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Information Taxonomy and Value Proposition Map to Enhance Value Flow and Digital Technology Adoption among Smallholder Farmers

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Abstract

Small-scale farmers face barriers in adopting digital agri-food technologies due to unclear value propositions and the difficulty of calculating individual return on investment within agriculture's inherently probabilistic production environment. This results in unsustainable business models for digital technology providers. The key challenge lies in coupling probabilistic agricultural production with deterministic supply chains. This study investigates how clear value propositions for digital farmer-to-business (F2B) agri-food technologies can be designed by explicitly linking enhanced information flows to market parameters such as perceived value, opportunity cost, and transaction costs. Using a Design Science Research (DSR) methodology, the study develops and validates an information taxonomy, grouped into the broader categories of plumbing and trust flow, which classifies information flows across five key dimensions: material flow, money flow, knowledge exchange, trust in the party, and trust in the ability. Information taxonomy is derived from theoretical models, stakeholder engagements, and analysis of eight digital F2B platforms. A value proposition map is then constructed to demonstrate how digital technologies can reduce transaction costs, lower opportunity costs, and increase perceived value. The findings emphasize that while material and money flows are essential, the integration of knowledge exchange and, critically, trust flows is crucial to reducing search costs and mitigating opportunistic behavior. Furthermore, plumbing and trust flow form the foundation for enabling value flow; however, to sustain it, value realization must occur on the deterministic side of the market, where enhanced information flows can convert probabilistic agricultural production into measurable returns on investment. This study provides a roadmap for digital technology providers to develop clear value propositions and develop sustainable business models that support broader adoption of digital technologies in the agri-food sector.

Categories: Digital business, Sustainability in Supply Chain Management, Innovation Economics
Keywords: value proposition, business models, digital agri-food technologies, value flow, information taxonomy, transaction cost, trust flow, digital adoption

Introduction

Small-scale farmers face persistent barriers in adopting digital agri-food technologies, due to unclear value propositions, and the specific benefits that these technologies are expected to deliver (Cook et al., 2021), (Hansen et al., 2022), (Puntel et al., 2022), and (Shepherd et al., 2018). Clear value propositions are essential, as investment in digital technologies is often evaluated based on the expected return on investment (Pfister and Lehmann, 2022). However, agriculture's inherently probabilistic nature, shaped by weather variability, pest outbreaks, perishability, and quality inconsistencies (Behzadi et al., 2018) (Sporleder and Boland, 2011), makes it difficult to reliably estimate the return on investment at the individual farm level. This uncertainty hampers the ability of technology providers to build sustainable business models. Instead, evaluating digital technology impacts at the cluster level, where patterns across multiple farms emerge, provides more reliable insights, highlighting the need for a shift from an individual to a systems view of digital agriculture adoption.

This challenge is compounded by the structure of the agri-food system, which consists of multiple interconnected subsystems, including input supply, agricultural production, processing, distribution, retail, and consumption (Nguyen, 2018) as shown in Figure *1*. While many of these subsystems are undergoing digital transformation successfully, the agricultural production remains under-digitized (Duric, 2020) due to its biological complexity and probabilistic nature. In contrast, supply chains operate more deterministically and are thus more receptive to digital coordination and investment. This asymmetry creates a coupling challenge at the market interface, where uncertain agricultural production must align with structured, deterministic supply chains. Since value realization typically occurs on the deterministic side, this is also where value propositions can be most effectively converted into return on investment. Digital platform providers are uniquely positioned to address this gap by operating within the

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probabilistic production environment while using data to create and capture value downstream in the deterministic system.

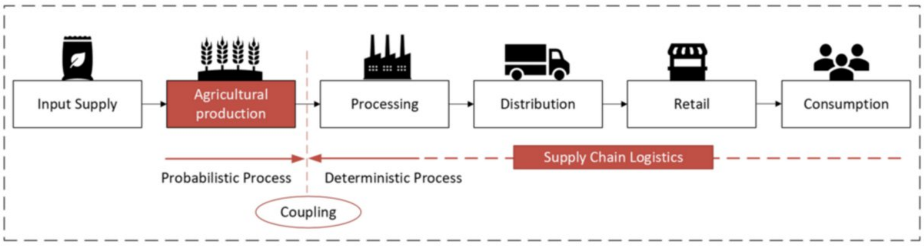

FIGURE 1: Agri-food System and the Coupling of Probabilistic and Deterministic Processes

Authors' own illustration

Although despite the proliferation of digital agri-food platforms offering advisory services and market insights for cultivation, many smallholder farmers remain hesitant to pay for such services unless the value is immediate and tangible (Abate et al., 2023) (Mazwane et al., 2022). This hesitation reveals fundamental barriers to value exchange within the probabilistic domain. One potential solution lies in digital marketplaces, online intermediaries that collect, process, and disseminate information between buyers and sellers to facilitate transactions (Pavlou and Gefen, 2004). In the agri-food sector, marketplaces typically operate under two models: farmer-to-consumer (F2C) and farmer-to-business (F2B). While F2C models eliminate intermediaries and reduce transaction costs, the essential functions performed by intermediaries such as bulk procurement, logistics, storage, and management of post-harvest losses cannot be fully removed from the market system (Canavari et al., 2010) (Delfmann et al., 2002). Small-scale farmers often lack the capacity to manage these functions independently. In contrast, F2B platforms, which connect farmers directly with bulk buyers, hold a comparative advantage by coordinating such services efficiently, offering clearer economic returns, and improving market efficiency.

Digital platforms thus serve as infrastructure enablers that bridge probabilistic agricultural production and deterministic supply chains. They do this by facilitating the smooth movement of material flow, money flow, and knowledge exchange, a function we metaphorically refer to as "plumbing," or more formally, digital infrastructure coordination mechanisms. However, the differing characteristics of the two systems also create space for opportunistic behavior of the stakeholders. In response, building “trust flow” through mechanisms such as reputation systems, traceability, and digital identities is essential for reducing risk and encouraging repeated interactions. Together, plumbing and trust flow form the digital foundation for enabling value flow within agri-food systems, strengthening market coordination at the harvest-sale interface.

To examine how digital technologies influence this value flow, this study focuses on three interrelated market parameters: perceived value, opportunity cost and transaction cost, to understand how digital technologies affect market mechanisms (Bowman and Ambrosini, 2000), (Lepak et al., 2007), (Moran and Ghoshal, 1996), and (Stoelhorst, 2023). Perceived value reflects the buyer's maximum willingness to pay, while opportunity cost reflects the seller's minimum willingness to accept. The exchange value is often eroded by transaction costs, including search, negotiation, monitoring, and logistics. Digital technologies, however, have the potential to reconfigure value flows in market by reducing opportunity costs, enhancing perceived value, and minimizing transaction costs, thereby encouraging a more frictionless environment for exchange.

In this context, digital technologies, encompassing electronic devices integrated with digital data and software systems, enhance the flow of information (Schroeder et al., 2021). This study builds an information taxonomy and a value proposition map to systematically link these enhanced information flows to the key market parameters: perceived value, opportunity cost, and transaction costs. In information systems research, taxonomies are designed artifacts used to analyze complex domains and guide the development of digital solutions (Lösser et al., 2019) (Nickerson et al., 2013). By mapping information flows to market parameters, this study provides a roadmap for creating clear value propositions and sustainable business models to adopt digital agri-food technologies.

