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Framing behaviour change for sustainable agriculture: Themes, approaches, and future directions

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ABSTRACT

Despite the growing demand for behaviour change research and the benefit of understanding how human behaviour influences use cases and the adoption of agricultural innovations, research on how behaviour change occurs and the state of knowledge in the field remains scarce. To address this concern, this study conducted a systematic literature review of behaviour change in sustainable agriculture between 2015 and 2024. Our search identified 568 studies. After careful evaluation, 74 primary studies were selected and analysed to synthesize key themes relevant to our research objectives. Findings point to four promising approaches (innovative, empowerment, historical and knowledge co-creation, and structural and systemic) that can effectively address the complex challenges and promote sustainability in behaviour change agriculture. By emphasizing long-term solutions and empowering farmers to make informed decisions, these approaches contribute to improved environmental health, increased farm economic profitability, and enhanced social equity and well-being for farmers. Further, we found socio-economic factors and environmental conditions as two key determinants that affect the adoption of sustainable agriculture practices. Thus, adoption of sustainable practices is influenced by a combination of factors, rather than any single variable behaviour and the implication of these factors can vary significantly across different regions and cultural contexts. Our analysis makes important contributions, namely, (i) defining behaviour change in sustainable agriculture, (ii) approaches on how behaviour change can occur, and (iii) model development on sustainable agriculture behaviour change. The study provides practical implications for government agencies, agricultural extension services, research institutions and non-governmental organisations (NGOs) to identify specific behaviours that contribute to food insecurity and unsustainable agriculture practices. Such knowledge can help the creation of targeted interventions that address the root causes of these problems.

1. Introduction

The relationship between behaviour change research (BCR) and agriculture remains unclear despite years of research in this field with meta-analyses reporting different interventions (e.g. improving farmers' access to climate information ease their access to crop insurance) as more effective for certain behaviours (Osbaldiston and Schott, 2012). Consequently, this has attracted growing attention and investment from development donors, research for development organisations, and governmental agencies in developing countries (FAO, 2022). The main problem in BCR lies in our conceptualisation of the processes by which behaviour change (BC) occurs in the agricultural sector (World Bank, 2017; Badiane et al., 2021; Hidrobo et al., 2022).

Conducting BCR offers a promising way to improve agriculture in low and middle-income countries by providing farmers with better information, access to markets, insurance coverage and financial tools (Mugambiwa and Tirivangasi, 2017). This intervention could lead to higher yields, more income for farmers and sustainable benefits. Unlike digital technologies in agriculture, BCR itself doesn't inherently widen social disparities – in reality, it is a powerful tool to narrow them. However, the design and implementation of BC interventions can unintentionally exacerbate existing social inequalities (Leta et al., 2018). E.g.

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research might focus on the behaviours and needs of the most easily accessible population, thereby neglecting the specific circumstances of a marginalised group.

Behaviour theorists (e.g., Darnton and Evans, 2013) have defined BC as the process resulting in an individual or group modifying or adopting new behaviours. BC seems straightforward at first glance, but the closer we examine it, the more elusive its definition becomes. For instance, the Food and Agriculture Organisation (FAO) described BC as a strategy (desired changes) to achieve improvements in agricultural productivity (FAO, 2022). Thus, research on BC in agriculture has been largely phenomenological in exploring how things appear to us; neglecting a more cross-disciplinary investigation into its themes, antecedents and underlying causes or approaches. In short, our current understanding of BC conceptualisation in agriculture is limited. Therefore, this study aims to review relevant BC studies in sustainable agriculture and analyses classifications, definitions, measurements and concurrences. Specifically, the literature analysis answers the following questions.

a How can we effectively identify and prioritize specific agricultural behaviours that, if changed, would have the greatest positive impact on sustainability?

We answer these questions by conducting a systematic literature review. By answering these questions, this study provides a more systematic understanding of how BC occurs in the agrifood system across different actors (farmers and government agents) to inform policy and research on behavioural change. By understanding the needs, preferences and challenges of farmers, implementers and policymakers can significantly increase the effectiveness of BC initiatives.

This review article is organised as follows. First, is the classification of the BC framework and its related conceptual themes. Second, the methodology outlines the criteria for articles included or excluded from the literature review resulting in 74 identified studies. The rest of the paper shows the results in different phases including definitions, approaches, measurements, and implication and recommendations.

2. Methodology

This literature review involves two stages as suggested by Webster and Watson (2002). The first stage was more rigorous towards identifying the keyword search in peer-reviewed journal articles. Fig. 1 shows the search and selection process for the review. Literature searches were undertaken across Google Scholar, Emerald, Scopus, and Science Direct to cover relevant studies, targeting publications from 2015 to 2024. We chose this period because the field of BCR especially in agriculture has

