

REVIEW

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Digital behaviour change ecosystems for sustainable innovation

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Abstract

This paper presents a systematic review of the literature on digital behaviour change ecosystems (DBCE) in the context of sustainable innovation. The concept of digital behaviour change ecosystem is gaining increasing attention across multiple domains, including agriculture, information systems, health, and environmental management. This emerging paradigm requires research institutions and organizations to design their digital models around innovative digital behaviour change ecosystems that contribute to organisational value while mitigating risks associated with opportunistic practices. However, research examining how agricultural business models and digital ecosystems can be designed to foster behavioural change toward sustainability remains fragmented and underdeveloped. Building on this premise, we identify DBCE trends, the methodological landscape, theoretical underpinnings, four thematic areas and future research direction. . Through this analysis, we seek to advance understanding of how digital ecosystems can be strategically designed to promote sustainable behavioural change within agricultural contexts and beyond.

Keywords Digital behaviour, Digital behaviour change ecosystem (DBCE), Systematic literature review, Themes, Sustainable innovation, Grounded theory

1 Introduction

Digital innovation is transforming agriculture, impacting how farmers, businesses, and other stakeholders collaborate and participate in agrifood systems [36]. This transformation is driving the development of new collaborative value creation networks, which can be understood through the lens of digital behaviour change ecosystems (DBCEs). In this context, a DBCE is an ecosystem or network of digital tools, platforms and strategies designed to influence, aid, and sustain behaviour change [57]. Thus, it represents the complex interplay of human behaviours and digital technologies within the agricultural sector. It encompasses how farmers adopt new technologies, how consumers make food choices, how businesses interact and share data, and how these behaviours are influenced by and, in turn, influence the digital tools and platforms they use [58]. These interconnected behaviours, facilitated and shaped by digital technologies, drive value creation within the agrifood system, influencing everything from production practices and supply chains to market access and food security [30].



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DBCE concept, recognised from Chang and West [20] has become increasingly prominent in various fields, notably agriculture, business management, health [40], and environmental management [34]. In practice - interventions and strategies, DBCE has also gained increasing attention as programmes strive for effective solutions for modifying behaviours using digital tools [27].

In agriculture, the shift toward sustainability increasingly relies on digital behaviour change ecosystems that integrate digital, social, economic, and environmental goals. Firms and institutions are required to reconfigure value networks, organizational structures, and stakeholder relationships to embed sustainable innovation principles [25]. Digital platforms and ICT tools are central, enabling new forms of coordination, knowledge sharing, and farmer engagement that reshape value propositions and encourage sustainable practices across agri-food systems [25].

However, research on how agricultural business models and digital ecosystems are designed to foster behavioural change toward sustainability remains fragmented. While scholars acknowledge the potential of digital innovations and agro-advisories, systematic insights into their integration with behaviour change and sustainability are limited [33, 50, 57]. This highlights fertile ground for advancing frameworks that connect digital ecosystems, behavioural change, and sustainable model in agriculture. Such work can guide researchers, intergovernmental agencies and policymakers in understanding emerging digital behaviour trends, addressing adoption barriers, and identifying strategic pathways for fostering sustainable agricultural transformations.

This paper is organised as follows; the trends in DBCE concept are first presented. Then, the description of methodology is discussed, and the findings are then presented to address the research objective. Following this, we advance the DBCE research framework that clusters the key findings. We conclude by outlining promising directions for future research and offering some final remarks.

2 Trends in digital behaviour change ecosystem

This study explores DBCEs, extending the work of Kaiser *et al.* [35] on environmental attitudes, and ecological and behaviour change. Here, digital innovation plays a dominant role in driving behaviour change. Inspired by ecological systems analogous to environmental and biological ecosystems [20], the behaviour change ecosystem is conceptualized as an interconnected network of digital and non-digital elements working together to facilitate sustainable behaviour modifications. While behaviour change ecosystems generally highlight the interconnectedness of interventions, DBCEs specifically emphasize the critical role of digital innovation in this process.

DBCE is a complex network that can be broadly categorised into two main tiers: digital ecosystem and behaviour change ecosystem [54]. A digital ecosystem is a dynamic, interconnected network environment of digital elements, including software applications, hardware components, and digital processes [51]. These elements interact and collaborate to create a rich and interactive digital environment. Conversely, behaviour change ecosystem is a complex and interconnected system that influences and shapes individual and collective behaviours [44]. It encompasses a wide range of factors, including individual factors (e.g. knowledge and beliefs), social factors (e.g. social norms, influence and support) and environmental factors (e.g. technological and policy and regulatory environment). The key characteristics of a behaviour change ecosystem

comprises of interconnectedness, dynamic, complex and context specific. Thus, in this study, DBCE is defined as a dynamic and interconnected network of digital elements (software applications, hardware, digital processes, and online platforms) designed to influence and shape individual and collective behaviours to co-create value. It leverages technology to interact with and modify the complex interplay of individual, social, and environmental factors that drive behaviour, creating a digitally mediated environment where change is promoted and supported.

DBCE is complex, and can be examined as a concept, intervention or ecosystem service [27, 44, 54]. As a concept, DBCE recognizes the importance of digital innovation and interconnected entities to promote behaviour change. As an intervention, DBCE refers to an approach to promoting positive specific changes in human behaviour [54]. Finally, as an ecosystem service, a DBCE represents a research pathway that investigate how human activities impact ecosystems, how ecosystems changes affect services and how services changes affect well-being. This pathway led to the developments of frameworks and the creation of the Millenium Ecosystem Assessment 45.

