

## Enhancing sustainable smart farming: an analysis of Thai farmers' information behavior for achieving SDGs

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### ARTICLE INFO

#### Keywords:

Information behavior  
Smart farming  
Sustainable development  
Agricultural resilience  
SDGs

### ABSTRACT

The transition to sustainable smart agriculture (SSA) is vital for promoting food security, reducing poverty, and enhancing resilience to climate change (CC) in developing countries. However, limited understanding of rural farmers' information behavior (IB) remains a key barrier to advancing the Sustainable Development Goals (SDGs). While various IB models exist, gaps persist regarding their suitability to smart farming contexts. This study aimed to develop a conceptual framework that describes the information process of Thai farmers using a qualitative case study approach. Data were collected through in-depth interviews with 25 farmers in Satun Province, a region highly impacted by CC, characterized by unseasonal rainfall, water shortages during dry spells, and sudden floods. A focus group discussion with 13 participants was conducted to improve the model. Thematic content analysis was used to analyze the data. The research proposes an eight-stage model of Thai farmers' IB for SSA: recognizing information needs (IN), specifying IN, information seeking, browsing and exploration, information selection and evaluation, information use, information sharing and communication, and process reflection. This model conceptualizes adaptive IB, differing from traditional linear, problem-solving paradigms by emphasizing experiential decision-making, reflective practice, and iterative, context-responsive strategies that evolve with each season and situation. Accordingly, the study expands existing theoretical knowledge and introduces a novel perspective relevant to CC adaptation in the agricultural sector of developing countries. These findings highlight the need for policy and extension strategies tailored to farmers' real-world IB, thereby facilitating more effective adoption of SSA and contributing to broader SDG objectives.

### 1. Introduction

Over the past three decades, agricultural technology has advanced considerably, with the primary aims of increasing productivity, overcoming physical, chemical, biological, and socio-economic constraints, and fostering sustainable food systems. Consequently, there is a growing recognition of the importance of adopting technology and innovation to support the United Nations Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) and SDG 17 Partnerships for the Goals.

However, despite continuous advancements in agricultural technologies, developing countries including Thailand continue to face

persistent challenges. These include both quantitative and qualitative shortages of labor, insufficient digital skills, limited access to modern technologies, and inadequate information for planning, marketing, and production, particularly regarding high-quality, safe, and environmentally friendly products [1–3]. Data from the Office of Agricultural Economics indicate that the agricultural product price index declined by 3.36%, from 166.23 in March 2023 to 160.64 in March 2025 [4]. The agricultural census further shows that southern farmers face high input costs (54.8%), fall and surplus product prices (52.5%), and insufficient yields (36.3%). Additionally, the sector suffers from a labor shortage as high as 13.6%, mainly due to a lack of new-generation farmers and the digital skills necessary for technology adoption [5,2].

These circumstances significantly impact farmers' food self-

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sufficiency and pose risks to national food security [2]. Furthermore, CC remains a major threat to global agriculture and sustainable development [6]. In response, the Food and Agriculture Organization [7] has advocated for the accelerated adoption of digital agriculture to enhance the competitiveness and sustainability of global agri-food systems a strategy aligned with Thailand's national agenda for agricultural competitiveness [8].

Promoting the transition of farmers into "smart farmers" through effective IB is a key strategy to ensure that technology is efficiently utilized, contextually appropriate, and responsive to localized needs. Strengthening farmers' knowledge, understanding, and readiness to use information in decision-making processes can improve productivity, reduce costs and labor, increase income, and enhance sustainable competitiveness [6,9]. In-depth understanding of farmers' IB is vital for providing useful agricultural information [10], knowledge transfer, and tailoring information to meet specific needs [11]. Moreover, IB supports agricultural development in marketing and value addition [12], production (e.g., pest management), as seen in studies among Ugandan smallholders [13], and long-term quality of life particularly the positive impact of internet-based IB on poverty reduction [14].