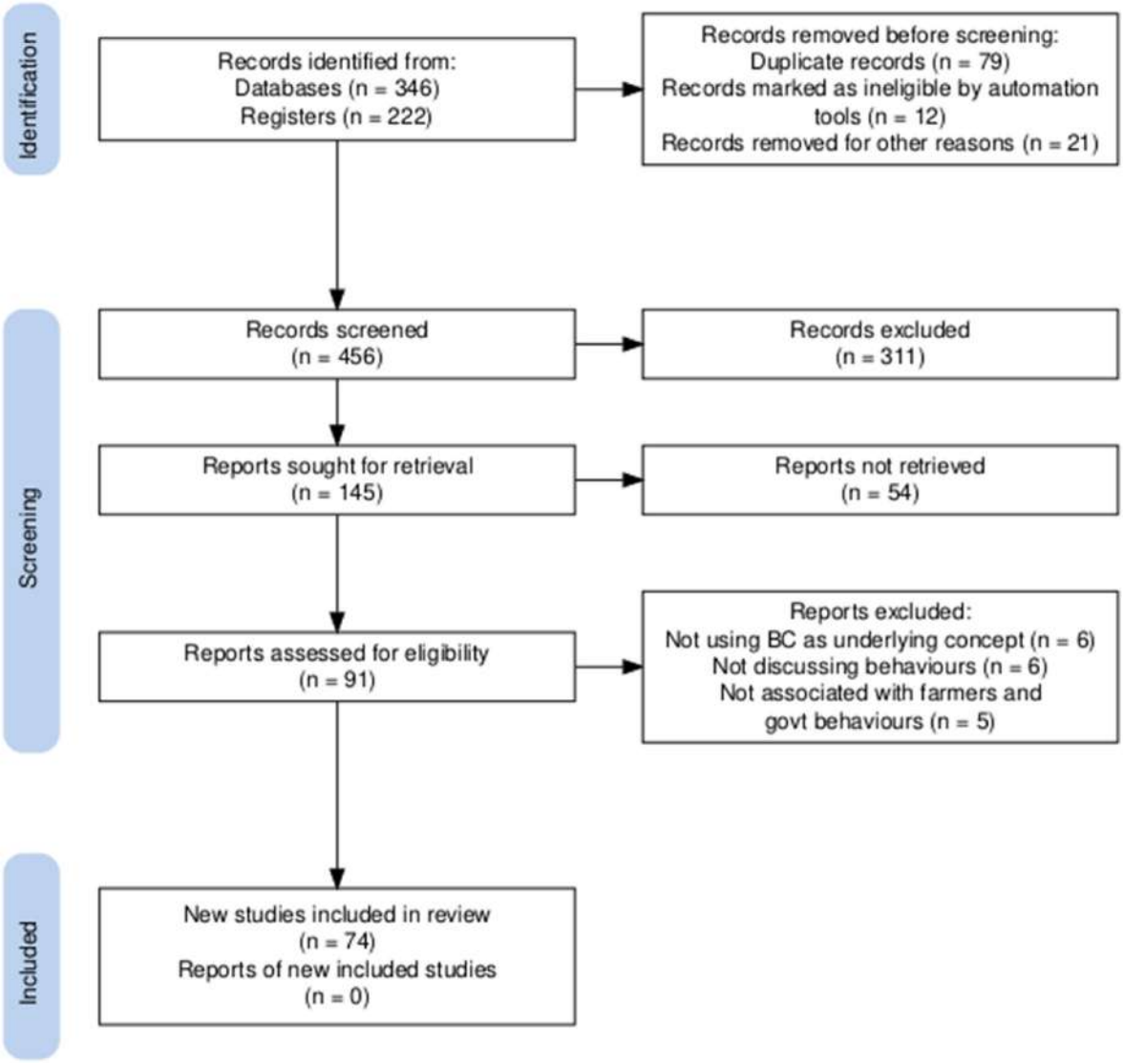

Fig. 1. Search and selection process.

seen significant growth in recent years. Thus, studies from 2015 capture the emergence of new approaches, interventions and theories that were not as prevalent before. However, the Scopus database was used as our key data source. Boolean operators were used on a range of terms associated with key stakeholders (e.g. farmers, government) and behavioural change. The strings used include *behaviour* or *behavioural change* and (farmers* OR *sustainable practices* *agriculture*) and (sustainable agriculture, agrifood system, or farming*) and ("Behaviour change" "behaviour" OR ("sustainability") AND "agriculture" "farmers" "agrifood system"). The focus was on farmers' behavioural change; however, we considered the government agencies and marginalised groups in agriculture such as women and youth. Using the keywords we found 568 articles relevant to our study from 2015 to 2024. Further, we refined to agricultural sciences. It should be noted that the topics and articles were mostly focused on health, education, and consumer behaviour studies with a limited review of BC in the agricultural sector. Given that we seek to define and understand BC and how it occurs, our search targeted articles that incorporate human-centred influence and behaviour factors in research. Our continuous refinement resulted in the selection of 145 articles.

In the second stage, we enhanced the inclusion and exclusion criteria by including studies that a) used BC (including influence behaviour) as the underlying conceptual term and focus of the research and b) addressed farmers and government issues associated with behaviours in sustainable agriculture in the paper review. We excluded papers that did not discuss behaviours, sustainable agriculture, farmers and government perspectives and issues, papers with no empirical findings and those not centred on behavioural and human factors in agriculture. Finally, we identified 74 relevant research articles necessary for the literature analysis.

3. Definitions and conceptualisation of BCR: themes and sub-themes

This section synthesises the existing BC literature in agriculture and elaborates on the key themes and approaches listed in Table 1 from the literature review. Studies included in the classification were identified using the abovementioned keywords. The thematic classification, similar to those employed in previous studies, underscores the significance of the research gap (see Hazell and Wood, 2008; Osbaldiston and Schott, 2012; Harriss, 2023). These classifications reflect the BC conceptualisation and the historical context of how the field has changed over time. In all, we found 4 themes that exist in the literature, 11 new sub-themes classification and 4 new classification approaches to how behaviour occurs. Thus, the existing themes were broken down into their core components and reassembled into innovative sub-themes. Consequently, we combined the new sub-themes to create hybrid concepts (i.e. BC approaches).

The four themes are typology of change, drivers of change, level of analysis of change and conceptualisation and strategies of change, while the four approaches of BC occurrence for this review include innovation, historical and knowledge co-creation, empowerment and structural and systemic.