The main characteristics of DBCEs are interconnectedness, data-driven, dynamic and adaptive, collaborative elements, and self organisation. Interconnectedness refers to a network of interconnected DBCE elements which includes the individual behaviours targeted, digital tools and platform used for the intervention, entities or organisations involved in implementing and the information generated and shared within the ecosystem [24, 41]. Data plays a central role in a digital behaviour change ecosystem. Data is collected from various sources, analysed to understand behaviour patterns and trends, and used to personalize and optimize interventions. Dynamic and adaptive focuses on the constantly evolving nature of DBCE due to new technologies, user needs and preference change. Dynamic and adaptive leads to integrating new technologies, responding to user feedback and adapting to context [41]. Building and maintaining a DBCE requires collaboration among various stakeholders; hence the involvement of collaborative elements like researchers, behaviourists, technologists, policymakers and practitioners [42]. Value creation in modern organizations transcends individual capabilities, as Adner [1] emphasizes that the collective power of an ecosystem surpasses the potential of any single organization. This underscores the critical importance of organizational interdependence, where entities strategically combine their respective strengths and mitigate weaknesses to forge enhanced value propositions that benefit all stakeholders. Self organisation signifies that each DBCE is independent, self-empowered and self-prepared, and has the ability to learn from the environment and respond accordingly [20]. The multifaceted relationships within DBCEs enable them to learn and adapt autonomously to evolving needs, opportunities, and threats.

3 Methods

To ensure a comprehensive literature review and a robust analysis, a systematic literature review (SLR) was conducted which builds upon the framework of Ofosu-Ampong et al. [50]. The SLR provided a structured process for searching and refining the literature. Also, a grounded theory literature review (GTLR) method of Wolfswinkel et al. [66] was followed to identify the connections and relationships between the individual studies. Examining this review from these two approaches broaden the deep understanding of the existing research. Figure 1 shows the process underlying the review 1).

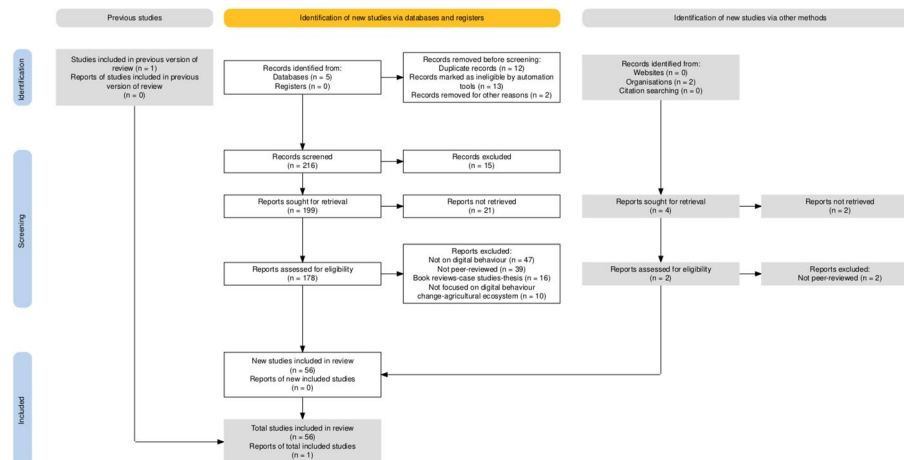


Fig. 1 Review selection process

3.1 Literature search

The literature search strategy prioritised exploring six (6) prominent databases crucial to agricultural systems, digital behaviour behavioural change and innovation: Emerald journals, Science Direct, Scopus, Sage, Springer Link and Wiley Online Library. These databases were chosen for their extensive indexing of relevant behaviour change and agricultural journals and proceedings, which aligns with established best practices [65]. Recognising the importance of top-tier publications, a targeted search of top agricultural systems journals was performed. The search strategy employed defined keywords across titles, and author-supplied keywords. This approach yielded a collection of 156 peer-reviewed journal articles, which formed the basis for subsequent refinement and analysis.

3.2 Literature refinement

The initial literature search yielded several articles, some of which were duplicates or explored but not directly relevant to the DBCE concepts. Therefore, a rigorous refinement process was implemented. This involved a thorough review of titles, abstracts, and full text to eliminate duplicates and exclude articles that did not meet the review's specific inclusion criteria. Specifically, articles that merely mention digital behaviour were excluded, similar to articles that listed it as a keyword without substantive discussion within the article itself. This meticulous manual review resulted in a final selection of 56 journal articles for in-depth analysis.

3.3 Analysis of selected literature

The selected articles were systematically coded to identify key themes, methodologies, theoretical underpinnings, and areas of future research with DBCE. As previously stated, the thematic analysis followed the grounded theory literature review method outlined by Wolfswinkel et al. [66]. First, we performed open coding and read each article which generated 60 initial codes. These open codes were then analysed for overlapping concepts, leading to the development of 18 axial codes. The 18 axial codes were iteratively analysed through mapping and integration, ultimately distilling them into four selective codes that represent the core themes of DBCE research.

Articles were excluded if they did not focus on digital behaviour, were not peer-reviewed, were book reviews, case studies, or theses, or lacked relevance to digital behaviour change in agricultural systems. Included articles were peer-reviewed and specifically addressed digital behaviour, behaviour change, agricultural systems, and related technologies.

4 Results

This section presents the findings of the literature review, organised as follows: (1) trends in DBCE research, (2) themes in DBCE research (3) research methodologies and methods, and (4) theories explored within DBCE research.

4.1 Trends in DBCE

This section analyses the distribution of publications by journal, along with yearly trends. Table 1 details the DBCE articles across the journals. Since the focus was not on conference papers, journal articles were significantly more prevalent. The *Agricultural Systems* journal dominates with 8.9% of the publications. Other notable journal articles include the *Technological Forecasting and Social Change* (7.1%), *Computers and Electronics in Agriculture* (5.4%), *International Journal of Agricultural Sustainability* (3.65), *Development and Change* (3.6%), *Journal of Environmental Management* (3.6%), *Technology in Society* (3.6%), *Food and Energy Security* (3.6%), *Food and Energy Security* (3.6%), *Ecosystem Services* (3.6%) and *Smart Agricultural Technology* (3.6%), while the remaining journal articles each accounted for 1.8%. The data clearly demonstrate a strong preference for agricultural and technological journals combined.

Furthermore, Fig. 2 illustrates the yearly publication trend from 2019 to 2025 inclusive. The most productive years were 2023 (16 articles), 2022 (15 articles), and 2021 (8 articles). In 2024, seven articles were published; in 2020, five; in 2019, two; and in 2025, three. The data suggest that the marked jump in publications from 2021 to 2023 could be potentially attributed to specific events or trends that heightened the focus on DBCE initiatives. This could include the increases reliance on digital platforms due to Covid-19 pandemic, the growing awareness of persuasive technology and advances in data analytics and AI. While the data shows a positive trend, the slight dip in 2024 leading to 2025 warrants attention. Hence, a continued monitoring of publication trends is needed to understand the long-term evolution of DBCE.