Although several significant models of IB have been developed such as Wilson's context-focused model [15], Ellis's activities framework [16], Savolainen's [17] everyday life information seeking (ELIS), and Dervin's [18] "gap" concept these foundational theories primarily reflect Western socio-cultural contexts and environments distinct from those of developing country farmers. As such, they often fail to capture the complexity and unique characteristics of adaptive IB required for smart agriculture in such contexts.

Existing research on IB tends to address only selected dimensions, such as information seeking (IS) [19,20], internet use [14,21], or general IN [1,22], agricultural innovation [23–29], and climate adaptation [9,30–34], as well as on agricultural trade, food security [35], and digital sustainability [36], integrated research that systematically links IB to the context of promoting smart agriculture for sustainable development remains limited. In particular, there is a lack of practical models that capture the dynamic adaptation process in continually changing environments. While [37] examined Thai farmers' IN to develop a mobile application, a comprehensive behavioral model reflecting such dynamics has not yet been established.

Therefore, this research addresses a critical gap by analyzing Thai farmers' IB processes in support of smart agriculture and the achievement of the SDGs. It covers food security, rural poverty alleviation, natural resource restoration, and enhanced adaptive capacity to environmental change. A deep understanding of Thai farmers' IB will inform the design of policies and systems that optimize access to and use of agricultural technology. The eight-step IB model presented in this study not only differs structurally from Western theories but also offers a novel perspective for understanding IB, comprehensively filling gaps in previous theory. It is directly aligned with the SDGs SDG 1, SDG 2, SDG 4, SDG 12, SDG 13, and SDG 17 by emphasizing self-directed learning, community participation, and ongoing adaptation through reflection. This demonstrates that the model not only bridges theoretical gaps but also "translates theory into concrete practice" and constitutes a sustainable-oriented knowledge model with significant potential for scaling up in grassroots communities worldwide. As such, the findings offer substantial value both theoretically and practically, serving as a policy guideline for SSA in Thailand and informing the development of community-driven SDGs initiatives in tangible ways.

Ultimately, this research seeks to generate theoretical knowledge within the domain of 'IB for development' by formulating the concept of 'adaptive IB' based on empirical data from smallholder farmers in the Global South. The proposed model reflects processes of practical learning, real-world experimentation, and continuous reflection under the conditions of intensifying CC and the economic vulnerability of smallholder farmers crucial contexts for sustainable development. Consequently, this study expands the scope of IB theory by linking it

directly to issues of food security, poverty reduction, and the enhancement of adaptive capacity against environmental risks. Furthermore, it offers a concrete policy foundation for designing digital agricultural extension systems and fostering sustainable agricultural development in alignment with the SDGs.

## 2. Theoretical framework

The conceptual framework of this research is grounded in the concepts of IB and SSA. It is based on the theoretical assumption that farmers' IB serves as a procedural mechanism that influences the development of SSA and supports the achievement of the SDGs.

This research systematically developed an inductive conceptual framework derived from field data. This approach was adopted because existing IB models do not comprehensively explain the dynamics of experiential learning and contextual adaptation within agricultural communities, particularly under the conditions of transitioning toward smart agriculture.

Consequently, the researchers synthesized a process-oriented IB model that links IS, interpretation, utilization, and exchange with the outcomes of SSA development. This synthesis utilized the theoretical frameworks of Wilson [38,39], Ellis [16], Dervin [18], and Savolainen [17] as a foundational basis for interpretation and contextual expansion. This led to the development of a conceptual structure comprising four main dimensions, as illustrated in Fig. 1:

Dimension 1: Contextual structuring factors.

This dimension consists of the following factors:

1. Structural context: Encompassing economic, social, and institutional structures, as well as the level of access to resources and technology.
2. Sociocultural context.
3. Resource and constraint conditions.
4. Experiential context.

Dimension 2: IB.