3.1. Typology of BC in agriculture

The first group emphasises the kind of outcome resulting from behaviour in agriculture (Pathak et al., 2019; Adams et al., 2021). From the review, three main oriented typologies were identified: literature that focuses on understanding production-oriented, conservation-oriented and socioeconomic-oriented BC. However, some studies (Bartkowski et al., 2022; Huber et al., 2024) classified the typologies into two, namely farmer typologies (focusing on farmers' characteristics and behaviour) and farm system typologies (focusing on socio-environmental and structural characteristics of farming) due to a conceptual overlap of the typologies.

However, from a productivist perspective, we found three typologies of behaviour. First, the *production-oriented typology* refers to changes in behaviour in farming practices that significantly affect yield stability, reduced risk, climate adaptation and resource use efficiency (Hyland et al., 2016; Bartkowski et al., 2022). Investments in this category have shown a highly efficient use of public funding in sub-Saharan Africa (Pardey et al., 2016). Examples include the adoption of new technologies for improving irrigation management, food processing and crop varieties (Mashnik et al., 2017). Precisely, BC at this stage leads to the adoption of new technologies and vice versa. Typologies of behaviours in this category engage in farming as a full-time activity and are innovators who are open to trying new technologies (Bartkowski et al., 2022), hence their behavioural change patterns can be studied for a long period.

Conservation-oriented typologies are widely promoted for their role in achieving sustainable agricultural intensification (Brown et al., 2018). These farmers prioritize the conservation of natural resources and the environment, feeling responsible for their practices. Examples include soil conservation practices that increase soil fertility and moisture, reduce toxic contamination of water sources, and promote reduced pesticide use and cover cropping practices (Marongwe et al., 2012).

Socioeconomic-oriented typologies highlight behavioural changes that enhance the well-being and livelihoods of farmers and communities. Examples include changes that increase access to agricultural advisory support and financial resources, as well as adopting new marketing

Table 1
Classification of behaviour change (BC).

Themes *What exist*	Sub-themes *New classification*	BC approaches *New classification*	Citations
Typology of change	Production-oriented, conservation-oriented and socioeconomic-oriented typology	Innovation approach	Pathak et al. (2019); Hrustek (2020); Adams et al. (2021); McNamara et al. (2021); Bartkowski et al. (2022); Huber et al. (2024); Kumar and Pant (2023); Pan et al. (2024)
Drivers of change	Economic and regulatory, social and technological, and psychological drivers	Empowerment or participatory approach	Alizamir et al. (2019); Alston and Pardey (2021); Kumar et al. (2021); Ruzzante et al. (2021); van Ewijk and Ros-Tonen (2021); Giua et al. (2022);
Level of analysis of change	Individual, household and community perspectives	Historical and knowledge co-creation approach	Dolinska and d'Aquino (2016); Lankoski and Thiem (2020); Chaudhuri et al. (2021); Giller et al. (2021); Dutta and Shambu (2022); Devkota et al. (2023); Hsu et al. (2023),Pan et al. (2024);
Conceptualisation of change	Multi-level and model development	Structural and systemic approach	Lambe et al. (2020); Tama et al., (2021); Kurniawan et al. (2023); Graskemper et al. (2022); Maulu et al. (2021)

strategies and forming cooperatives (Hrustek, 2020). Interestingly, a growing need exists for "well-being" advisors as a source of support for farmers' well-being, classified as a socioeconomic need (Hammersley et al., 2023). Proponents of "well-being" advisory services under this typology (McNamara et al., 2021) argue that supporting farmers and their communities with a wide range of services, like access to knowledge and information, can improve their farming practices and ultimately enhance their socioeconomic status. Socioeconomic typology can account for the characterisation of farms and farmers according to spatial differences in the economy and SSA.

3.2. Drivers or determinants of BCR

The second category of definition is the drivers or determinants of BC. Under this category, there are three (3) main determinants. The first is economic and regulatory determinants (Alston and Pardey, 2014, 2021). This determinant highlights factors like governmental policies or incentives, subsidies and financial incentives, or market forces (demand and supply) that affect farmers' decisions to adopt new technologies or practices (Alston and Pardey, 2014; Alizamir et al., 2019). The socio-technical determinants (Massresha et al., 2021) emphasise the influence of social influence, social networks, and community norms on farmers' behaviour. Thus, the social and technological determinants are appropriate for uncovering internal and external drivers of farmers' BC (Giua et al., 2022). The third driver is the psychological determinants, i.e., individual factors such as attitude, self-efficacy, knowledge, privacy concern and knowledge that influence farmers' decision-making. Prior studies show that long-term habits serve as a resistance to BC initiatives (Mankad, 2016). Furthermore, our findings revealed divergent adoption patterns. Improved varieties and chemical inputs were more readily adopted on larger farms, suggesting potential inequities for smallholders (e.g., Ruzzante et al., 2021). Given the wide variation in adoption determinants across technologies, cultures, and geographies, our review underscores the necessity of tailored approaches to technology promotion, as a one-size-fits-all strategy is unlikely to succeed.

3.3. Level of analysis of BCR

The level of analysis categorization considers BC focus in terms of individual, household, and community perspectives (Dolinska and d'Aquino, 2016; Chaudhuri et al., 2021). This level helps to shape the scope of defining BC within the context of agricultural inputs. The majority of articles fell within the individual category, focusing on farmers' perspectives (Pan et al., 2024). These articles explore farmers' behavioural preferences and adoption (Giller et al., 2021; Devkota et al., 2023). However, a significant number focused on household BC compared to community-based behaviours (Chaudhuri et al., 2021; Tran-Nam and Tiet, 2022; Wu et al., 2024). For instance, Pan et al. (2024) highlight that rural households' innovation and entrepreneurship positively impact regional agriculture change and rural economic development in China, but there is room for improvement. This indicates that BC remains a recognized issue among farmers and households, and it has a spillover effect on regional agriculture development.