4.2 Methodological landscape of DBCE research

This section presents findings on methodologies and methods used in DBCE research, as summarised in Table 2. The research strategy classification of Michie et al. [43] was adapted for this analysis due to its coverage of behaviour change research methodologies and methods.

The findings reveal that a majority of DBCE research (42.86%) is non-empirical and therefore conceptual in nature. The predominance of untested conceptualisation raises concerns, as it lacks real-world validation and difficulty in measuring impact with limited generalisability. DBCE is a relatively new area of study, hence experiencing a period of theoretical development and exploration especially in the agricultural research before robust empirical methods become established.

Table 1 Publications by count

Journal articles	Counts	Percentage
Economy and Society	1	1.79
NJAS-Wageningen journal of life sciences	1	1.79
Scientific Reports	2	3.57
International Journal of Agricultural Sustainability	1	1.79
Journal of Agriculture and Food Research	1	1.79
Organization & Environment	1	1.79
Development and Change	2	3.57
Journal of Responsible Innovation	1	1.79
Regional Environmental Change	1	1.79
Journal of Environmental Management	2	3.57
Farming System	1	1.79
Agricultural and Food Economics	1	1.79
Land Use Policy	1	1.79
Journal of Agromedicine	1	1.79
People and Nature	1	1.79
Environmental Management	1	1.79
Agricultural Systems	5	8.93
Journal of Agrarian Change	1	1.79
Journal of Agriculture and Food Research	1	1.79
Ecological Indicators	1	1.79
Irish Veterinary Journal	1	1.79
The Journal of Agricultural Education and Extension	1	1.79
Journal of Rural Studies	1	1.79
Technology in Society	2	3.57
Environmental Science and Ecotechnology	1	1.79
Food and Energy Security	2	3.57
Environmental Science and Pollution Research	1	1.79
The European Journal of Development Research	1	1.79
Applied Economic Perspectives and Policy	1	1.79
Sustainable Production and Consumption	1	1.79
Sociologia Ruralis	1	1.79
The Journal of Strategic Information Systems	1	1.79
Frontiers in Ecology and Evolution	1	1.79
Technological Forecasting and Social Change	4	7.14
Computers and Electronics in Agriculture	3	5.36
Ecological Economics	1	1.79
Journal of the Science of Food and Agriculture	1	1.79
Ecosystem Services	2	3.57
Journal of Innovation & Knowledge	1	1.79
Smart Agricultural Technology	2	3.57
Total	56	100

Among the empirical studies, participatory design (16.07%) emerges as the most widely used approaches within the user centred design. These were followed by surveys (8.93%), with randomised control trails, case study and sequential mixed methods representing 5.36% each. Usability testing, interviews and contextual inquiry followed with 3.57% each, with prototype evaluation, log data analysis and digital phenotyping representing the least used method (1.79%). The empirical results which were classified into experimental research, mixed method and user centred design indicate a clear preference for user centred design approaches specifically participatory design (a qualitative approach) in empirical DBCE research.

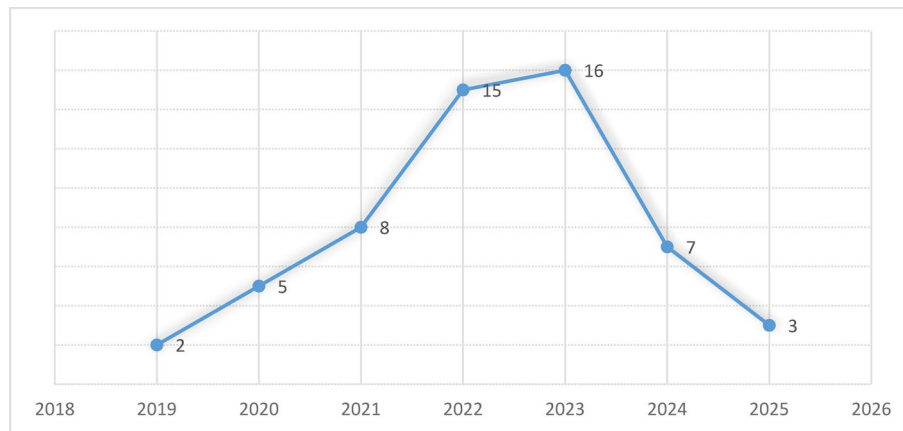


Fig. 2 Article distribution by year of publication

Table 2 Methodological landscape of DBCE research

Research classification	Research methodologies	Research methods	Count	Percentage
Empirical	Experimental research	Randomised control trials (RCT)	3	5.36
		Cluster RCT		
	Mixed method	Survey	5	8.93
		Interviews	2	3.57
		Case study	3	5.36
		Sequential mixed method	3	5.36
	User centred design	Participatory design	9	16.07
		Usability testing	2	3.57
		Prototype evaluation	1	1.79
		Contextual inquiry	2	3.57
		Log data analysis	1	1.79
Digital phenotyping		1	1.79	
Non-empirical	Conceptual orientation	Perspectives, viewpoints, theoretical lens, interpretation, approaches	24	42.86
Total			56	100

Traditional research approaches—experiments, randomised controlled trials, surveys, and case studies—provide useful evidence on what works but fail to capture how behaviour evolves within digital ecosystems. Controlled trials privilege short-term metrics over adaptive learning, while qualitative and mixed-method studies offer context but lack temporal resolution. Also, user-centred and participatory design improve relevance but often represent only digitally literate groups [76, 78]. Usability testing and prototype evaluation optimize functionality rather than long-term engagement. Meanwhile, log data analysis and digital phenotyping produce vast behavioural datasets but without context or interpretation, risking algorithmic bias and exclusion of less active users [79].

