculture within the knowledge economy context, focusing on how human capital facilitates innovation and technology adoption in the Russian region of Yekaterinburg.	Europe	Not mentioned	Not mentioned	Not mentioned	Human capital is critical for innovation in the knowledge economy, enhancing productivity and supporting the adoption of advanced technologies in agriculture.	Not mentioned
21	LANG et al. 2022	Examines the influence of social capital on agripreneurs' diversification intentions in emerging markets using the extended theory of planned behavior. The goal is to understand how social capital dimensions foster strategic diversification under dynamic market conditions.	Asia	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital, assessed through an integrated scale, positively affects diversification intent by enhancing access to resources and innovation. It emerges as a key resilience asset in times of crisis.

22	LEVY & LUBELL 2018	Aims to identify structural patterns in social networks among viticulturists in California and how these patterns support innovation diffusion, collaboration, and agroecological resilience under environmental change.	North America	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Centralized and well-connected networks promote innovation by enabling quick access to knowledge and practices. Intermediaries bridge structural holes and facilitate sustainable transitions.
23	LI et al. 2022	Seeks to evaluate how internal, external, and human capital factors shape the adoption of agricultural technologies in small farming enterprises in Ghana, while also proposing evidence-based policy recommendations.	Africa	Not mentioned	Not mentioned	Not mentioned	Higher education levels and younger age profiles enhance innovation propensity; larger households and greater access to resources also support implementation.	Not mentioned
24	MICHEELS & GOW 2015	Explores how market orientation, organizational learning, and innovation capacity contribute to farm performance, highlighting how managerial experience and age may affect responsiven	North America	Not mentioned	Not mentioned	Not mentioned	Experience and age influence adaptability to new practices. Less experienced managers show more openness to learning-driven change.	Social capital influences innovation capacity indirectly, and organizational culture may act as a critical moderator.

		ess to innovation.						
25	MICHEELS & NOLAN 2016	Analyzes the contribution of social capital, knowledge networks, and absorptive capacity to innovation adoption rates in grain and livestock farms across the Canadian Prairies, while accounting for farm-level characteristics.	North America	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Farms with stronger social networks are more likely to adopt innovations and modern agricultural practices.
26	MINVIEL et al. 2022	Assesses how synergistic agroecological innovations contribute to reconciling technical and environmental performance on farms, by incorporating contextual variables such as complementarity among practices.	Europe	Not mentioned	Not mentioned	Not mentioned	Training services and advisory support emerge as key drivers of agroecological adoption, empowering farmers to implement innovations that improve technical efficiency.	Not mentioned
27	MUTYABA et al. 2024	Investigates the drivers behind knowledge, attitudes, and perceptions of smallholder farmers in Uganda towards cage	Africa	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital enhances innovation adoption by facilitating knowledge sharing and fostering favorable attitudes toward novel aquaculture practices.

		aquaculture technologies.						
28	O'DONOGHUE & HEANUE 2018	Evaluates the impact of formal agricultural education on farm income and innovation pathways in Ireland.	Europe	Not mentioned	Not mentioned	Not mentioned	Formal education strengthens both technical and allocative efficiency, encouraging uptake of technologies and better management practices, especially in the dairy sector.	Not mentioned
29	PAN et al. 2021	Explores how green intellectual capital enhances the sustainable competitiveness of agricultural firms through innovation and environmentally responsible leadership.	Asia	Employees' environmental skills and commitment support the development of green products and processes, contributing to long-term innovation performance.	Encourages collaboration and resource sharing around ecological practices, reinforcing green innovation.	Promotes institutionalization of sustainable approaches that underpin competitive advantage.	Not mentioned	Not mentioned
30	PAOLONI & LOMBARDI 2022	Analyzes how relational capital contributes to innovation in women-led farming enterprises, particularly under challenging conditions.	Europe	Not mentioned	Strong personal and professional networks provide vital support for accessing resources and technical advice, playing a pivotal role in fostering innovation.	Not mentioned	Not mentioned	Not mentioned
31	PAOLONI et al. 2022	Examines how structural and relational capital contribute to the sustainability and resilience of agri-food enterprises	Europe	Not mentioned	Strategic partnerships, including those with universities, enhance innovation capacity by promoting adoption and optimization of technologies,	Improves operational efficiency and competitiveness, ensuring consistent production and cost reduction—vital for continuous	Not mentioned	Not mentioned

		in Italy during and beyond the COVID-19 pandemic.			improving resilience and adaptability to emerging challenges.	innovation in uncertain times.		
32	SÁENZ et al. 2023	Assesses the influence of external relational capital on product, process, and managerial innovation in Spanish organic agriculture, emphasizing its role in sustainable food production.	Europe	Not mentioned	Vertical relationships drive innovation across products, processes, and management. Horizontal ties and knowledge-intensive institutions support process innovation, while government collaboration fosters managerial improvements.	Not mentioned	Not mentioned	Not mentioned
33	SAINT VILLE et al. 2016	Explores the influence of social capital on knowledge flows and innovation among smallholder farmers in Caribbean communities (Saint Lucia).	Central America	Not explicitly addressed	Not explicitly addressed	Not explicitly addressed	Not mentioned	Network analysis reveals that bonding and bridging social capital influence self-reported innovation, facilitating knowledge exchange and adoption across communities.
34	SAUER & LATACZ-LOHMANN 2015	Analyzes how investment, productivity, and efficiency interact in German dairy farms, emphasizing the mediating role of education in innovation outcomes.	Europe	Not mentioned	Not mentioned	Not mentioned	Complementary education is necessary to realize the full potential of technological investments. Educational attainment proves essential for sustained efficiency gains through innovation.	Not mentioned
35	SHIBLI 2021	Investigates the interplay	Asia	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital—built on strong