This dimension comprises four key aspects:

1. Contextualized IN: IN arise from problems, uncertainties, or knowledge gaps, and are shaped by lifestyles, social structures, and resource constraints (integrating concepts from Wilson, Savolainen, and Dervin).
2. Information engagement: The initiation of information searching, selection of sources, and adaptation of search strategies (integrating concepts from Ellis and Wilson).
3. Sense-Making construction: The cognitive linkage of new information with prior experiences and the bridging of "knowledge gaps" through the construction of new understanding (incorporating Dervin's framework).
4. Application and adaptive learning: The utilization of information in practical decision-making and agricultural practices (integrating concepts from Wilson and Savolainen).

Dimension 3: Adaptive smart farming development.

This involves the sustainable development of smart farmers through strategic adaptation that aligns with their structural and social contexts, as well as their IB.

Dimension 4: Sustainability outcomes.

This pertains to sustainable development outcomes aligned with the SDGs.

Therefore, the conceptual framework of this study proposes a processual relationship at the conceptual level. It posits that IB functions as a mediating mechanism bridging the contexts of change and uncertainty with farmers' processes of experiential learning, practical decision-making, and adaptation. This concept is theoretically positioned to play a critical role in facilitating the transition toward sustainable smart agriculture, thereby driving development across economic, social, and

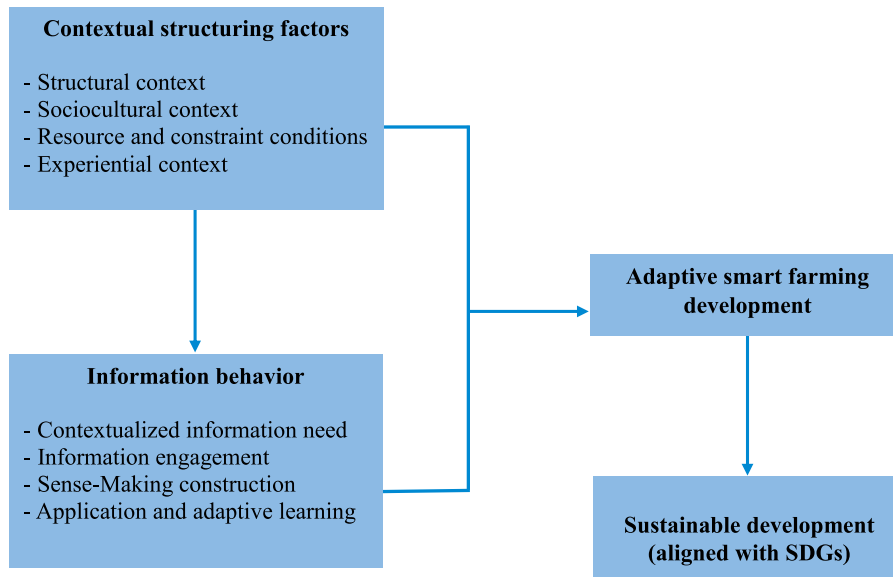


Fig. 1. Theoretical framework.

environmental dimensions in accordance with the SDGs framework.