Furthermore, we found that randomised controlled trials remain one of the most reliable ways to determine whether a digital behaviour change intervention delivers real impact beyond perceived usefulness. For tools deployed at community or system level—such as early-warning, monitoring, or decision-support systems—cluster randomised controlled trials (CRCTs) offer the most appropriate design [77]. By randomising entire geographic or institutional units, CRCTs capture the real environments where digital interventions operate and allow policy makers to assess population-level outcomes,

including adoption, behavioural shifts, and reductions in risk or disease burden. Multi-stakeholder platform for agricultural research has used CRCTs extensively to test large-scale interventions, demonstrating their value in complex social settings [3]. For digital behaviour change work, this design also supports integrated cost-effectiveness analysis, helping governments and partners understand whether a digital tool provides value for money and fits long-term sustainability plans [75]. CRCTs are not without limitations. They often require large numbers of clusters, especially when communities are internally similar, and small cluster counts may leave room for chance imbalances. Digital systems also create risks of cross-contamination when information or behaviours spill across groups [80]. These challenges can be managed through careful design—such as stratified randomisation or buffer zones—making CRCTs a strong, credible methodology for high-stakes digital behaviour change programmes. Collectively, these methods still isolate behaviour rather than treating it as co-evolutionary—a process in which users, technology, and context continuously influence one another.

4.3 Theoretical underpinnings of DBCE research

To understand the theoretical underpinnings of the sampled papers, this subsection focuses on analysing the use of established and dominant theories to address RO3. As shown in Table 3, a significant majority (51.79%) of the publications did not explicitly employ any theoretical framework. These articles were categorised as “no theory”. Among the remaining articles that used theory, Technology acceptance model (TAM) was the most prevalent (5.36%) with several modifications or extensions; followed by Social learning theory (3.57%), Transtheoretical model (3.57%), Theory of planned behaviour (3.57%), COM-B model (3.57%), and Actor-network theory (3.57%). Several

Table 3 Dominant theories underlying DBCE research

Theories	Count	Percentage
Evolutionary theory	1	1.78
Technology acceptance model (TAM)	3	5.36
Social network theory	1	1.78
Theory of planned behaviour (TPB)	2	3.57
Unified theory of acceptance and use of theory (UTAUT)	1	1.78
Social influence theory	1	1.78
Transtheoretical model	2	3.57
Self-determination theory	1	1.78
Social learning theory	2	3.57
COM-B model	2	3.57
Social cognitive theory	1	1.78
Fogg behaviour model	1	1.78
Socio-technical systems theory	1	1.78
Social feature learning	1	1.78
Economic constraint theory	1	1.78
Knowledge-attitude-practice model	1	1.78
Diffusion of innovation theory	1	1.78
Nudge theory	1	1.78
Adaptive structuration theory	1	1.78
Actor-network theory	2	3.57
Uncertainty reduction theory	1	1.78
Ecological systems theory	1	1.78
No theory	27	48.2
Total	56	100

other theories, including Evolutionary theory, Social network theory, Economic constraint theory, Socio-technical systems theory, Unified theory of acceptance and use of theory and Ecological systems theory, each appeared in only one publication (1.78%).

The analysis reveals two observations: (1) The first major revelation is that successful DBCE in agriculture is predominantly driven by social factors rather than technical capabilities. This finding is supported by several converging theories, including Diffusion of innovation, Social network theory, and Actor-network theory. These theories highlight the crucial role of social influence in technology adoption, demonstrating that farmers are more likely to adopt new digital technologies when they observe successful implementation by their peers [56]. Furthermore, local farming networks and community leaders play a crucial role in facilitating technology diffusion within these communities [6]. Second, (2) DBCE research currently lacks its own distinct theoretical base. The absence of DBCE-specific theories could be a consequence of researchers drawing heavily from existing theories in other fields like Sociology and Information Systems. However, from the review we found that all the 22 theories (Table 3) converge on the understanding that behaviour change is a dynamic, socially embedded, and context-dependent process. They differ in focus—some emphasizing cognition, others technology or social structure—but they all describe how individuals interact with environments (social learning), technology, and others to produce adaptive behaviour.

In the context of digital behaviour change, both theoretical and empirical evidence indicate that individuals tend to imitate others when uncertain, a well-documented principle in social learning theory and digital diffusion of innovation models [64]. Unlike the dominant theories (TAM, TPB and COM-B model), the Social Feature Learning (SFL) model offers a mechanistic explanation for this adaptive social strategy within digital environments. Conceptually, the model suggests that social influence intensifies as individual uncertainty increases—a phenomenon central to models such as Bandura's Social Cognitive Theory and Rogers' Diffusion of Innovations. When users feel confident about their choices based on non-social cues (e.g., clear interface design, personal experience, or algorithmic recommendations), the weight of social information—such as peer actions, reviews, or engagement metrics—has minimal impact on their digital behaviour [55]. However, in novel or ambiguous digital contexts, where users face higher uncertainty, social signals become dominant behavioural drivers. This aligns with uncertainty reduction theory, suggesting that users rely more heavily on others' digital behaviours (likes, trends, testimonials) when internal confidence is low [37]. Thus, social influence peaks when informational clarity is weakest, reinforcing the power of social proof in shaping online adoption, engagement, and compliance behaviours.

From a behavioural modelling standpoint, the SFL structure bridges uncertainty-biased learning with broader social influence theories, illustrating how users weigh different social features dynamically rather than rigidly following single heuristics such as “adopt the dominant behaviour” or “adopt the successful.” By framing decisions as weighted features, the model accounts for how digital users assign greater importance to social signals with stronger historical reward associations (e.g., popular features, trusted influencers, or verified sources) [28]. Thus, individuals are more likely to follow cues that have previously correlated with positive digital outcomes or rewards. With the proliferation of digital platforms, the SFL and UTAUT seems to be the most suitable model

options for DBCE. In fact, recent studies [60] have called for SFL testing of innovation and digital behaviour change.

4.4 Themes in DBCE research

This subsection addresses the study's first research objective (RO1). As shown in Table 4, the research on DBCE can be categorised into four main themes: digital innovation value, behaviour change, knowledge systems, and sustainability. The digital innovation value theme comprises 12 open codes and 4 axial codes, while the behaviour change theme includes 16 open codes and 4 axial codes. The knowledge system theme has 15 open codes and 3 axial codes. Finally, the sustainability theme consists of 17 open codes and 4 axial codes. In all, there are 4 selective codes, 15 axial codes and 50 open codes.