Accordingly, this study is guided by the central research question: How can clear value propositions for digital agri-food technologies be designed by explicitly linking enhanced information flows to market parameters such as perceived value, opportunity cost, and transaction costs?

The remainder of this paper reviews the relevant literature and theoretical frameworks, outlines the design science research methodology, presents the information taxonomy alongside the value proposition map, discusses the findings in depth, and concludes with key implications and future research directions.

Literature review

Value Flow Market Model

Value flow in a market depends on facilitating value exchange, encompassing resources, materials, money, and knowledge. Value exchange occurs when created value materializes in transactions driven by buyers' subjective perceptions (Lepak et al., 2007), and exchange is the primary mechanism through which perceived value is realized (Moran and Ghoshal, 1996). In practical terms, exchange occurs when the perceived value of a product or service exceeds the combined burden of transaction costs (such as time, effort, and money spent acquiring it) and the opportunity cost, defined as the value of the next best alternative forgone by the seller in allocating their resources (Stoelhorst, 2023). When perceived value falls short of the opportunity cost, transactions may fail to materialize due to an inherent mismatch in value expectations. Consequently, exchange value is influenced by the buyer's perceived value and the seller's opportunity cost, with transaction costs, such as search, negotiation, and administrative fees, further eroding the exchange value. Within the agri-food domain, these transaction costs are especially impactful at the procurement stage, spanning from the farm gate to intermediary buyers' warehouses (Figure 2). Alongside search costs, logistics and quality assurance substantially shape the overall value exchange. A mutually acceptable price must exceed the seller's combined threshold of opportunity cost and transaction cost but remain below the buyer's perceived value.

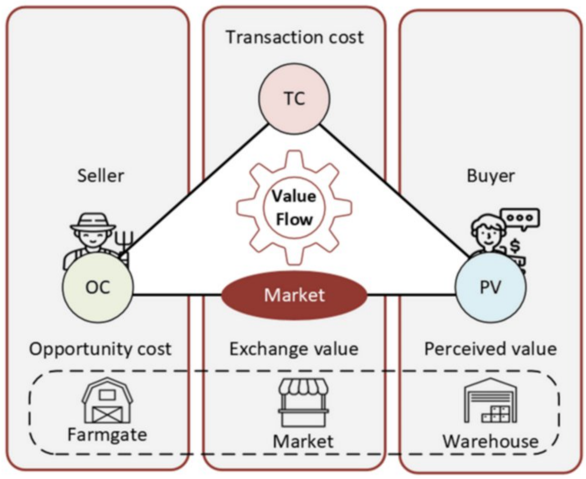

FIGURE 2: Value Flow Market Model

Authors' own illustration. TC, transaction cost; OC, opportunity cost; PV, perceived value

While digital technologies have the potential to reduce transaction costs and clarify perceived value, there is limited understanding of how they specifically influence value exchange mechanisms in agri-food systems, especially for smallholder farmers. This underscores a critical gap in existing research.

Transaction Cost Economics

Transaction cost economics (TCE) provides a valuable lens for analyzing the frictions that impede efficient exchange. The foundation of TCE originates from Ronald Coase, who argued that economic exchanges are organized through market mechanisms until the cost of using the market exceeds the cost of internal coordination within firms (Coase, 1937). These costs, later formalized by Oliver Williamson, are now widely recognized as transaction costs, the expenses incurred when coordinating, monitoring, and enforcing economic exchanges (Williamson, 1975), (Williamson, 1985), and (Williamson, 1996). Transaction costs are influenced by several key factors such as transaction frequency, asset specificity, uncertainty, limited rationality, and opportunistic behavior (Williamson, 1996). Effective governance structures are therefore critical in mitigating opportunism and reducing these costs, which makes the principles of TCE highly applicable to digital marketplaces, where platform-based coordination can streamline exchange processes (Sussan and Acs, 2017).

Over time, scholars have expanded the definition and scope of transaction costs, especially within agricultural markets where such costs are intensified due to perishability, dispersed production, and information asymmetries (Cuevas, 2014). Eggertsson (Eggertsson, 1990) broadly defines transaction costs as the expenses associated with transferring and enforcing ownership rights over economic assets, encompassing activities such as information search, negotiation, contracting, and enforcement. Hobbs (Hobbs, 1997) offers a detailed categorization within agricultural contexts: information costs arise ex-ante and involve identifying trading partners and obtaining relevant market data; negotiation costs occur during the transaction and include expenses related to bargaining, commissions, and formalizing agreements; and monitoring or enforcement costs are ex-post, covering efforts to ensure compliance with agreed terms, such as quality verification, payment enforcement, and dispute resolution. Building on this foundation, further contributions have identified additional categories relevant to agri-food systems. These include transportation and handling costs, the costs of physically moving goods, coordinating logistics, and managing losses due to spoilage or delays (De Silva and Ratnadiwakara, 2008), (Hobbs, 1997), (Key et al., 2000) and trust establishment costs, which relate to screening and verifying the credibility of unknown trading partners, often via third-party certifications, ratings, or digital trust mechanisms (Holloway et al., 2000) (Key et al., 2000). Taken together, these six categories, information and search costs, negotiation and bargaining costs, monitoring costs, enforcement costs, transportation and handling costs, and trust establishment costs capture the multidimensional frictions that prevent efficient exchange in agri-food markets. These categories also offer a foundation for analytically modeling transaction costs in such contexts.

Despite this potential, the specific application of TCE principles within digital agri-food technologies integrated with farmer-to-business (F2B) marketplaces remains largely underexplored. Existing literature does not sufficiently demonstrate how digital information flows systematically reduce transaction costs or how such platforms can explicitly communicate and deliver added value. Addressing this gap is essential for understanding the economic incentives that can drive the adoption and sustainability of digital solutions in the agriculture sector.

Building Trust in Digital Agri-food Marketplaces

Uncertainty is a central determinant of transaction costs, arising from two primary sources: environmental uncertainty such as unpredictable weather or volatile markets and behavioral uncertainty, which reflects the difficulty of anticipating the actions of exchange partners (Williamson, 1996). In the agri-food domain, biological variability, perishability, and fragmented trading systems intensify these risks. Given that opportunistic behavior is difficult to detect in advance and contracts are often incomplete or costly to enforce, trust emerges as a critical governance mechanism for facilitating transactions under such uncertain conditions. Trust reduces transaction costs by serving as a substitute for formal control in contexts where enforcement is impractical.

Trust has evolved significantly over time, shifting from local trust built through personal relationships, to institutional trust enforced by third parties such as cooperatives or regulators, and now toward digital or distributed trust mediated by technology (Botsman, 2017). In digital marketplaces, trust is increasingly established through platform-based mechanisms such as peer reviews, ratings, reputation scores, and transaction histories (Botsman, 2017) (Pavlou and Gefen, 2004). These mechanisms are especially important in agri-food platforms, where farmers and buyers often lack prior relationships and must navigate uncertainties related to product quality, payment reliability, and delivery performance.

Trust in digital marketplaces can be established through both physical and digital mechanisms. Physical trust, developed through in-person interactions, agents, or on-ground presence, remains valuable, particularly for building early-stage confidence. However, physical trust faces scalability challenges in dispersed agricultural settings. In contrast, digital trust mechanisms such as digital identities, transaction histories, certification systems, and traceability tools offer scalable solutions that can adapt quickly to market changes and support broader participation without requiring heavy infrastructure investments.