3.4. Conceptualisation of BCR

This part of our analysis focused on the three conceptualisation levels of BC in agriculture that emerged from the multi-level perspective and model development. The conceptualisation level of analysis was done based on micro, meso and macro levels of BC. Table 2 shows the conceptualisation and its levels and a research issue describing how to incentivize BCR. The *multi-level perspective* considers the individual farmer demographics such as a focus on motivation, access to resources, risk tolerance, climate variability and shocks, income and education, farm typologies, land use, and values to decide (Tama et al., 2021; Huber et al., 2024; Muriithi et al., 2024).

Table 2
Conceptualising BCR.

Conceptualisation	Level of conceptualisation	Research issue	Reference
Multi-level perspective	Individual farmer level	Focus on motivation, access to resources, skills, risk tolerance, knowledge and beliefs, values, farm typologies, climate variability and shocks	Lambe et al. (2020); Tama et al. (2021); Huber et al. (2024); Muriithi et al. (2024)
	Community level and social influence	Social influence and norms, networks, community heads and peers shaping farmers' choices, cooperative links	Kurniawan et al. (2023); Moghfeli et al. (2023)
	Contextual institutional level	Regulations, market forces, subsidies, policies and access frontiers that affect farmers' decision	Cheng and Cheng (2021); Xie and Huang (2021)
Model development – *behaviour change techniques*	COM-B model	Model of human behaviour: capability, opportunity (market access) and motivation framework	Tensi et al. (2022); Farrell et al., 2023
	Theory of planned behaviour	Socio-economic and psychological factors e.g. attitude, perceived behavioural control, subjective norm, knowledge, perceived financial and agricultural benefit, risk perception	Tama et al. (2021); Pan et al. (2021)
	Diffusion of innovation theory	Process of adoption of innovation via time, communication channels, innovation and social system; new crop varieties, promoting best farm practices	Lambe et al. (2020); Upadhaya et al. (2023)

Community context and social influence shape farmers' choices through norms, leaders, and peer interactions. For example, Kurniawan et al. (2023) found that social and economic benefits significantly influence how farmers perceive resource availability. However, Moghfeli et al. (2023) highlight instances where weak cooperative links within communities limit information and resource sharing. Additionally, Bennett and Cattle (2014) describe farmers' hesitation to collaborate due to program-specific motivations. While farmer organisations are often seen as pathways to sustainable agriculture (Jelsma et al., 2024), their effectiveness can vary over time. This highlights the diverse nature of social networks and the need for further research on their role in building capital for sustainable agriculture.

The contextual institutional level shapes how regulations, market forces, subsidies, policies, and access limitations affect farmers' decision-making. For example, farmers' willingness to participate in a program, their knowledge of the policy, compensation for resettlement, and pre-settlement conditions were all significantly influenced by the level of satisfaction with policy and regulation implementation (Cheng and Cheng, 2021). These regulations and policies can directly impact farmers' decisions (e.g., subsidies, land use) and indirectly influence them through factors like market stability, research, and development. **BC**

model development in agriculture research draws on three major theoretical frameworks: the COM-B model, the theory of planned behaviour (TPB), and the diffusion of innovation theory. The COM-B model highlights the importance of building trust through financial (e.g. subsidies, crop insurance), non-financial (e.g., technical assistance, research, market access) and environmentally focused incentives (e.g. conservation programs). This is crucial because farmers expect advisors to have extensive knowledge and field experience (Tensi et al., 2022).

The TPB focuses on socio-economic and psychological factors influencing behaviour, such as perceived control, social norms, and expected benefits (Tama et al., 2021; Pan et al., 2021). Recent research expands the TPB by incorporating environmental risk perception, moral norms, and perceived policy effectiveness (Li et al., 2024). Finally, the diffusion of innovation theory helps researchers understand new practices, identify target audiences, and manage the communication process in farming (Lambe et al., 2020; Upadhaya et al., 2023). However, successful modelling of BC must consider context specificity, ethical considerations, individual agency, and long-term strategies for maintaining BC (Cheng and Cheng, 2021; Huber et al., 2024).

Based on the four thematic areas explained above (Table 3), we *define* behaviour change research, as in the case of agricultural context, as the act of identifying an *agricultural-oriented behaviour* by understanding its determinants, selecting an appropriate level of analysis and employing relevant conceptualisation/frameworks or strategies to develop a sustained positive change through effective interventions. Conversely, BC is an act of modifying farmers' behaviours.

Additionally, ***ethical considerations*** are paramount in behaviour change research, particularly in sensitive areas like agriculture, where livelihoods, environment, and public health intersect. Our review of behaviour change revealed the growing importance of ethical considerations within sustainable agriculture (Coskun et al., 2015). While behaviour change interventions aim to reduce negative or enhance positive impacts by shaping user perceptions and interactions, they also carry the potential to raise ethical concerns (Lilley and Wilson, 2013). Thus, the exploration of ethical dimensions in behaviour change implementation remains limited. Currently, there is a significant lack of a framework to ethically evaluate interventions or assess their potential ethical implications within and beyond their intended context. Consequently, behaviour change implementers must anticipate and assess the ethical implications of their interventions on users, society, and the environment. Key ethical issues associated with behaviour change research include informed consent, privacy and confidentiality, power dynamics, economic impact and vulnerable populations. In Table 4, we highlight the ethical considerations, ethical concerns and ethical safeguards related to behaviour change research.

Ethical research is fundamental to building trust and ensuring the integrity of behaviour change interventions in agriculture. By adhering to ethical principles and implementing appropriate safeguards, researchers can contribute to positive change while safeguarding the rights and well-being of farmers and the environment.

Table 3
Summary of definitions of BCR in agriculture.