5 Digital behaviour change ecosystem framework

Our systematic review of literature at the intersection of digital ecosystems and behaviour change enabled the development of a theoretical framework for digital innovators and behavioural scientists (Fig. 3). This framework synthesizes key themes from existing research and highlights the core themes and sub-themes of digital behaviour change ecosystem. This research shows that the visibility of agricultural innovations depends on everyday behaviours (moderators and mediators). When farmers or users and practitioners demonstrate, share, and adapt innovations in their routine work, they make them tangible to others. By collaborating with the people who shape these behaviours, innovations gain credibility and spread more naturally across communities. The following sections provide a detailed explanation of these themes and their respective sub-themes.

What makes the Digital Behaviour Change Ecosystem (DBCE) Framework (Fig. 3) distinct and innovative is its shift from viewing digital interventions as isolated tools aimed at individual adoption to conceptualising them as dynamic, adaptive, and interconnected systems that evolve with users, institutions, technologies, and environmental conditions [15]. While traditional frameworks such as TAM, UTAUT, COM-B, Social Cognitive Theory, and Diffusion of Innovation focus largely on linear adoption processes, individual intention, or static determinants of use [40, 57], the DBCE recognises digital behaviour change as a co-evolutionary process shaped by continuous feedback loops and context variability. This moves beyond technology acceptance to address *what* happens *after* adoption—how systems survive, scale, and sustain impact over time.

The DBCE is theoretically innovative because it explicitly incorporates dimensions largely overlooked in earlier models, including temporal variation, spatial dynamics, competition, and behavioural heterogeneity, acknowledging that behaviour unfolds differently across time, place, and social conditions. Its sustainability logic is grounded in three axial codes: (a) pre-implementation—building ownership and relevance, (b) implementation—integration and adaptability, and (c) post-implementation—institutionalisation and knowledge continuity, which collectively demonstrate how ecosystems evolve rather than stagnate.

Moreover, four central operational areas, as shown in Table 4—the DBCE pact and design, infrastructure and connectivity, data management and security, and user experience and technical support—provide a practical foundation for translating theory into real-world implementation. These areas ensure that digital systems are not only technically sound, but also ethically governed, locally appropriate, and institutionally

Table 4 Themes in DBCE research

Selective codes	Axial codes	Open codes
Digital innovation value theme	DBCE pact and design Infrastructure and connectivity Data management and security User experience and technical support	Core technology infrastructure components Platform interoperability and connectivity Data collection mechanisms Storage and processing systems Security protocols and privacy measures Analytics capabilities Real-time data handling Interface design principles Mobile-first approaches Offline functionality Multi-language support Accessibility features
DBCE Knowledge Systems Theme	DBCE Systems thinking DBCE Socio-technical system design DBCE Behavioural change modelling	Digital transformation theories Behaviour change models Innovation diffusion frameworks Systems thinking approaches Socio-technical perspectives Conceptual model design Framework validation methods Integration and interoperability approaches Theory application Model testing protocols Knowledge mapping Information flow design Cognitive models Learning frameworks Knowledge integration systems
Behavioural change theme	Time-based variation Spatial dynamics Competition Behavioural Heterogeneity	Technology acceptance factors Resistance points and barriers Implementation strategies User engagement cycles and time Adoption measurement metrics Skill acquisition processes Knowledge transfer methods Capacity building approaches Training methodologies Competency development Incentive structures Behavioural triggers and heterogeneity Long-term engagement Habit formation and competition Sustained usage patterns Farmer-to-farmer digital networks
DBCE Sustainability Theme	Pre-implementation phase: building ownership and relevance, Implementation phase: integration and adaptability, and Post-implementation phase: institutionalization and knowledge continuity.	Cost-benefit analysis Resource allocation Financial sustainability Market integration Deployment methods Scaling approaches Replication models Risk management Quality assurance Performance metrics Success indicators Evaluation frameworks Impact measurement Long-term monitoring Economic viability and ROI Market integration and value chains Scalability and replication potential

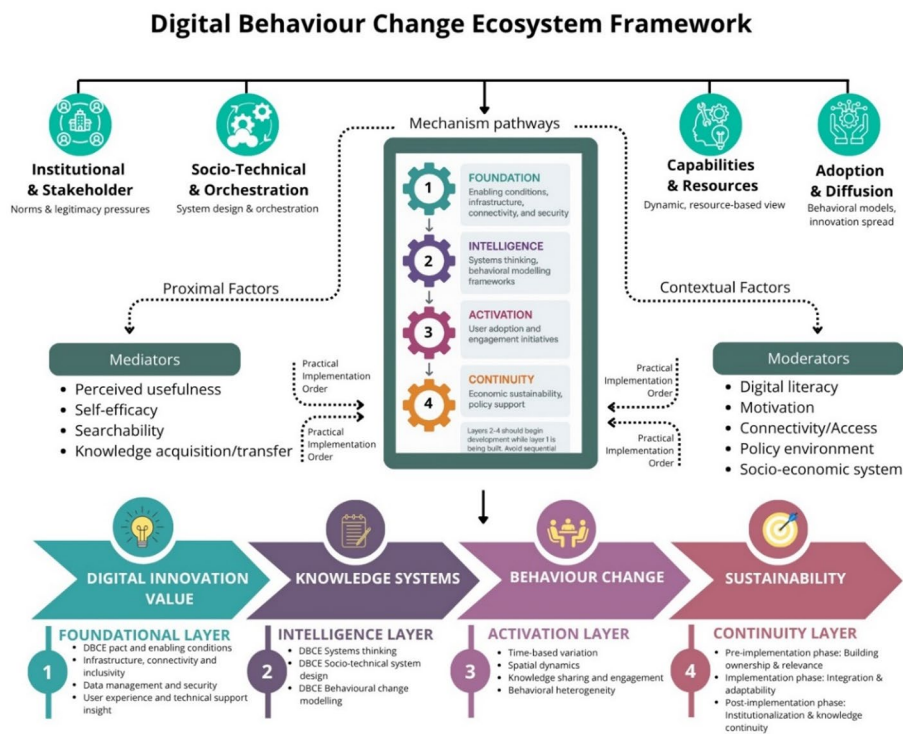


Fig. 3 DBCE Framework

embedded. By embedding collaboration, ethical governance, and cross-sector alignment at the core rather than the periphery, the DBCE positions digital interventions as living systems that learn, adapt, and scale over time, offering a transformative and future-ready foundation for research, policy, and innovation. The next section details the development of the DBCE into four sections.