Tan and Thoen (Tan and Theon, 2002) propose that a user's willingness to engage in a transaction depends on whether their overall trust in the transaction exceeds a personal threshold. This trust is composed of two elements: trust in the party and trust in the ability. Trust in a party refers to confidence in the other party based on expectations of their actions and the reliability of the information. This trust can be based on reputation, past interactions, personal connections, or the perceived reliability and integrity of the entity. On the other hand, trust in ability refers to the confidence in the ability to meet the contract. This trust is enhanced by the effectiveness of formal mechanisms such as rules, protocols, certification systems, and platform procedures to mitigate risk and prevent opportunistic behavior. When party trust is lacking, these control mechanisms become essential to enable the transaction.

Thus, building trust, either in the counterparty or in the platform's governance mechanisms, is critical to reducing uncertainty and ensuring successful digital transactions. Trust is essential in agri-food exchanges along the value chain, and its absence or inadequacy can hinder the development of effective electronic relationships (Canavari et al., 2010). However, the literature has not fully explored how the dual dimensions of trust, trust in the party and trust in the ability, systematically influence value flows within the agri-food domain, particularly in emerging F2B digital marketplaces.

While existing studies in transaction cost economics and trust mechanisms offer valuable insights, they often lack a structured framework, specific to agri-food domain that classifies the information flows necessary to enhance value flow. Addressing these gaps, the present research proposes an information taxonomy and value proposition map that clarifies how information flows lower transaction costs, lower opportunity costs and enhances perceived value to boost value flows in the agriculture domain, leading to increased adoption of digital agri-food technologies.

Research Method

Design science research

Design Science Research (DSR) address real-world problems through the creation of innovative artifacts, thus contributing new scientific knowledge (Hevner and Chatterjee, 2010) (Peffers et al., 2007). The DSR methodology is structured around three iterative cycles, relevance, rigor and design, that guide both artifact development and evaluation (Hevner et al., 2004). This study applies DSR to address a real-world problem by creating innovative artifacts: an information taxonomy. The DSR methodology is typically structured around three interrelated cycles relevance, rigor, and design, which guide both the development and evaluation of the artifact. Figure *3* presents an adapted version of the DSR framework, customized to reflect the specific research activities and context of this study. Rather than depicting the generic DSR model, this version illustrates how the core DSR cycles have been operationalized to guide the construction of the information taxonomy and value proposition map.

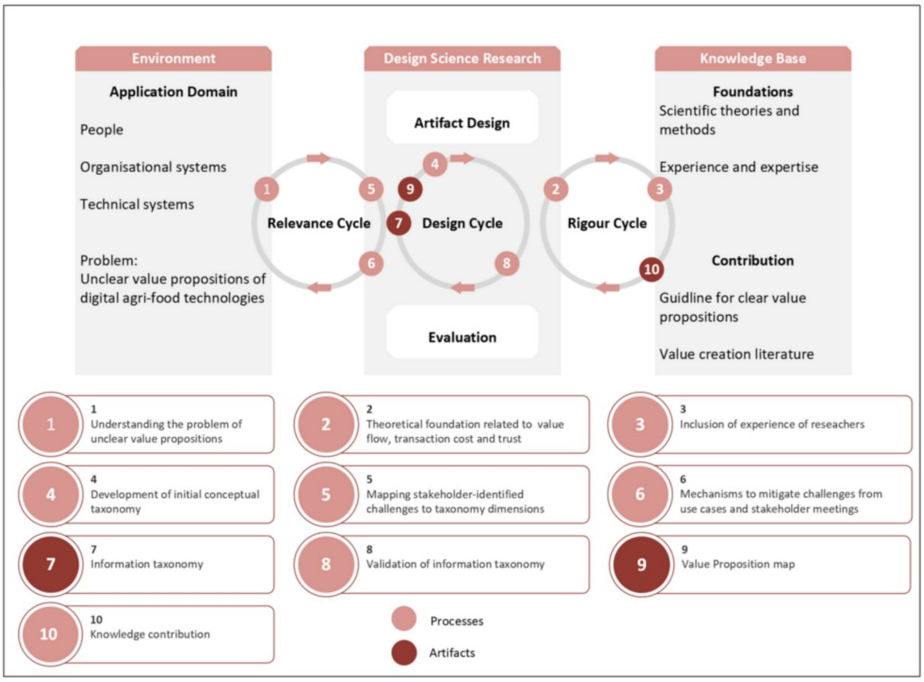

FIGURE 3: Design Science Framework of the Study

Authors' own illustration

The relevance cycle establishes the research's connection with the real-world environment by identifying the application domain, including people, organizational systems, and technical systems and focuses on identifying real-world problems and setting the criteria for evaluating research outcomes in practical contexts (Hevner et al., 2004). In this study, the relevance cycle initially involved identifying key challenges related to the adoption of digital agri-food technologies. Specifically, it addresses the issue of unclear value propositions that hinder the widespread adoption of digital agri-food technologies.

The rigor cycle ensures the scientific robustness of the research by integrating established theories, methods, and literature and contributes to the advancement of the knowledge base (Gregor and Hevner, 2013) (Peffers, 2007). This study is underpinned by a comprehensive review of published literature, drawing on the value flow market model, transaction cost economics, and trust mechanism. Integrating this scholarly knowledge with practical insights not only strengthens the theoretical foundation but also informs the initial design of the information taxonomy. Additionally, the expertise and experiences of researchers in agriculture and digital platform development further enrich the analytical framework.

The design cycle involves creating and iteratively evaluating the artifact, drawing on the requirements identified in the relevance cycle and insights from the rigor cycle (Peffers et al., 2007). To address barriers to the adoption of digital agri-food technologies, particularly unclear value propositions identified in the relevance cycle, this study contributes new knowledge through the development of a structured information taxonomy and value proposition map as design artifacts. The taxonomy is a clear framework for understanding information flows (Nickerson et al., 2013). Within F2B marketplaces, taxonomies are essential for designing effective digital platforms that meet the needs of farmers and other stakeholders. The design cycle also involves validating the taxonomy by applying it to understand information flows within the selected use cases, ensuring that it meets the identified needs of the stakeholders (Kuechler and Vaishnavi, 2012).

Data collection and analysis in DSR

Following the DSR methodology, this study progressed through a structured sequence of conceptual development and validation activities. First, the researchers developed a conceptual taxonomy by synthesizing key theories and market models relevant to F2B digital agri-food marketplaces. This taxonomy defines core dimensions essential for structuring F2B platforms.

During the relevance cycle, the research team attended stakeholder meetings focused on the development of an F2B digital agri-food marketplace. To identify stakeholder challenges, data were collected through participant observation of these meetings, convened via Zoom by an agri-food digital-technology provider that granted access to support our research objectives. The stakeholder cohort comprised a digital technology solution provider, intermediary bulk-harvest buyers and their on-the-ground operations teams, smallholder farmers, and industrial policymakers, all integral to the design, deployment, and regulation of digital platforms in the agri-food sector. Observing their real-time discussions on platform design and adoption yielded critical insights into the practical barriers farmers and intermediary buyers face when engaging with these solutions. These challenges were then systematically mapped onto the dimensions of the developed conceptual information taxonomy.