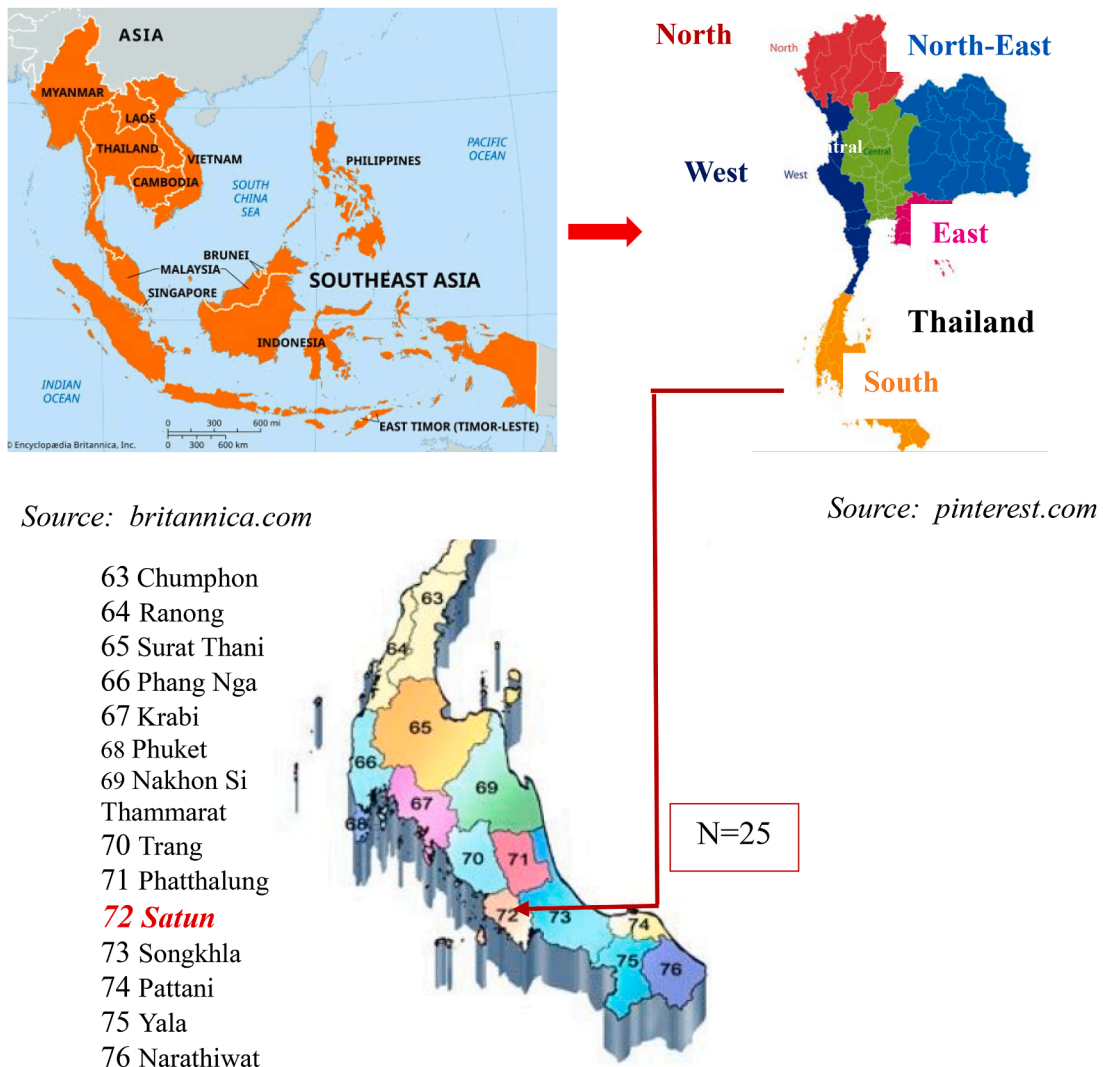


Fig. 2. Study area.

### 3. Materials and methodology

This research was conducted within the interpretivist paradigm, aiming to understand IB from perspectives and lived experiences of participating farmers. A qualitative case study approach was employed, which is particularly suited for exploring complex phenomena in real-life contexts [40] and enables a holistic understanding in natural environments, consistent with the framework of Aspers and Corte [41]. The study’s objective was to describe and interpret the information behavior processes (IBP) of farmers in the context of SSA. While the researchers reviewed established theoretical models such as Wilson [38,39], Ellis [16], Dervin [18], and Savolainen [17] these frameworks, especially Wilson’s focus on IN, Savolainen’s emphasis on everyday life, and Dervin’s gap-crossing model, were found inadequate for capturing the real-life dynamics and experiential learning found within communities. This research thus developed a new model grounded in direct field data.

#### 3.1. Study area and field access

The study was conducted in Udai Charoen subdistrict, Khuan Kalong district, Satun province (see Fig. 2), selected for several reasons: it is an area where farmers actively adapt to climate variability (such as unseasonal rainfall, drought, and flash floods); there is widespread adoption of mixed farming and progressive approaches toward smart agriculture; the community’s cultural context supports mutual assistance and information sharing; and the area is rich in social capital emphasizing farmer participation in professional development. Field access followed Creswell and Creswell’s recommendations [42], with local leaders facilitating contacts and building trust with farmer participants.