Themes	Definitions	Reference
Typology of behaviour change	*identifying an agricultural-oriented outcome of a behaviour*	Hrustek (2020); Adams et al. (2021); Bartkowski et al. (2022)
Drivers of behaviour change	*understanding its determinants of change*	Alston and Pardey (2014, 2021); Ruzzante et al. (2021)
Level of analysis of behaviour change	*selecting an appropriate level of analysis*	Tran-Nam and Tiet (2022); Wu et al. (2024)
Conceptualisation	*employing relevant conceptualisation/frameworks or strategies to develop a sustained positive change through effective interventions*	Pan et al. (2021); Farrell et al. (2023)

Table 4
Ethical consideration in behaviour change.

Ethical consideration	Ethical Concerns in Behaviour Change Research	Ethical safeguards	Reference
Informed consent	Participants must fully understand the research, its potential benefits and risks, and their right to withdraw	Obtain ethical approval from relevant review boards	Lambe et al. (2020); Hammersley et al. (2023); Moghfeli et al. (2023);
Privacy and Confidentiality	Protecting sensitive information about participants, their practices, and animals is essential	Conduct regular ethical reviews throughout the research	Huber et al. (2024);
Power Dynamics	Recognizing and addressing power imbalances between researchers and participants is crucial to prevent exploitation	Involve participants in the research process to ensure their perspectives are considered	Alizamir et al. (2019); Alston and Pardey (2021); Tama et al. (2021);
Economic Impact	Considering the financial implications of behaviour changes on farmers is essential to ensure sustainability and fairness	Provide transparent information about the research and its potential impacts	
Vulnerable Populations (data sharing and ownership)	Farmers often face unique challenges, requiring extra care to protect their rights and well-being	Offer support and resources to participants during and after the study. Implement robust data protection measures	Pan et al. (2024)

3.5. Sustainable agriculture and BCR

Sustainable agriculture encompasses farming practices that minimize environmental harm, ensure profitable and promote social equitable (Shrestha et al., 2021). It includes the use of data-driven methods to optimise resource use (precision farming). Furthermore, sustainable agriculture promotes ecological balance like soil health improvement, biodiversity and organic farming (Mugambiwa and Tirivangasi, 2017). Promoting sustainable agriculture practices is essential for ensuring food security, which encompasses practices throughout the food chain value system to minimize food waste (Jelsma et al., 2024).

Sustainable agriculture is the fundamental shift in how food production is approached, not just about fancy technology (Rusdiyana et al., 2024). BC sits at the heart of this transformation. It acts as the engine that drives farmers and communities towards a more sustainable future. Therefore, BC is crucial for achieving sustainable agriculture because it helps to bridge the knowledge-action gap. For example, farmers often know sustainable practices but translating that knowledge into action can be difficult (Barnes et al., 2013). In this regard, BC initiatives close this gap by addressing the social norms, psychological barriers and economic considerations that might hinder adoption (Giua et al., 2022). Also, BC can scale up its impact by fostering peer learning and showing successful examples that can turn localised efforts into a powerful movement for social change.

3.5.1. What are the behavioural change factors that affect sustainable agriculture?

Promoting sustainable agriculture requires a shift in behaviours among farmers, consumers, and policymakers. Previous studies have identified several factors such as farmer and household characteristics, economic and financial factors, environmental and health concerns, social considerations, and psychological and institutional factors as behavioural factors affecting the adoption of sustainable agriculture practices (Huber et al., 2024; Priya and Singh, 2024). Based on the analysis of the reviewed literature, we found socio-economic factors and environmental conditions as key determinants that affect the adoption of sustainable agriculture practices. Often, older farmers are more risk-averse and resistant to change due to long-standing practices. Conversely, younger farmers are more likely to adopt new technologies due to risk-taking behaviour and higher education levels (Melesse, 2018). We also found a positive correlation between higher education and sustainable practices. For example, higher education often leads to increased knowledge and environmental awareness, promoting the adoption of sustainable practices (Joshi et al., 2019). In some countries, like Malaysia education levels do not significantly impact adoption decisions. Gender-wise, female farmers often show high motivation to adopt new technologies and innovation, while studies in Sri Lanka found gender as a non-predictor of adoption (Laosutsan et al., 2019). Also, their psychological attributes towards intention to adopt, productivity, cost and access to credit, knowledge and insurance influence sustainable practices (Melesse, 2018; Priya and Singh, 2024).

Furthermore, the adoption of sustainable agriculture practices has been shaped not only by socio-economic factors but also by the underlying environmental conditions, often site-specific practices dependent on location or geography. Key environmental factors found in the literature include soil fertility, adverse effects of fertilizer, farm size, distance to market, rainfall patterns, dry spells, soil type and groundwater (Mugambiwa and Tirivangasi, 2017; Jelsma et al., 2024). These factors combine to drive farmers' need for technical and financial assistance, such as access to knowledge, machinery, credit, crop insurance, and information (Lambe et al., 2020; Tama et al., 2021). In short, adoption of sustainable practices is likely influenced by a combination of factors, rather than any single variable behaviour and the implication of these factors can vary significantly across different regions and cultural contexts.

4. Conceptualisation of BC approaches (how it occurs)

From the review, we identified four main pathways through which BC occurs in sustainable agriculture (Table 1): i) innovative approach ii) historical and knowledge co-creation approach iii) empowerment approach and iv) structural and systemic approach. These four approaches are both an elaboration of how normative theories tailored to agricultural societies are changing and a description of the digital transformation processes in different contexts.