5.1 Digital innovation value

The willingness of organisations to leverage digital innovation—seen as a *foundational layer* of the digital behaviour change ecosystem (DBCE)—is often driven by productivity gains, social impact, and the regulatory direction and rest on robust ethical provisions that prioritize transparency and accountability. Recent studies [2, 10] highlight how technical infrastructure, the adoption of digital solutions, and the broader DBCE framework create tangible value for stakeholders across value chains. As shown in Table 4, four central areas emerge under this theme: the DBCE pact and design, infrastructure and connectivity, data management and security, and user experience and technical support.

DBCE pact and design requires a structured and user-centred approach that ensures long-term impact, institutional adoption, and adaptability [14]. The foundational *setting up* phase determines whether the digital solution is appropriate for the behavioural challenge and establishes the conditions for sustainable design [82]. This phase begins with analysing the behavioural context, clarifying the use case, and identifying the specific decisions or habits the ecosystem must influence [49]. It requires close engagement with users, communities, and institutional actors to understand needs, constraints, and motivations. Insights from interviews, observations, and participatory sessions guide the creation of behavioural profiles and define what success looks like. A critical step is

determining functional and non-functional requirements, ensuring the system is usable, secure, scalable, and aligned with organisational goals [48]. Designers then model the behavioural and interaction flows, anticipating different user pathways and embedding mechanisms—such as personalised prompts, feedback loops, and nudges—that support sustained action [38]. The system's communication style and identity are also defined to build trust and engagement. Furthermore, selecting an appropriate technological platform ensures integration with existing systems and the flexibility to adapt as needs evolve. Strong foundations in this early phase enable the DBCE to scale effectively, remain contextually relevant, and deliver sustainable behaviour change across communities and institutions. The *technical creation* phase translate storyboarded user–DBCE interactions into structured intents and backend rules, enabling the system to deliver guided, sequential support based on real user tasks, while the *implementation and improvement* phase focus on technical refinement, structured user testing, and ongoing updates to ensure the DBCE performs reliably, meets user needs, and evolves as new functionalities and behaviours emerge (.

On *infrastructure and connectivity*, DBCE research [4, 62] underscores the inseparable link between physical and technological systems. Reliable internet, sufficient bandwidth, and access to appropriate devices are not optional—they are the lifeblood of digital engagement [68]. Without them, motivation alone cannot drive adoption [63]. Connectivity not only enables participation but also fuels a feedback loop: as digital solutions are adopted, demand for better infrastructure grows, prompting further investment [67]. Yet, infrastructure gaps risk deepening the “digital divide,” leaving farmers in poorly connected regions excluded from the benefits of digital agriculture [11, 29].

A third dimension is *data management and security*. Concerns over privacy, ownership, and control of agricultural data remain central barriers to trust and adoption [61]. Trust depends on transparency, clear communication, and robust safeguards [63]. Beyond security, issues of digital literacy, platform interoperability, offline functionality, data quality, and incentives for data sharing [8, 26] shape the effectiveness of DBCE interventions. The message is clear: without confidence in how their data is managed, farmers are unlikely to embrace digital ecosystems fully.

Finally, *user experience (UX) and technical support* form the human interface of digital transformation. Evidence shows that intuitive design and user-friendly platforms are essential for initial adoption, while positive experiences encourage self-efficacy and continued use [15, 19]. Conversely, frustrating interfaces reinforce resistance. Strong technical support further builds trust and empowers farmers to troubleshoot challenges, while mechanisms for user feedback ensure tools evolve with real-world needs [32, 46]. By prioritizing user-centred design, accessible support, and trust-building, DBCE initiatives strengthen digital confidence and accelerate behavioural change. Furthermore, we found that population-level approaches for the design of digital behaviour change systems tend to be more equitable in reducing inequalities than individual-level interventions because they don't rely on individual capacity to engage with interventions [25,33]. These findings suggest that digital innovation value in agriculture is not simply about the availability of technology. It is about building ecosystems where infrastructure, trust, behavioural insight, and user experience align to create lasting change.

5.2 Knowledge systems theme

This theme examines the extent to which users engage with, interpret, and integrate digital knowledge into their everyday decisions. Serving as the *intelligence layer* of the digital behaviour change ecosystem (DBCE), it provides critical guidance for design choices and adaptive strategies. Three core sub-themes are addressed: DBCE systems thinking, DBCE socio-technical system design, and DBCE behavioural change modelling.

5.2.1 DBCE systems thinking

This sub-theme draws on studies [53, 59] that highlight how technology can enable long-term behavioural transformation through systems thinking approaches. Research in this area explores complex adaptive systems, socio-technical integration, and multi-level analysis spanning individuals, communities, and institutions. Central insights include the role of intervention mechanisms, AI-driven nudges, and personalized feedback in shaping sustainable behaviours. By mapping interconnected behavioural patterns, feedback loops, and stakeholder dynamics, these studies offer frameworks for more resilient digital interventions. Methodologically, they combine longitudinal designs, mixed methods, and complex systems modelling to advance scalable solutions that consider the social, technical, and environmental dimensions of sustainability.

5.2.2 DBCE behavioural change modelling

Studies in this area [47] integrate established theoretical frameworks such as TAM, UTAUT, and TPB with modern predictive analytics and machine learning. The goal is to improve user adoption of digital tools and interventions. Research focuses on designing behavioural levers such as nudging, gamification, and real-time personalized feedback to support sustainable choices. Key contributions include methods for measuring behavioural indicators, tracking adoption trajectories, and evaluating the durability of interventions over time. Importantly, this strand of research links theory to practice by testing how digital platforms can modify behaviour at scale while retaining user trust and agency.