#### 3.2. Key informants

Key informants were selected through theoretical sampling [43], consistent with the notion articulated by Taylor et al. [44] that individuals possess diverse experiences and have acquired different social meanings. Twenty-five farmers were purposively selected based on the following four criteria, all of which had to be met: (1) adaptation of agricultural practices utilizing information and technology in response to climate variability; (2) experience or interest in SSA; (3) agricultural income of no less than \$1500 per year; and (4) continuous engagement in farming for no <15 years. The sample size of 25 was determined to be sufficient for achieving data saturation, which is a recognized standard in qualitative research [45]. To ensure a holistic understanding, basic demographic information was also collected from key informants. Although not subjected to statistical analysis, these demographic factors

**Table 1**  
Demographic profile of key informants (n = 25).

Demographic variables	Category	Number of informants	Percentage (%)
Gender	Male	3	12.0
	Female	22	88.0
	<b>Total</b>	<b>25</b>	<b>100.0</b>
Age (years)	35–40	1	4.0
	41–45	3	12.0
	46–50	5	20.0
	51–55	5	20.0
	56–60	7	28.0
	61–65	3	12.0
	65–70	1	4.0
	<b>Total</b>	<b>25</b>	<b>100.0</b>
	Education level	Primary	12
Secondary		11	44.0
Vocational diploma		2	8.0
<b>Total</b>		<b>25</b>	<b>100.0</b>

were considered potentially influential on the IB of farmers, as summarized in Table 1.

#### 3.3. Research tools

The initial draft of the interview guide was subsequently reviewed by five experts in the field of IB. Expert feedback was incorporated to refine and adjust the questions to ensure greater clarity, comprehensiveness, and alignment with the study’s objectives and conceptual framework.

The open-ended questions used for in-depth interviews with the key informants included:

- What situations make you seek information or knowledge related to agriculture?
- What types of information or knowledge do you need to develop smart agriculture, and in what ways?
- For what purposes do you intend to use agricultural information?
- What are your preferred sources for accessing agricultural information or knowledge, and why?
- What types of information resources do you regularly use in your pursuit of agricultural knowledge, and why?
- Can you describe the process you undertake when searching for agricultural information, from the beginning until you acquire the desired information or knowledge?
- How do you evaluate and select information obtained through your searches?
- What kinds of agricultural information have you found most helpful in supporting your agricultural development, and how?
- How do you assess the credibility and usefulness of information before applying it?
- What obstacles do you encounter in using agricultural information?
- How important do you perceive the exchange or sharing of agricultural information to be in your work?
- What technologies or innovations would you like to apply to develop smart agriculture?

#### 3.4. Data collection and data analysis

This study was approved by the Songkhla Rajabhat University Human Research Ethics Committee, Thailand (HRCE No 012/2023). All participants provided written informed consent prior to data collection. Participation was voluntary, and participants’ confidentiality was protected. Participant data were anonymized, securely stored, and all data were de-identified prior to analysis.

##### 3.4.1. Data collection

Data was collected between April and July 2023 through two primary methods. First, in-depth interviews were conducted with 25 farmers. To minimize bias and enhance credibility, the principal researcher and co-researchers with agricultural and information science expertise conducted the interviews jointly. Data was captured via audio, video, and field notes. Transcripts were cross-checked against recordings for accuracy and returned to the informants for verification to ensure no misinterpretation occurred.

Second, a focus group discussion using semi-structured questions was conducted to validate the IBP model. Participants evaluated its appropriateness, feasibility, and reliability in explaining Thai farmers’ IB toward advancing sustainable smart farming and supporting the SDGs. The panel comprised five IB experts, five smart agriculture experts, and three experienced farmers.

The participants were selected based on specific qualifications. The IB experts possessed at least five years of academic or research experience in Information Science, Information Systems, or knowledge management, supported by relevant publications. The smart agriculture experts had a minimum of five years of experience in modern agricultural technologies (e.g., IoT, sensors, precision agriculture) within

research, technology transfer, or the agricultural sector. Finally, the participating farmers were drawn from the interview phase, chosen for their recognized practical expertise in climate adaptation, water management, and agricultural technology application within their local communities or networks.