4.1. Innovative approach

The first approach to the study of BC of farmers in sustainable agriculture is what we describe briefly as an *'innovative approach'*. Studies in this category are concerned with how farmers *respond* to the allocation of resources and markets, and how the farmers innovate (Kumar and Pant, 2023). The dominant innovative approach includes the application of new agricultural technologies, development of new agricultural markets, resource allocation, promotion of new agricultural varieties and the emergence of new forms of agricultural organisations (Pan et al., 2024). For instance, there is a growing acceptance of nutritionally enhanced (maize) varieties, while new agricultural plant varieties often prioritise the protection of intellectual property through patents and plant variety rights (Prasanna et al., 2020). Thus, behavioural insights on nutritional sufficiency and increased adoption of modern agricultural practices (e.g.use of molecular marker-assisted selection) are now applied to rural innovation for sustainable agriculture. Furthermore, studies on the application of new technologies have focused on mechanisation, rural internet development, digital financial services (mobile money), implementation of electronic commerce and rural commodity price index as determinants of BC (Mei et al., 2020; Wu et al., 2024). Interestingly, e-commerce development in rural areas increases entrepreneurial BC and stimulates entrepreneurial enthusiasm and culture (Mei et al., 2020). Developing new agricultural markets is of keen interest, with a particular focus on e-commerce market platforms and the structure of agricultural input resources (e.g. expenditure on research and development). There is also strong interest in new forms of agricultural organisations. Studies in this category seek to understand farmers' specialised cooperatives and large professional households (Pan et al., 2024). The essence of e-commerce development in agriculture is to promote economic transformation in five key areas: *improved market access, reduced wastage, enhanced price transparency, increased efficiency, and improved product traceability*. Substantially, most studies have explored how farmers respond to agricultural technologies using technology acceptance models *where they perceive usefulness, ease of use, attitude towards using and behavioural intentions to use* to explain access to resources and technologies, and venturing into uncertain markets (Li et al., 2024; Ofosu-Ampong, 2024). In the absence of technologies to explore farmers' productivity, this approach provides a good understanding of *how farmers innovate and make decisions*.

4.2. Historical and knowledge co-creation approach

The second approach, which we distinguish and define as historical and knowledge co-creation attempts to represent a shift from traditional agricultural knowledge to a more collaborative and inclusive approach (Kumar et al., 2021). Historically, agricultural knowledge flowed unidirectional (e.g. from scientists and extension officers to farmers) and is often location-specific (Norgaard, 1984). The behaviour concern of this historical approach is that it often ignored valuable practical knowledge held by the farmers themselves in favour of scientific methods. Interestingly, this practical knowledge was adapted to local contexts as passed down by generations (Norgaard, 1984; Kumar et al., 2021). However, the knowledge co-creation approach has strengthened the collaborative creation of historical behaviours and bridges the gap between different agricultural knowledge systems. Precisely, knowledge co-creation highlights the collaborative creation of knowledge through interaction among different stakeholders (van Ewijk and Ros-Tonen, 2021). This approach recognized the scientific knowledge generated through research, farmer knowledge based on practical experience and indigenous knowledge rooted in cultural understanding of agriculture in context. Our review suggests that by building on the strength of all stakeholders' knowledge – *from traditional to scientific*, a more resilient, sustainable, and equitable food system can be achieved for UN SDG Goal 2. Thus, a framework for historical and knowledge co-creation consists of co-historical insights (traditional-scientific joint briefing), co-design (joint stakeholders and decision makers meeting), co-production of knowledge (scientific integration and relevance) and co-dissemination (dissemination of results and reflections among stakeholders) (Maulu et al., 2021).

4.3. Empowerment approach

The empowerment approach, also known as *participatory approach* is the process where farmers or groups are allowed to actively participate in decision-making and implementation of activities that affect their farming systems and lives. As many global sustainability issues stem from human behaviour, empowerment becomes a critical hurdle in the agricultural system to promote a shift in the mindsets and actions of smallholder farmers, women and rural youth. Many studies in this category focus on farm economies that are concerned with the allocation of resources and farmers' responses to policies, markets and new technologies

(Lankoski and Thiem, 2020; Dutta and Shambu, 2022; Hsu et al., 2023). For example, some studies found that increasing women's assets and income influences household food and education expenditure (Anderson et al., 2021). This position is however contested as some studies found no significant association or mixed results of women's asset control or increase in income and empowerment (Anderson et al., 2021; Aziz et al., 2022). In comparison with men, other studies found no difference in productivity gains towards empowerment (Wossen et al., 2017). Interestingly, we found that empowerment is a highlighted issue in Africa. For instance, a study in Kenya found that there is a positive association between women's empowerment and maize productivity, where a unit increase in women's decision-making on production influences 32% increase in maize production (Diiro et al., 2018). Technically, women in farming were found to be more technically efficient than men in Cameroon (Akamin et al., 2017) while in Bangladesh, closing the empowerment gap between men and women was found to significantly improve technical efficiency for plots (assets) management (Seymour, 2017). Notwithstanding the mixed results, our findings show that farmer empowerment concerns improved nutrition, female earning status and income, youth interest in farming, mothers' education, economic benefits and overall household commercialisation of farm production (Anderson et al., 2021). Overall, empowering women and minority groups in agriculture with ownership, education and economic power seems to lead to better sustainable outcomes for families and promotes a more participatory approach to interventions. Generally, empowering actors in agriculture creates a positive change towards increased productivity and sustainability, food security, economic growth and rural development, and social equity and gender parity. Empowering approaches require support from government policies, public-private partnerships, and knowledge sharing and capacity building.