To design mechanisms to mitigate the identified challenges, the research team further examined both the stakeholder meeting discussions and the insights drawn from eight real-world use cases of F2B digital platforms operating in India, Sri Lanka, and South Africa. This dual-source approach ensured that proposed mitigation strategies were grounded in both stakeholder perspectives and practical platform experiences. Some platforms remained operational, while others were inactive at the time of data collection. The research team gathered data from diverse sources, including on-hand platform testing, website content, app stores, social media, and news articles. In this study, we focused on front-end or user-facing aspects, such as mobile apps and web portals, rather than backend processes like software updates or data aggregation, which are often inaccessible (Bhaskara and Bawa, 2021).

Subsequently, the study focused on identifying the information flows critical for supporting material flow, money flow, knowledge exchange, and trust flow between farmers and buyers. These flows were then structured into an information taxonomy, which aligns platform functionalities with stakeholder needs. To validate the conceptual and information taxonomies, the research team conducted an in-depth analysis of the eight selected use cases.

Building on the taxonomy, the research further developed a value proposition map linking information flow with key market parameters. By clarifying how each stakeholder gains value, this mapping process highlights potential areas for improving platform design. Ultimately, this approach ensures guidance for digital technology providers to create clear value propositions for participants, increasing adoption and sustained usage.

Use cases: digital agri-food technologies integrated with F2B harvest selling marketplace

To contextualize and validate the research, eight F2B use cases were analyzed. These digital agri-food platforms act as intermediaries, coordinating logistics, aggregation, communication, and transactions between farmers and buyers. This study focuses on F2B marketplaces that directly link small-scale farmers to bulk buyers, such as wholesalers, retailers, institutional buyers, processors, and exporters. Below is an overview of eight prominent F2B platforms from Asia and Africa, each illustrating varied operational models.

Electronic National Agriculture Market (e-NAM), India: Launched in 2016 by the Indian government, e-NAM digitally integrates multiple Agricultural Produce Marketing Committees into a unified online auction platform for agricultural commodities. Its core objectives include enhanced price discovery, reduced transaction costs, and competitive pricing for farmers (Balkrishna et al., 2024) (Singh and Kolar, 2024).

KrishiHub, India: Founded in 2016, KrishiHub targets improvements in farming productivity through technology, data science, and user-centered design. The platform operates an online marketplace, KrishiHub Store, connecting farmers directly with institutional buyers such as restaurants, canteens, and hostels. Although it initially aimed to remove intermediaries, improve farmer incomes, and optimize the supply chain (Gummagolmath et al., 2021), the platform is currently inactive.

DeHaat, India: DeHaat delivers a “360-degree” seed to market digital solution that empowers farmers across India by integrating physical centers and technology. It offers a wide range of services, including farm input procurement, crop advisory, and market linkage, eliminating intermediaries and ensuring better prices for farmers. By partnering with local retailers and micro-entrepreneurs, DeHaat improves efficiency in the agricultural value chain, fostering a transparent, sustainable ecosystem for both farmers and buyers (Sinha and Jha, 2019).

Khula, South Africa: Khula offers a Produce Trader app, as a part of its platform, aimed at facilitating the sourcing, trading and contracting of fresh fruits and vegetables. It directly links farmers with buyers to trade fresh produce aiming to create a more efficient and transparent agriculture supply chain. By integrating various services, Khula assists farmers in adopting sustainable practices and streamlining their operations (Morepje et al., 2024).

FarmSell, Africa: FarmSell focuses on connecting farmers with bulk buyers (F2B), including retailers, processors, and exporters, across Africa. Since its 2023 redevelopment, it has emphasized features that enhance market access for fresh produce, promoting transparency and fair pricing. It also aims to eliminate middlemen and improve transaction efficiency (https://farmsell.org/).

HelloChoice, South Africa: HelloChoice offers a digital marketplace linking farmers with bulk buyers, such as restaurants and retailers, aiming for an efficient and transparent supply chain, enabling farmers to secure better prices for their produce. By providing information and instruction on effective agricultural methods, the platform promotes sustainable practices (Morepje et al., 2024).

Govipola F2B Marketplace, Sri Lanka: Govipola offered a digital marketplace for the Sri Lankan farming community, facilitating the procurement of agricultural commodities and services. Govipola rolled out its marketplace in 2020, but it is no longer active. The app was specifically developed to benefit farmers as well as buyers by creating price transparency and helping them buy and sell their produce in a more convenient way (Kumarathunga et al., 2020) (SLEvA, 2022).

Helaviru Digital Economic Centre, Sri Lanka: Helaviru is a digital marketplace launched in 2021, designed to facilitate direct trading of agro-produce and commodities. It aims to connect farmers directly with various bulk buyers. The platform seeks to provide farmers with fair prices, reduce post-harvest losses, and improve market access through digital technology (Jayalath et al., 2024) (SLEvA, 2022). Despite its potential to transform agri-food trading, the platform is no longer active.

These platforms varied in design, functionality, and market engagement strategies. Some, like e-NAM and DeHaat, demonstrated scalable, integrated solutions. Others, like KrishiHub, Helaviru, and Govipola faced sustainability issues. Platforms such as Khula, HelloChoice, and FarmSell illustrated innovation in real-time trading and logistics. The diverse experiences of these platforms helped refine both the taxonomy and the value proposition map by showing what works in practice, what challenges persist, and how digital tools can bridge the gap between farmers and bulk buyers.

Results

Conceptual information taxonomy

In agri-food systems, the harvest sale interface acts as the coupling point between two fundamentally different processes: the probabilistic cultivation system, characterized by biological variability and uncertainty, and the deterministic supply chain, governed by logistics and planning predictability. Bridging these systems requires digital platforms to not only coordinate transactions but also reduce uncertainty and opportunistic behaviors that undermine market efficiency.

This coordination is achieved through two foundational enablers: plumbing and trust flow. In this study, we use the term “plumbing” as a metaphor to describe the core transactional channels that enable material flow, money flow, and knowledge exchange within digital agri-food platforms. Similar to how physical plumbing facilitates the reliable flow of water, digital “plumbing” refers to the infrastructural systems, such as logistics networks, payment gateways, and data management tools, which support the execution of exchanges. While metaphorical, the term is consistently used throughout the paper to represent the essential enabling mechanisms that underpin value flow in platform-based transactions. Trust flow, on the other hand, encompasses mechanisms that build and sustain confidence among users.

While trust often begins through informal, face-to-face relationships or community validation, it can be translated into the digital domain through user reviews, ratings, and verified transaction histories and then amplified to enable broader, scalable exchanges on digital platforms. By combining plumbing and trust flow, digital platforms can enable smoother value realization at the harvest sale interface.

Figure 4 illustrates the core information flows that underpin marketplace transactions. Material flow involves the physical transfer of produce from sellers to buyers, while money flow occurs in the opposite direction as payment moves from buyers to sellers. Underlying these transactions is a critical knowledge exchange regarding production practices, pest and disease management, and market insights. These exchanges are significantly influenced by mutual trust, comprising trust in the party (based on reputation and past interactions) and trust in the ability (based on operational competence and quality assurances). Without trust, transactions become risky, uncertain, and ultimately more costly.