#### 3.4.2. Data analysis

Data from verbatim transcripts of in-depth interviews and focus group discussions were analyzed using thematic analysis as outlined by Braun and Clarke [46]. This flexible and effective method allows for systematic identification, analysis, and reporting of patterns or themes within qualitative data, following these key steps:

The researcher first became familiar with the data through repeated readings and carefully listening to the recordings, making detailed observations to understand content, context, and the tone of participants. Significant statements related to IB were then identified and openly coded to capture a wide range of concepts, such as adaptation to CC, mutual assistance in information sharing, and links between IB and sustainable development. These initial codes were then grouped into broader themes that meaningfully explained the phenomena under study, reflecting repeated or salient patterns relevant to the research questions.

Themes were continuously reviewed and refined to ensure coherence within themes and clear distinction between them, especially for the three main themes and eight sub-themes under the “behavioral process.” The sequence and relationships among the eight sub-themes were carefully adjusted to form an intelligible and logical cycle, and both themes and sub-themes were precisely defined and named to reflect their core meaning.

Ultimately, three principal themes were established: (1) the behavioral process (consisting of eight sub-themes: awareness of IN, articulation of IN, IS, browsing and exploration, selection and evaluation, IU, information sharing and communication, and process reflection); (2) the connection between IB and the goals of sustainable development; and (3) contextual factors influencing IBP.

Results are presented by systematically linking these themes to demonstrate the eight-step IB model for Thai farmers, explaining the cyclical relationships between each stage, and connecting the entire IBP to the SDGs. Throughout the analysis, emphasis was placed on rigor and consistency to ensure that the findings accurately reflect the qualitative research standards.

#### 3.5. Ensuring trustworthiness of the data

To enhance the credibility and trustworthiness of qualitative data, this research employed triangulation through four complementary strategies designed to mitigate potential biases arising from researcher involvement and familiarity with the research context.

First, the researcher cross-verified the information obtained from key informants with other relevant individuals within their families or the local community to ensure the consistency and accuracy of the reported data.

Second, member checking (or participant verification) was employed by returning transcribed and categorized in-depth interview materials to each respective informant for verification, thereby ensuring that participants’ perspectives were accurately captured and that the researcher’s interpretations aligned with what the informants intended to convey.

Third, peer debriefing and expert review were utilized by engaging in critical discussion with subject matter experts in information science and sustainable development, as well as with fellow qualitative researchers. Through these consultations, feedback, alternative perspectives, and critical advice were solicited, facilitating the identification and mitigation of potential errors or biases in data coding, theme development, and interpretation.

Finally, the researcher engaged in prolonged and intensive

observation in the field, spending substantial time within the study area to develop deep familiarity with the context and the daily realities of the farmers.

## 4. Results

This research aimed to analyze the IB of Thai farmers to promote the sustainable development of smart farming. The presentation of the research results consists of two main areas: the IBP and the connection between the IBP, sustainability, and the SDGs, as detailed below.

### 4.1. IBP

The IBP that facilitates farmers’ development into smart farmers consists of eight key processes: : recognition of IN, specification of information requirements, IS, exploration and investigation, selection and evaluation of information, utilization of information, information sharing and communication, and reflecting on the processes. These eight processes form a continuous IB cycle, as shown in Table 2.

The IBP is therefore not necessarily a strictly sequential process. It allows us to return to earlier stages whenever confusion arises, to clarify one’s actual needs at each step before deciding to proceed further. These processes are illustrated in Fig. 3.

### 4.2. The relationship between IBP and sustainability and the SDGs

The analysis of IBP is essential to advancing economic, social, and environmental transformation through information-based approaches toward sustainable development. Based on the collected data and subsequent analysis and synthesis, key conclusions can be drawn regarding the relationship between IB and sustainability as follows:

#### 4.2.1. Recognizing IN

Recognizing IN is the starting point for food security and adaptation to CC. This stage is critical for initiating positive transformations in the agricultural sector. Farmers in this study acknowledged knowledge gaps, particularly in pest control and climate adaptation, in response to irregular rainfall and water scarcity. This awareness directly supports SDG2, SDG13. Such recognition prompted farmers to seek solutions that lead to more stable and sustainable production practices, thereby reinforcing agricultural resilience.