4.4. *Structural and systemic approach*

Studies under the structural/systemic approach are concerned with the inter-relationship of farmers and the natural environment (Brown et al., 2018; Devkota et al., 2023). This approach highlights how structures enable systems to function. While studies on the systemic approach place more emphasis on the ownership and control of resources (Graskemper et al., 2022), the structural approach focuses on social relationships to unravel the social classes in the ownership and control of resources by individuals, groups or communities (Haynie et al., 2021). Thus, the structural/systemic approaches are necessarily historical and take on many specific forms in different contexts of the interconnectedness of stakeholders in the agricultural system.

The synergy of the approaches is that the structural approach provides a building block mostly in the form of regulations, traditional norms and incentives. In contrast, the systemic approach fosters long-term solutions and promotes new sustainability practices. Studies on this approach reflect rural developments in policy and process and are mostly concerned with distribution and poverty eradication in agricultural systems (Maulu et al., 2021).

Furthermore, the relevance of structural and systemic approaches in recent agricultural practices stems from the interconnectedness of various behavioural components within the agricultural value chain (Savage et al., 2023). It considers the entire agricultural system and models on understanding how changes in one section affect others. Fig. 2 shows how a structural and systemic approach can be applied to collaboratively address complex challenges and achieve sustainable results.

An example of the structural and systemic approach is where a farmer considers the entire ecosystem to manage pests rather than relying solely on chemical control. The systemic approach ensures resilient, efficient and digitising agricultural development that benefit all stakeholders. While digitising development holds great potential for a structural and systemic approach, individual-level maturity may hinder its progress. As Ofosu-Ampong (2024) points out, overcoming the 'technology asset exposure myth'—*the belief that withholding information due to superstition and accountability is good and won't harm progress*—and reducing political interference in the economy is essential for digitising development in the agricultural sector, especially in Africa.

5. Sustainable agriculture BC model

Our literature analysis indicates that previous studies have not explored how BC occurs at various stages and how key stakeholders evolve with time, functions and context. Also, studies have shown that it is not possible to engineer and control the behaviour of complex human and ecological systems (Woodhill et al., 2020). Consequently, our framework (see Fig. 3) provides a system relationship that nudges intervention approaches toward more desirable outcomes and reduces undesirable directions. By acknowledging concepts and research gaps in BC in agricultural studies, this study builds on the diffusion of innovation concept to propose an integrative framework for BC of stakeholders in sustainable agriculture. The findings of innovative strategies, historical and knowledge co-creation strategies, regulatory and structural strategies and empowerment strategies signify the importance of having a comprehensive understanding of how behavioural change occurs towards a sustainable world.

The proposed sustainable agriculture BC model is schematically represented in Fig. 3. As shown, the innovative approach, historical and

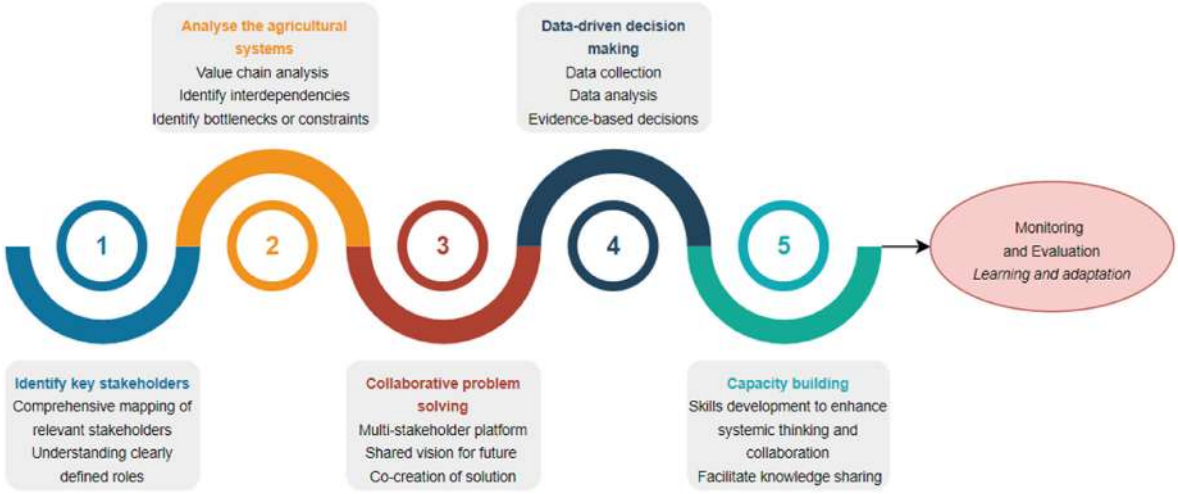

Fig. 2. Structural and systemic approach to behaviour change.