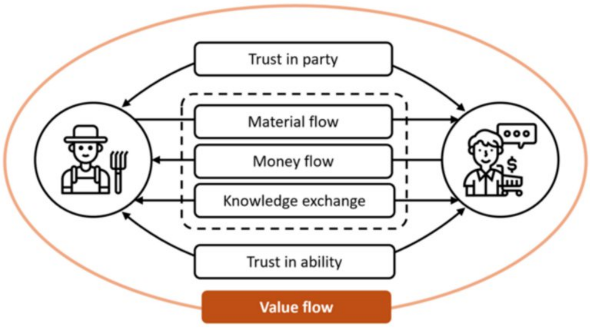

FIGURE 4: Core Flows in a Market

Authors' own illustration

The working definitions of key taxonomy dimensions are presented in Table 1.

Dimension	Definition
Value flow	A series of coordinated exchanges that culminate with the exchange of a product or service for money.
Plumbing	Technological infrastructure, enabling digital coordination of material flow, money flow, and knowledge exchange.
Trust flow	Mechanisms enabling trust in parties and control mechanisms, facilitating efficient information flow.
Material flow	Coordination of physical goods movement from the seller to the buyer.
Money flow	Coordination of financial payments from buyer to seller.
Knowledge exchange	Sharing of agricultural and market information to enhance decision-making.
Trust in the party	Confidence in individuals or entities involved in a transaction.
Trust in the ability	Confidence in the capacity to meet contractual obligations.

TABLE 1: Working Definitions of Terms in the Information Taxonomy

Authors' elaboration

Mapping stakeholder-identified challenges to taxonomy dimensions

Stakeholder consultations revealed a range of critical challenges occurring at the harvest sale interface, where the probabilistic cultivation system connects with the deterministic supply chain. These challenges disrupt value flow by introducing uncertainties and inefficiencies into transaction processes. The specific challenges identified are discussed below:

Supply inconsistencies: Buyers frequently face supply inconsistencies, primarily due to unpredictable harvest yields and weather impacts. These discrepancies not only disrupt order fulfilment but also highlight the inherent unpredictability of agricultural supply chains. Improving visibility into actual harvest availability is crucial to minimize search costs.

Logistical challenges: The lack of an integrated logistics solution necessitates reliance on ad hoc arrangements for produce transportation. This approach often leads to coordination challenges that complicate the supply chain further.

Price expectation: Farmers are more vulnerable to their price expectations. For instance, when dealing with exporters, farmers tend to expect higher prices.

Payment issues: Delayed payment, where funds are transferred days after procurement, has emerged as a significant challenge. The introduction of digital platforms capable of secure, instant, or escrow-based payments could increase seller confidence in the payment process.

Pest and disease problems: Issues related to pest and disease control were noted, often detected only after produce reaches warehouses. Insufficient knowledge among farmers about effective pest and disease management leads to substantial crop losses.

Unpredictable weather: The adverse effects of unpredictable weather affect harvest timing, yield estimation, and planning for input application planning. Such variability necessitates digital tools to provide accurate weather forecasts.

Cultivation knowledge gap: Farmers often lack understanding of optimal farming practices, particularly regarding the timing and quantity of inputs like fertilizers and pesticides. Disseminating best practices is critical to align production standards with buyer expectations.

Opportunistic behavior: Buyers express concerns about farmers' commitment to supply. Instances of farmers selling to competitors for slightly higher prices, even after receiving advances or securing contracts, indicate opportunistic behavior. Addressing this trust deficit requires mechanisms that enhance trust in procurement practices.

Traceability inefficiencies: Buyers often struggle to track produce beyond the farmgate to the warehouse stage due to limitations in the current physical system, and they lack full life cycle traceability of the produce.

Quality inconsistencies: Persistent concerns about inconsistent produce quality were raised, with buyers noting failures to meet established standards. Such inconsistencies undermine confidence in farmers' ability to deliver acceptable produce, compromising overall procurement reliability.

These challenges were systematically mapped to the five taxonomy dimensions, material flow, money flow, knowledge exchange, trust in party, and trust in ability, to guide the identification of necessary digital information flows. Table *2* summarizes the mapping between stakeholder-identified pain points and the corresponding taxonomy dimensions. Table *6* provides illustrative stakeholder quotes supporting these mappings (See appendices).

	Pain Points	Taxonomy Dimension
1	Supply inconsistencies	Material flow
2	Logistical challenges	Material flow
3	Price expectation	Money flow
4	Payment issues	Money flow
5	Pest and disease problems	Knowledge exchange
6	Unpredictable weather	Knowledge exchange
7	Cultivation knowledge gap	Knowledge exchange
8	Opportunistic behavior	Trust in the party
9	Traceability inefficiency	Trust in the party
10	Quality inconsistencies	Trust in the ability

TABLE 2: Stakeholder-Identified Challenges and Mapping to Taxonomy Dimensions

Authors' analysis based on data collected from stakeholder insights.

Mechanisms to mitigate challenges and identification of information flows

Following the mapping of stakeholder-identified challenges to the five taxonomy dimensions, mechanisms to mitigate these challenges were further analyzed through an examination of eight digital F2B platform use cases, including e-NAM, Krishihub, DeHaat, Khula, HelloChoice, Farmsell, Govipola, and Helaviru, complemented by insights from stakeholder meetings.

This cross-case analysis revealed how different digital mechanisms can systematically reduce frictions related to material flow, money flow, knowledge exchange, and trust flow. Building on this analysis, the specific information flows necessary to operationalize these mechanisms were identified. These flows represent the essential digital functionalities that platforms must enable to address the barriers to sustainable value flow at the harvest sale interface. Table *3* summarizes the key platform functions, the corresponding required information flows, and their alignment with the taxonomy dimensions. These findings guided the creation of a unified information taxonomy for digital F2B marketplaces, ensuring comprehensive coverage of both plumbing and trust flow.

	Platform Function	Required Information Flow	Taxonomy Dimension
1	Produce type, variety, quantity, price, image, availability, quality-related description	Product specification	Material flow
2	Buyer requirements, farmer harvest availability, algorithmic recommendations	Matching mechanism	Material flow
3	Cart management, watchlist, order status updates	Order management	Material flow
4	Delivery integration, delivery tracking, logistic updates	Logistic arrangement	Material flow
5	Auction, spot or fixed price, negotiation tracks	Price discovery	Money flow
6	Payment method, secure transactions, wallet, escrow systems	Payment processing	Money flow
7	Pest and disease information	Crop care	Knowledge exchange
8	Real-time weather update	Weather	Knowledge exchange
9	Market price data, trend analysis	Market intelligence	Knowledge exchange
10	Crop details, best practices	Cultivation knowledge	Knowledge exchange
11	Discussion threads, posts, comments and replies, reactions	Community engagement	Knowledge exchange
12	User profile, location, contact details, payment methods, verified badge	User verification	Trust in party
13	Order history, and transaction logs	Order history	Trust in party
14	Star rating, feedback, review	Review and rating	Trust in party
15	Produce tracing systems	Traceability	Trust in party
16	Quality assays, inspection reports, third-party accreditation	Certification	Trust in ability
17	Digital contracts, terms and conditions	Contract	Trust in ability
18	Tailored alerts and real-time notifications	Actionable notification	Trust in ability

TABLE 3: Platform Functions, Required Information Flows, and Mapping to Taxonomy Dimensions

Authors' analysis based on data collected from use cases and stakeholder insights.