5.2.3 DBCE socio-technical system design

Work in this area exposes critical gaps in understanding how socio-technical systems can drive lasting behavioural change, particularly in sustainability transitions [47]. The literature underscores that technology functions most effectively as an enabler within holistic frameworks that combine social and technical dimensions. Central themes include adaptive intervention design, meaningful stakeholder engagement, and system-wide evaluation. Research highlights the need for integrated approaches that reflect diverse social contexts, technical capacities, and behavioural dynamics. Looking forward, developing robust measurement frameworks and embedding long-term perspectives will be essential. Success in this domain depends on balancing technological innovation with social equity and sustainable adoption practices [17]. Thus, these three sub-themes demonstrate that advancing digital behaviour change ecosystems requires more than technological innovation alone. Systems thinking, behavioural modelling, and socio-technical design must converge to create adaptive, inclusive, and evidence-based interventions.

5.3 Behaviour change theme

The behaviour change theme represents the *activation layer*, built on the understanding that human adaptation on digital platforms depends on individuals deliberately choosing whose behaviour or guidance to follow for specific actions. Key areas within this theme include time-based variation, spatial dynamics, competition and behavioural heterogeneity.

Time-based variation theme challenges the assumption that past behaviours or successes are reliable guides for future action [69]. When environments change rapidly—such as in shifting markets, evolving climate conditions, or policy transitions—social cues lose predictive value [70]. Individuals naturally reduce their dependence on conformity and instead give greater weight to current payoffs and immediate outcomes. Digital platforms, therefore, must design temporal adaptation mechanisms that update feedback and guidance in real time, ensuring relevance and maintaining user trust [71]. Static leaderboards or outdated “best practices” can quickly become counterproductive.

Spatial dynamics, by contrast, emphasizes the role of movement between social or geographic contexts. People navigating diverse communities or digital spaces tend to rely more on social information, using peer behaviour as a guide to local norms and success patterns [72]. However, the credibility of traditional indicators such as age or past experience declines when context shifts. Hence, effective digital systems should incorporate localized social learning layers, allowing norms, recommendations, and community examples to adjust by region, demographic, or peer group [12]. Such contextual tailoring enhances both relatability and adoption.

Competition In any behavioural ecosystem—whether in agriculture, health, business, or education—individuals compete for limited resources, attention, or rewards [13]. Learning models such as social network show that as competition intensifies, social imitation becomes less beneficial. When too many people adopt the same action, its relative payoff declines, reducing the incentive to copy others [60, 73]. In digital environments, this manifests as “behavioural saturation,” where uniform adoption leads to diminishing benefits or engagement fatigue. For DBCEs, this insight calls for diversity-sensitive design. Rather than promoting identical actions to all users, systems should encourage a portfolio of adaptive behaviours. Algorithmic diversity, context-aware recommendations, and differentiated goal structures can prevent overcrowding around a single behavioural path. In other words, the most effective digital ecosystems are not those that maximize conformity but those that sustain variation, ensuring the overall resilience of the system [9].

Behavioural heterogeneity Not everyone learns—or responds to digital cues—the same way. Even when exposed to identical environments and interfaces, individuals diverge in how they perceive, interpret, and act on information [74]. Learning-based models such as the COM-B, SFL and social network framework suggest that differences in how people learn and adapt arises naturally from personal experience, random feedback, and differing histories of success [22]. This variability presents both a challenge and an opportunity for digital design. It means that behaviour change systems must move toward personalized and adaptive feedback loops—using data to recognize when users are more responsive to social influence, experimentation, or payoff-based motivation. A dynamic system might, for instance, emphasize social proof for some users while reinforcing independent experimentation for others. Over time, this adaptive

personalization transforms digital interventions from static behaviour guides into evolving learning companions [22].

5.4 Sustainability theme

Following Janker et al. [31], this theme discusses the continuity layer of DBCE which maintains system viability over time. Ensuring the sustainability of a DBCE requires intentional planning across all stages of its life cycle—before, during, and after implementation. Sustainability here goes beyond maintaining technical functionality; it means ensuring long-term relevance, institutional integration, community ownership, and continuous learning within the ecosystem. The axial codes under the sustainable themes are pre-implementation phase: building ownership and relevance, implementation phase: integration and adaptability, and post-implementation phase: institutionalization and knowledge continuity.

5.4.1 Pre-implementation phase: building ownership and relevance

Sustainability begins with co-creation [16]. Engaging key stakeholders early—including policymakers, researchers, digital innovators, behavioural scientists, community representatives, and end-users—ensures the design reflects both system-level needs and local realities. Stakeholder participation should not only validate the project's technical design but also shape its behavioural logic: what motivates users, what digital cues resonate locally, and what barriers may limit uptake. By embedding local voices and institutional partners from the start, the project builds shared ownership and positions the tool as part of a wider digital transformation strategy, rather than a one-off innovation.

5.4.2 Implementation phase: integration and adaptability

During implementation, sustainability depends on how well the digital ecosystem aligns with existing institutional and behavioural systems [81]. We found that the platform must integrate seamlessly into users' daily routines and organizational workflows. This requires conducting continuous needs and acceptability assessments to ensure the tool remains appropriate for diverse user groups and adaptable to emerging feedback. It also involves designing pilots or trials—such as cluster-randomized or pragmatic trials—that reflect real-world conditions, so the digital system complements rather than disrupts existing practices. In addition, the system should be built with modularity and interoperability, allowing it to evolve, scale, and connect with other digital systems over time. Finally, incorporating feedback analytics and behavioural metrics is essential for monitoring how users interact, learn, and adapt, enabling ongoing refinement and improvement. This stage is where the system transitions from a prototype into a living ecosystem—adaptive, context-aware, and capable of evolving with its users and institutions.

5.4.3 Post-implementation phase: institutionalization and knowledge continuity

We found that most digital tools tend to phase out after implementation when they are not institutionalized—particularly when the digital solution is driven by short-term, project-based funding. For long-term sustainability, the digital behaviour change ecosystem must be embedded within established institutional and funding structures:

- Institutional adoption and endorsement by relevant authorities (e.g., ministries, agencies, district agricultural offices or organizations) ensure continued legitimacy and maintenance [39].
- Capacity building through a “training-of-trainers” model equips practitioners, facilitators, and digital stewards to sustain and expand implementation beyond initial sites.
- Integrate monitoring, evaluation, and learning (MEL) into existing operational systems to track real-world impact and behavioural outcomes over time.
- Ensure data governance, security, and ethical use policies are embedded to maintain trust and accountability.
- Promote open science and transparency: share research outputs, methodologies, and tool versions through open-access repositories (e.g., GitHub, agdata hub, institutional portals). This not only encourages replication but also fosters innovation across regions and sectors.