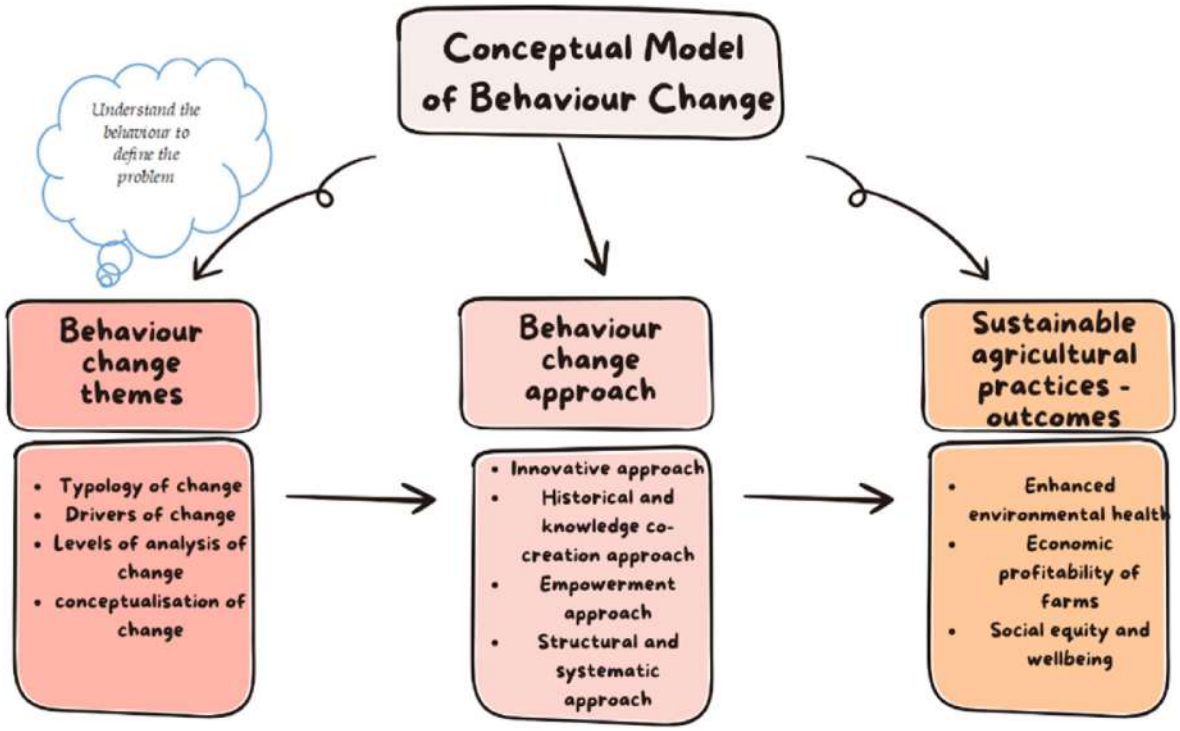

Fig. 3. Conceptual model of behaviour change in sustainable agriculture.

knowledge co-creation approach, empowerment approach, and structural and systemic approach are influenced by the typology of change, drivers of change, level of analysis of change and conceptualisation of change. In turn, when farmers adopt the appropriate BC approach, sustainable agricultural practice is achieved, resulting in enhanced environmental health, farm economic profitability, and social equity and well-being of farmers.

6. Theoretical implication

This study set out to analyse the current state of BC of key stakeholders in sustainable agriculture, including defining BC from the perspective of farmers and government and examining how BC occurs. Several key contributions have been outlined in this study for academia, government, and researchers. Only a few fragmented literature reviews of studies on BC have been conducted which espouse the four themes. Our discovery of new sub-themes and approaches can significantly contribute to theory development in many ways. Thus, the findings on the four new approaches to BC can introduce novel perspectives on existing BC theories, challenging assumptions of how BC may occur and broadening the scope of BC understanding. The eleven new sub-themes classification can highlight the inconsistencies in existing theories, prompting modifications of BC towards sustainable agriculture. Further, based on the proposed model for integrating behaviour change into projects and use cases, researchers can work on new frameworks that explain the interplay between the conceptualisation, approaches and the consequences of BC on sustainability.

6.1. Practical implication

The study provides practical implications for government agencies, agricultural extension services, research institutions like CGIAR and CSIR, input suppliers, and non-governmental organisations (NGOs) to identify specific behaviours that contribute to food insecurity and unsustainable agriculture practices. Such knowledge can help the creation of targeted interventions that address the root causes of these problems. Importantly, BCR can inform the development of policies and regulations that support sustainable food systems. To foster and build effective partnerships, our study has shown the need to understand the behaviours of different stakeholders in the food system. BCR can help agriculture organisations (such as FAO, CGIAR) identify common goals and develop strategies for collaboration and develop messages that promote desired behaviours.

6.2. Limitations

Several limitations were identified which need to be considered when applying the study's findings. First, our selection criteria may exclude some important studies e.g. information from books, industry and extension agents' reports could provide further insights. Also, BC is complex and seen at various stages of research with previous studies still fragmented making it difficult to perform a quantitative model to consolidate different stakeholders' BC stimuli in sustainable agriculture.

7. Conclusion and recommendations

The findings of this literature review analysis indicate that the number of studies on BCR is increasing and can be categorised into i) innovative approach, ii) historical and knowledge co-creation approach, iii) empowerment approach, and iv) structural and systemic approach. Further, we found socio-economic factors and environmental conditions as two key determinants that affect the adoption of sustainable agriculture practices. Given that sustainable agriculture is expected to become more widespread in the future, more empirical research is needed to theorise the BC of farmers and key stakeholders' experiences. We hope this review will help research institutions understand the current state of BC and develop research agendas for future sustainability investigations.

Future research can address these limitations and extend our findings by investigating BC in different contexts with different approaches. Thus, there is a need to focus on context-specific BC stimuli, such as traditional learning approaches. Future studies could focus on understanding the type of approaches outlined in this study that explain how farmers' experiences can enhance BC in a sustainable world. Methodologically, there is a need to diversify the approaches (e.g. experiments - interventions and

surveys) to capture BC in a longitudinal study. Finally, relatively little research has espoused how behavioural change can engender negative consequences in sustainable agriculture. Future research could enhance our understanding of the negative consequences of BC towards a sustainable world. Finally, we advocate for increased research on BC at the household and community levels. Research into nudge strategies at the community level shows promise in fostering understanding and support for policies that promote sustainable agricultural practices. This, in turn, can inform research and legislation at national and global scales.

CRediT authorship contribution statement

Kingsley Ofosu-Ampong: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Wuletawu Abera:** Writing – review & editing, Methodology. **Anna Müller:** Writing – review & editing, Formal analysis. **Samuel Adjei-Nsiah:** Writing – review & editing, Formal analysis. **Richard Boateng:** Writing – review & editing. **Bryan Acheampong:** Writing – review & editing, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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