Information taxonomy for digital F2B marketplaces

Building on the conceptual taxonomy, the mapping of stakeholder-identified challenges, and the empirical extraction of information flows from platform use cases and stakeholder meetings, this section presents the finalized information taxonomy for digital F2B marketplaces. As established, value flow in these platforms depends on the effective coordination of information that supports both plumbing and trust flow.

The resulting taxonomy consolidates and categorizes information flows across five dimensions, material flow, money flow, knowledge exchange, and trust in party and trust in ability, mapped across both plumbing and trust flow conditions (Figure 5). This classification serves as the foundation for designing targeted digital interventions that better align with stakeholder needs and create clearer value propositions.

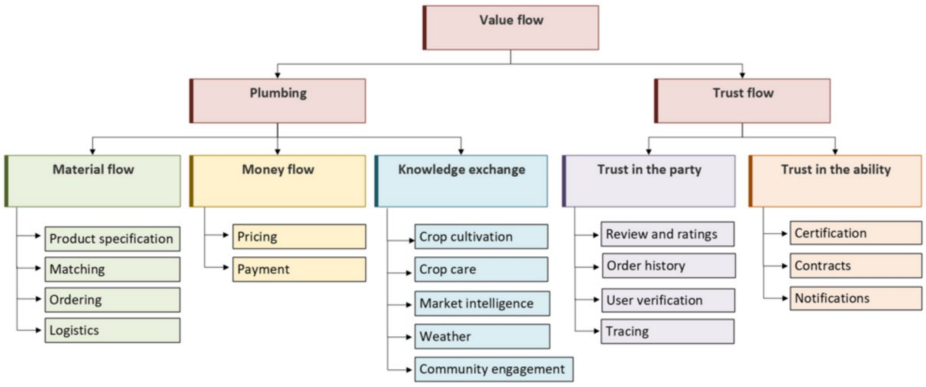

FIGURE 5: Information Taxonomy for Digital F2B Marketplaces

Authors' elaboration

Plumbing provides the channels for three primary conditions, material flow, money flow, and knowledge exchange. First, material flow coordinates the movement of agricultural produce from farms to businesses, encompassing activities such as product specification, order matching, order management, and logistics. Second, money flow ensures secure and efficient financial transactions between buyers and sellers, including price negotiation and payment processing. Third, knowledge exchange guides effective decision-making by disseminating cultivation best practices, market intelligence, pest and disease management strategies, and community engagement opportunities. Plumbing establishes the operational foundation for transaction execution. However, without trust flow, transactional risks remain high.

Trust flow acts as a catalyst that reduces uncertainty and risk, which are significant barriers to participation in digital F2B platforms. In traditional agri-food systems, transactions are often built on personal relationships and repeated interactions, but in digital marketplaces, where buyers and sellers may not know each other, such familiarity is absent. Trust flow addresses this gap through two key mechanisms. Trust in party refers to the confidence users have in the reliability and ethical conduct of other participants, such as a farmer's ability to deliver quality produce or a buyer's willingness to pay on time. This trust is reinforced through user verification, transaction histories, and review systems, which reduce the time and effort buyers need to spend searching for trustworthy partners. Trust in ability, on the other hand, relates to confidence in the platform's systems and processes to ensure a secure and fair transaction. Mechanisms like quality certifications, digital contracts, and real-time notifications provide assurance that even if something goes wrong, the system has built-in safeguards. When both types of trust are established, key transaction costs, especially search, negotiation, and enforcement costs, are significantly reduced. As a result, digital marketplaces become more efficient and appealing, ultimately enabling more frequent and reliable exchanges between farmers and buyers.

In summary, this information taxonomy integrates plumbing and trust flow to enable value flow within F2B agri-food ecosystems (Figure 6). Plumbing provides the structural means for material, money, and knowledge to move through digital channels, while trust flow secures the confidence necessary for stakeholders to engage in these channels. Together, these two components facilitate meaningful transactions and help sustain continuous value flow within digital agri-food platforms through value realization.

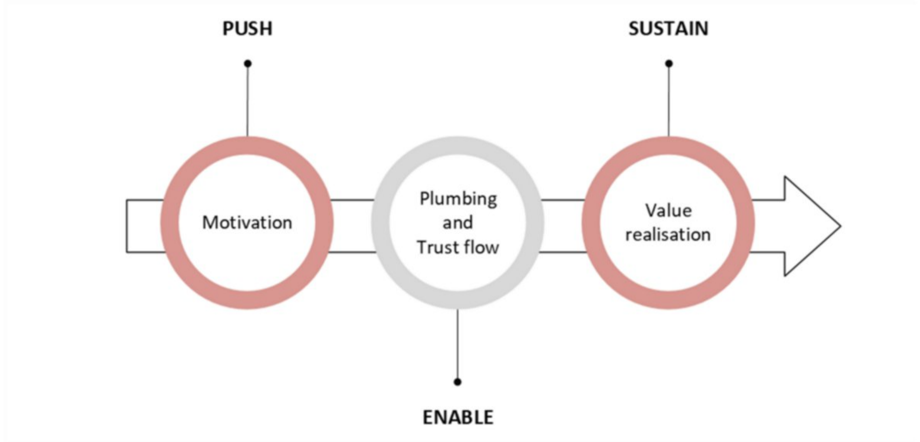

FIGURE 6: Sustaining Value Flow

Authors' own illustration

Validation of the information taxonomy

We applied the taxonomy to eight F2B digital agri-food platforms. Each platform was evaluated according to information flows identified. Detailed application of information taxonomy to the use cases are listed in the Table *4*.

Dimension	Information flow	e-NAM	Krishihub	DeHaat	Khula	Farmsell	HelloChoice	Govipola	Helaviru	Total platforms supporting
Material flow	Product specification	√	√	√	√	√	√	√	√	8
	Matching	√	√	√	√	√	√	√	√	8
	Order management	√	√	×	×	√	√	×	√	5
	Logistic	√	√	√	√	×	√	×	√	6
Money flow	Pricing	√	√	√	√	√	√	√	√	8
	Payment	√	√	√	√	√	√	√	√	8
Knowledge exchange	Crop cultivation	×	√	√	×	×	×	×	×	2
	Crop care	×	×	√	×	×	×	×	×	1
	Market Intelligence	√	√	√	×	×	×	√	√	5
	Weather	√	√	√	×	×	×	×	√	4
	Community engagement	×	√	√	×	√	×	×	×	3
Trust in party	Reviews and ratings	×	×	×	×	√	×	×	√	2
	Order history	√	√	√	√	√	√	√	√	8
	User verification	√	×	√	×	×	×	×	×	2
	Traceability	×	×	×	×	×	×	×	×	-
Trust in ability	Certification	√	×	√	×	×	×	×	×	2
	Contracts	×	×	√	√	×	×	×	×	2
	Notification	√	√	√	×	√	√	×	×	5
Total information flows per platform		12	12	15	7	9	8	6	10	

TABLE 4: Detailed Application of Information Taxonomy to Use Cases

"√" denotes that the platform supports the indicated information flow. This assessment reflects the status as of 1 March 2025; for active platforms, ongoing improvements may alter their capabilities.