		between social capital, extension services, and access to resources in driving the adoption of agricultural innovations in Malaysia.						networks and mutual farmer support—significantly enhances innovation uptake in rural contexts.
36	SUGIARTO et al. 2019	Identifies intellectual capital among livestock farmers and examines reinforcing factors to boost competitiveness and preparedness for Industry 4.0.	Asia	Human capital is key for enhancing overall intellectual capital and mediates the relationship between structural and relational capital, improving innovation capacity in livestock systems.	Relational capital enhances innovation capacity by supporting farmer adaptability and responsiveness to the opportunities and challenges of Industry 4.0.	Well-developed structural capital sustains operational efficiency and competitiveness in increasingly technological agricultural contexts.	Not mentioned	Not mentioned
37	TEMPLE et al. 2011	Examines how institutional and organizational innovations drive technical change in banana farming in Cameroon, assessing their influence on productivity and rural economic development.	Africa	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Social capital has played a critical role in accelerating innovation diffusion, enhancing adoption of advanced techniques, and reinforcing farmer collaboration.
38	VAN RIJN et al. 2012	Evaluates the impact of social capital dimensions—structural, cognitive, and linking—on innovation adoption	Africa	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Structural capital facilitates innovation uptake, whereas cognitive capital (shared norms and trust) tends to inhibit it.

		among smallholder African farmers.						
39	VECCHIO et al. 2022	Highlights the significance of social capital and network types in advancing sustainable innovation and multifunctional farming trajectories in Italy.	Europe	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Ambidextrous social capital, combining bonding, bridging, and linking ties, significantly enhances innovation capacity when all three forms coexist.
40	WOSSEN et al. 2015	Explores how different dimensions of social capital affect innovation adoption among farm households with varying levels of risk aversion.	Africa	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Variation in innovation adoption is linked to social capital types: linkages with authorities and collective networks support innovation, while kinship and funeral associations constrain it. Risk aversion modulates these effects.
41	XAYAVONG et al. 2016	Assesses the links between training, innovation, and farm performance in mixed-farming systems in Southwestern Australia.	Oceania	Not mentioned	Not mentioned	Not mentioned	Human capital serves as a key catalyst for improving farm outcomes through enhanced management and innovation uptake.	Not mentioned
42	XU et al. 2020	Examines the efficiency of intellectual capital and its role in supporting sustainable corporate growth in smart agriculture in China.	Asia	Executive human capital significantly enhances sustainable growth in high-tech firms, reflecting its relevance for innovation and	Not mentioned	Structural processes support daily operations but are not decisive for long-term innovation or growth in the context studied.	Not mentioned	Not mentioned

				market adaptation. In contrast, non-executive roles show no significant effect, suggesting that automated operations in modern farming reduce dependence on human input.				
43	YAKLAI et al. 2018	Explores how intellectual capital, knowledge management, and business context influence innovation in Thailand's food industry.	Asia	Although intellectual capital improves knowledge management, it has no direct effect on innovation. Its impact may be moderated by contextual variables such as corporate environment and IP regulations.	Not mentioned	Although intellectual capital improves knowledge management, it has no direct effect on innovation. Its impact may be moderated by contextual variables such as corporate environment and IP regulations.	Not mentioned	Not mentioned
44	YILDIZTEKIN & EROL 2022	Evaluates the role of human capital, social relations, and regional capacity in advancing sustainable agricultural practices in Izmir, Turkey.	Europe	Not mentioned	Not mentioned	Not mentioned	Human capital, enriched by education and social engagement, plays a pivotal role in fostering the adoption of sustainable farming.	Strong and diverse social networks, underpinned by robust social capital, drive innovation diffusion and support sustainable practices.
45	ZAINODDIN et al. 2018	Assesses the impact of social capital—structural, relational, and	Asia	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Only structural social capital significantly supports innovation development; relational and

		cognitive—on innovation among farmers in community-based projects in Malaysia.						cognitive dimensions show no statistically relevant influence.
46	MODAFFARI et al. 2023	Investigates how intellectual capital supports innovation in women-led agricultural start-ups, emphasizing the relational dimension.	Europe	Human capital enhances innovation by stimulating idea generation and enabling access to external knowledge.	Relational capital is vital for developing innovative start-ups, improving business operations, and closing gender-related financial gaps.	Structural capital facilitates business management and helps reduce gender-based financial disparities.	Not mentioned	Not mentioned