A truly sustainable digital behaviour change ecosystem is *socially grounded, institutionally embedded, and technically adaptive*. It thrives when users feel ownership, institutions see value, and systems are designed to evolve with changing needs and contexts [7]. The goal is not merely to deploy a digital tool but to cultivate a self-sustaining cycle of digital learning and behavioural adaptation—where evidence, feedback, and participation continually reinforce one another for lasting impact.

5.5 Future research direction of DBCE research

In addition to drawing on prior studies, this research highlights under-explored areas that present promising directions for future investigation. It also expands on the research gaps and questions outlined in Table 4. These gaps are discussed in detail below:

5.5.1 Designing digital innovation based on ethical frameworks and transparency

The foundation of any effective digital behaviour change ecosystem must rest on robust ethical provisions that prioritize transparency and accountability. We therefore call on organizations to establish clear methodologies and objectives in all research processes while implementing rigorous data privacy protections. This requires developing comprehensive consent mechanisms for participants and establishing regular ethical review processes that maintain public trust through demonstrable accountability. For organisations and agencies, this translates into creating standardized ethical review mechanisms across all entities, developing comprehensive training programs on ethical research methods, and establishing clear guidelines that protect participant data and privacy. The research emphasizes that without these ethical foundations, behavioural interventions risk losing credibility and effectiveness, particularly in diverse cultural contexts where trust in institutions varies significantly.

5.5.2 Systemic approach

As digital technologies evolve, new behaviours emerge. Thus, we recommend that digital behaviour change initiatives must move beyond individual-level interventions to address the structural and environmental determinants that shape behaviour at scale. This approach recognizes that many behaviours are more effectively changed by addressing environmental factors rather than relying solely on individual motivation and education.

As indicated, population-level interventions have the advantage of not requiring individual engagement to be effective, making them particularly valuable for addressing agricultural and social inequalities. Hence, we argue that the shift toward systems thinking requires organizations to design interventions that reshape contexts and environments, rather than merely educating individuals. This might involve policy-level changes that make desired behaviours easier or more attractive, or environmental modifications that naturally guide people toward better choices. Future studies may address the structural barriers that affect entire populations regardless of individual circumstances or capabilities.

5.5.3 Knowledge systems: testing assumptions underlying existing models and theories

Following the theories underlying DBCE, a deeper understanding of the impacts can be achieved by testing the assumptions underlying existing theories. This type of assumption testing is particularly recommended for established theories [21]. We argue that digital behaviour change brings the constructs, mechanisms, and assumptions of existing theories under scrutiny. As Ofosu-Ampong et al. [49] observed in the context of behavioural intentions and technology adoption, researchers must carefully test and question the assumptions that guide DBCE studies, ensuring that insights are both reliable and relevant for real-world policy and practice. A potential starting framework for evaluating and testing assumptions, is provided by Michie et al. [43]. The DBCE's fundamental shift in the paradigm of digital technologies and human interaction necessitates the articulation and rigorous testing of existing theoretical assumptions, particularly where they are implicit or unstated. This crucial process of assumption testing will not only illuminate potential flaws in current understandings but also pave the way for discovering new constructs and relationships, ultimately leading to the development of more robust and relevant theories. To support the effective implementation of DBCE, future research is encouraged to focus on developing practical tools such as frameworks, models, and methodologies. All interventions must be grounded in rigorous evidence while maintaining adaptability for local contexts and emerging challenges.

5.5.4 Sustainable digital behaviour change ecosystems

Despite increasing investment in digital behaviour change tools, there remains a significant gap in understanding how to build *sustainable digital behaviour change ecosystems* that can endure beyond short-term projects. Most existing systems focus on deployment rather than long-term adaptation, and they rarely integrate the social, institutional, and technical conditions required for sustained use. We still lack evidence on how to design platforms that foster genuine user ownership, institutional commitment, and continuous behavioural adaptation. Our study fills a critical gap by providing a framework that demonstrates how digital tools can evolve with changing contexts, creating a self-sustaining cycle in which evidence, feedback, and participation continually reinforce one another—an achievement that offers a foundation for future research and innovation to build upon.

6 Conclusion

This paper presents a systematic literature review examining the state of DBCE research and identifying potential areas for future investigation. The study examined the dominant themes in DBCE, methodology and methods employed in DBCE and the theories and frameworks underlying DBCE research. Research gaps that exist in current DBCE research for future studies was also addressed.

The analysis reveals that DBCE research can be categorised into four main themes: digital innovation value, knowledge systems, behaviour change, and DBCE sustainability. Organisations' willingness to adopt digital innovation—the foundational layer of the DBCE—is driven by productivity, social impact, regulatory direction, and the need for strong ethical standards that ensure transparency and accountability. This knowledge system theme explores how users engage with and apply digital knowledge in daily decisions, forming the intelligence layer of the DBCE through its focus on systems thinking, socio-technical design, and behavioural change modelling. From the DBCE sustainability perspective, we found that engaging key stakeholders early ensures the design reflects both system-level needs and local realities and categorise into pre-implementation, implementation and post-implementation phase. The behaviour change theme focuses on the activation layer that drives user engagement, highlighting the roles of temporal variation, spatial dynamics, competition, and behavioural heterogeneity.

Given the preliminary nature of this work, our objective is to establish a clear and practical reference framework for behavioural scholars and practitioners engaged in agriculture, information systems, and circular business models. In addition, we aim to identify and highlight promising pathways for future research and practical action in these areas. We encourage future studies to expand the scope of database coverage to include literature from health, business, and the digital economy, thereby strengthening and broadening the insights generated by our findings.

Acknowledgements

We extend our gratitude to the CGIAR Sustainable Farming Program and the Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) Ghana for their support. We also thank the editors and reviewers for their valuable contributions to improving the quality of this paper.

Author contributions

KOA wrote the main manuscript text, and E.M. and ARM prepared figures and performed analysis and framework. All authors reviewed the manuscript.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent to publish

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

Received: 23 March 2025 / Accepted: 22 December 2025

Published online: 03 January 2026

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