The detailed application was then summarized across five key dimensions material flow, money flow, knowledge exchange, trust in the party, and trust in the ability. A dimension was deemed adequately fulfilled if it incorporated more than half of the requisite information flows identified in Figure 5. Table 5 presents the results.

Use Case	F2B Launched Year*	Current Status	Material Flow (n = 4)	Money Flow (n = 2)	Knowledge Exchange (n = 5)	Trust in Party (n = 4)	Trust in Ability (n = 3)	Total Flows Adequately Supported
e-NAM	2016	Active	√	√		√	√	4
Krishihub Store	2016	Inactive	√	√	√			3
DeHaat	2012	Active	√	√	√	√	√	5
Khula	2022	Active	√	√				2
Farmsell	2023	Active	√	√				2
HelloChoice	2023	Active	√	√				2
Govipola	2020	Inactive	√	√				2
Helaviru	2021	Inactive	√	√				2
Total Platform Supporting			8	8	2	2	2	

TABLE 5: Application of the Information Taxonomy to F2B Use Cases

Authors' analysis

*The year represents the most recent publicly accessible version launched and considered for this study.

√ = Dimension is adequately fulfilled (i.e., the platform supports more than half of the corresponding information flows as identified in Figure 5).

× = Dimension is not adequately fulfilled.

n = Number of information flows considered in the analysis for each taxonomy dimension.

Several key observations emerged from this assessment. First, material flow and money flow are consistently implemented across all eight platforms, indicating that coordinating product movement and ensuring payment mechanisms are foundational for F2B marketplaces. However, knowledge exchange is less consistently integrated, with several platforms offering limited features for pest and disease management, best practices for cultivation, or community engagement features. This gap is significant because such knowledge features directly support risk management, especially in environments where product quality and consistency are affected by unpredictable biological and environmental conditions. When platforms provide reliable, timely information that helps farmers manage pests, diseases, or optimize production, it signals operational competence, a core element of trust in ability. From the buyer's perspective, a platform that supports farmer knowledge and resilience is more likely to deliver consistent quality, thereby reducing the perceived risk of procurement. Therefore, higher integration of knowledge exchange features strengthens the platform's ability to build trust in its systems and enhance its capacity to sustain reliable value flows in the F2B ecosystem.

The diverse strategies across platforms illustrate how different models affect sustainability. For instance, e-NAM operates primarily as an auction-based marketplace requiring farmers to physically bring produce to designated market yards. DeHaat and Krishihub complement digital transactions with extensive on-ground infrastructure, such as collection centers, storage, and transportation. In addition, HelloChoice includes a unique feature that allows surplus produce to be donated to registered charities, reducing food waste while building community goodwill. In contrast, some platforms, such as Govipola and Helaviru, functioned more as classified portals and provided limited trust mechanisms or knowledge exchange features, factors that may have contributed to their eventual inactivity. It is also important to note that some platforms included in the study are recent initiatives, and it may be too early to predict their long-term impact or sustainability. Further studies also confirm that these platforms often experience temporary surges in usage, typically when market prices drop, and risk obsolescence if they cannot sustain user engagement through consistent value delivery due to barriers such as lack of awareness, reluctance to join without clear financial incentives, distrust in digital systems, logistical hurdles, satisfaction with traditional methods, and limited internet connectivity in rural areas lead to poor adoption (Baddegamage et al., 2022) (Ellawala and Sachitra, 2021).

Overall, these findings confirm that material flow and money flow alone are insufficient to sustain digital F2B platforms in the long run. Trust flow emerges as a critical element for mitigating risks and encouraging participation. Moreover, the incorporation of knowledge exchange can strengthen user engagement and loyalty, as it helps stakeholders make more informed decisions. The inactive platforms in this study generally exhibit poor trust mechanisms and, in some cases, knowledge-sharing tools, underscoring the importance of a balanced approach to all dimensions of the information taxonomy.

Value proposition map

The value proposition map (Figure 7) explicitly illustrates how the five core dimensions of information flows, identified in the taxonomy, contribute to making the benefits more tangible for farmers and harvest buyers. By showing how enhanced information flows can lower opportunity costs, reduce transaction costs, and increase perceived value.

The integration of material and money flows, combined with trust flow, significantly reduces transaction costs in digital marketplace interactions. However, other information flows need to be employed to increase the perceived value and reduce the opportunity cost. For instance, knowledge exchange especially reduces farmers' opportunity costs by providing essential insights on cultivation techniques, pest and disease management, market dynamics, and weather conditions, by potentially increasing yields and reducing losses, thus making the digital platform more valuable beyond just a sales channel. Interestingly, all identified dimensions of information flows, both plumbing and trust flow, can increase buyers’ perceived value.

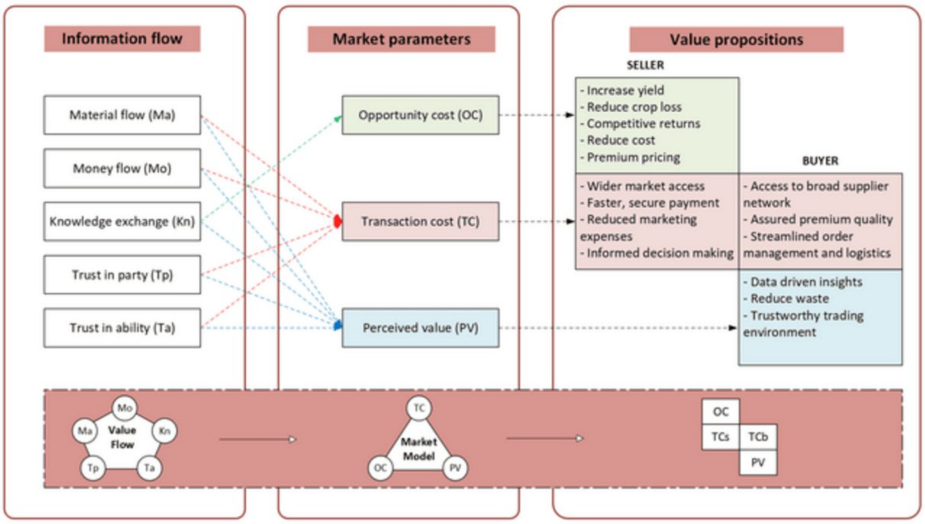

FIGURE 7: Value Proposition Map

Authors’ illustration

TC, transaction cost; OC, opportunity cost; PV, perceived value

Figure 7 visually maps specific value propositions to key market model parameters. Platform providers can utilize this value proposition map as a practical guide to design and communicate the benefits of their digital agri-food technologies. By explicitly mapping platform features that enhance material flow, money flow, knowledge exchange, trust in party, and trust in ability to the key market parameters of lowering opportunity cost, reducing transaction cost, and increasing perceived value, providers can create clearer and more compelling value propositions tailored to the needs and concerns of small-scale farmers.

Discussion

This study addresses a key research gap by developing and validating an information taxonomy that offers a structured understanding of how digital platforms facilitate value flow in F2B agri-food marketplaces. The accompanying value proposition map further strengthens this contribution by linking taxonomy dimensions to key market parameters, perceived value, opportunity cost, and transaction costs, thus supporting the creation of clear value propositions.

Among these market parameters, transaction costs remain a major concern in F2B agri-food marketplaces, especially when handling perishable produce. Stakeholder consultations highlighted search costs and those related to opportunistic behavior, such as unreliability in order fulfilment, as particularly problematic. Although buyers realize value once goods are delivered in good condition, the process of identifying trustworthy suppliers and ensuring timely delivery is often costly and uncertain.

The findings suggest that sustainable value capture is more feasible on the deterministic supply chain rather than within the probabilistic cultivation system, where outcomes are uncertain. By strategically managing information flows, and ensuring both plumbing (material, money, and knowledge flows) and trust flow (trust in party and ability) are in place, digital platforms can bridge this divide and support more viable and sustainable business models.

One critical mechanism for reducing transaction costs is the collection, organization, and deployment of structured data on farmers, crops, production practices, and harvest schedules. These data enable real-time automated matching algorithms that align buyer needs with supply availability in terms of quantity, quality, and pricing. Importantly, much of the data needed for effective matching is generated during cultivation stages, highlighting the role of knowledge exchange in strengthening value flows (Ginige, 2025).

Beyond reducing search costs, platforms also mitigate opportunism through built-in trust mechanisms. Features such as transaction records, digital ratings, reputation scores, and smart contracts improve transparency and accountability. These trust elements, framed in the taxonomy as trust flow, help reduce enforcement burdens by making behaviors more observable and predictable. Supporting this, research has demonstrated that establishing contracts through digital platforms can enhance farmers' social capital, which in turn reinforces digital identities that promote trustworthy engagement (Kumarathunga et al., 2022).

Another critical factor influencing sustainability and scalability is the physical infrastructure supporting F2B transactions. Many platforms that gained popularity during the COVID-19 pandemic could not sustain operations once market conditions normalized, partly due to inadequate logistics, storage facilities, or collection centers. As the discussion revealed, farmers often face disadvantages in transporting small volumes of perishable produce, leading them to either dump excess stock or revert to traditional sales channels. This underscores the importance of aggregator models, where consolidated shipments and shared infrastructure reduce transaction costs for all parties.

Closely tied to these logistics issues are concerns around quality assurance and perishability management. Without reliable verification procedures, buyers face risks of receiving inferior produce, risking trust and future transactions. Certifications, traceability tools, and grading standards increase buyer confidence and incentivize farmers to invest in quality improvements. While many digital interventions target cultivation uncertainties, such as pest management or weather forecasting, their true economic value materializes downstream, where outcomes like higher market prices, reduced rejection rates, and faster sales make benefits tangible. Thus, platform design must ensure that probabilistic improvements upstream are made visible and verifiable at deterministic transaction points.

Ultimately, sustained engagement depends on the platform's ability to communicate tangible value propositions. As outlined in the value proposition map, this means demonstrating how platform features lower opportunity costs, reduce transaction costs, and enhance perceived value. Long-term adoption will rely on a balanced integration of plumbing and trust flow with the value realization mechanisms. Only by consistently delivering on these fronts can digital agri-food technologies achieve sustainable growth and widespread adoption.

Limitations and scope for future study

The findings presented here are subject to certain limitations. While many platforms appear operational based on publicly available data, their actual transaction volumes or usage intensity may differ. Moreover, several platforms rely on temporary funding or policy support; once that support fades, so does their market presence. Future research could employ longitudinal methods to assess platform usage over time, explore how specific trust-building features influence adoption, and investigate whether aggregator-based logistics models can better address the unique challenges that perishable agri-food supply chains pose. Further exploration is also possible with a deeper quantitative analysis of the impact of the identified information flows, and a broader geographical scope could further strengthen the findings.

Conclusions

This study contributes to the literature by developing and validating an information taxonomy that offers a structured understanding of how digital platforms can enable value flow in F2B agri-food marketplaces. The corresponding value proposition map explicitly links these information flows to key market parameters, perceived value, opportunity cost, and transaction cost, providing a foundation for designing clear value propositions. The findings reveal that while the coordination of material, money, and knowledge flows, collectively referred to as plumbing, is necessary, it is insufficient for sustained digital platform adoption. The integration of trust flow, comprising trust in the party and trust in the ability, is critical for mitigating risk, reducing transaction costs, and promoting participation. The application of the taxonomy across eight F2B platforms shows that material and money flows are commonly implemented, while knowledge exchange and trust-building mechanisms are less consistently integrated. This gap may contribute to platform inactivity and highlights the need for a more holistic platform design that aligns digital features with the practical and behavioral needs of small-scale farmers and buyers. The value proposition map developed in this study serves as a practical tool for platform providers to communicate the tangible value propositions of digital agri-food technologies, by clearly linking platform information flows to market parameters and value propositions. Overall, the study advances a new understanding: plumbing and trust flow enable value flow, but value realization is essential to sustain it, and this is most effectively achieved on the deterministic side of the market, where transaction decisions are made. By bridging probabilistic production with deterministic supply chains through structured information flows, digital platforms can build trust, reduce friction, and support long-term adoption in the smallholder farming context.

Appendices

Pain Point	Quoted Insight
Supply inconsistencies	“When we engage directly with farmers, we give our farmers orders beforehand, but the quantities delivered often fall short of our orders." "We faced a significant shortage when sourcing some produce when there is flood etc, then we don’t know where to source them” “Farmers have migrating nature, they come and go”
Inconsistent quality	"Our ability to scale is hindered by inconsistent product quality”
Logistical challenges	"We do not provide transportation, relying on lead farmers for delivery”
Pricing expectation	“When the moment they know we are exporters, farmers expect us to pay them more”
Payment issues	“Some of our competitors pay in cash, but we deposit the money to the bank after few days”
Pest and disease problems	"We've observed significant pest and disease attacks upon receiving produce” “Farmers often lack the knowledge needed to effectively manage pests and diseases”
Unpredictable weather	"Predicting harvest times accurately is challenging due to weather variability.” "Predicting weather conditions, especially rainfall, is crucial for planning fertilisation”
Cultivation knowledge gap	“While many farmers have been farming for a long time, they may still benefit from advisory services to understand acceptable product standards buyers are looking for”
Opportunistic beahviour	“We train farmers, and our competitor ends up buying from them, sometimes at marginal higher rates." "When market prices fluctuate due to weather conditions, our suppliers tend to sell outside, but again wants to come back when prices go down”
Traceability inefficiency	"Each crate has a barcode that is linked to the specific farmer who produced it, allowing for easy tracking and identification at warehouse"
Quality inconsistencies	"We export to a few destinations not because we can't reach others, but because it's about selecting the best quality and maintaining our reputation"

TABLE 6: Stakeholder-Identified Challenges

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Rifana Buhary, Athula Ginige

Acquisition, analysis, or interpretation of data: Rifana Buhary, Athula Ginige

Drafting of the manuscript: Rifana Buhary

Critical review of the manuscript for important intellectual content: Athula Ginige

Supervision: Athula Ginige

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. Western Sydney University Human Research Ethics Committee issued approval H16483. Ethical approval for this project has been granted by the Western Sydney University Human Research Ethics Committee. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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Data are available upon reasonable request. The data are stored as de-identified participant data can be requested from Rifana Buhary (brifana@gmail.com). The authors will keep the data for five years.

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