#### 4.2.2. Specifying IN

The specification of IN reflects the prioritization required for sustainable production. Once farmers became aware of their information gaps, they were able to clearly identify their specific needs, such as smart irrigation systems, the use of biofertilizers, and sustainable pest management. These needs address issues such as drought, crop damage from pests, and value-added production. This phase aligns with SDG12 and SDG2, as farmers aim to optimize resource use and minimize environmental impacts core aspects of smart farming strategies.

#### 4.2.3. IS

Is the gateway to accessing knowledge and innovation for sustainable development. Farmers in the study area employed various sources of information, such as YouTube, training programs, field visits, and digital data platforms. This reflects support for SDG4, particularly in the form of non-formal and self-directed learning that develops agricultural skills integrated with innovative approaches. It also contributes to SDG9. In this case, farmers accessed knowledge on water management, application of biofertilizers through fertigation systems, soil assessment, smart agricultural technologies, and market adaptation demonstrating the fusion of IB with smart farming and sustainable development practices.

**Table 2**  
Information behavior process.

No.	IBP	Description	References	Relevant SDGs
1	Recognition of IN	The process begins when farmers encounter problems such as poor crop quality, pest infestations, or a lack of knowledge about agricultural technology. These issues create knowledge gaps that drive the need for IS. This process stems from the farmers' immediate problem recognition and personal motivation to improve crop yields and reduce costs.	"Leaf-eating insects, pest infestations, flower drop, and fruiting problems led me to seek solutions without resorting to strong pesticides. I still have not found a solution." (IDF9); "Fruit flies and pests caused infestation in chili plants, and I wanted to know how to fix this." (IDF10); "Black aphids and fruit flies lay eggs during flowering, causing fruits to fall." (IDF18); "Small worms cling to the chili plants, causing premature fruit drop before harvesting." (IDF22)	SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 13 (Climate Action)
2	Specification of information requirements	After recognizing knowledge gaps, farmers define the specific topics and types of information they need, such as knowledge about smart irrigation systems or safe pest control methods. This specification guides the next stage of IS.	"I want to learn about water installation systems." (IDF2, IDF11, IDF13); "I need knowledge about controlling irrigation via mobile phones, and how to manage it smartly." (IDF1); "I want to learn how to install solar panels for farming." (IDF5); "I want to learn how to sell products online on Lazada and TikTok." (IDF1, IDF9)	SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production)
3	IS	Farmers seek information from a variety of sources, including local experts, neighbors, community leaders, government officers, and online platforms. Source selection	"I ask and talk to farmer neighbors in the village." (IDF6); "I ask Uncle Yot because he has long experience, and I trust what I see." (IDF11); "I watch YouTube videos about planting and	SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), SDG 17 (Partnerships)

**Table 2 (continued)**

No.	IBP	Description	References	Relevant SDGs
		depends on credibility and accessibility. If initial searches fail, farmers may redefine their needs and seek through other methods, such as using technology aids.	farming." (IDF22); "I search on Google for techniques to cultivate and prune durians." (IDF11)	
4	Exploration and investigation	During IS, farmers browse and compare information from various sources. Sometimes, browsing leads to confusion about what they truly need. If information does not align with the problem, they redefine their IN.	"Sometimes, searching on YouTube and asking experts confused me whether I really needed that information." (IDF4); "Watching multiple videos on YouTube sometimes leads to confusion about which method to choose." (IDF22, IDF23)	SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action)
5	Selection and evaluation of information	Farmers evaluate information for credibility, relevance to their problems, and practical usefulness. If information is found unsuitable, they return to redefining needs and re-seeking information through different channels.	"I choose knowledge that matches the real problem and check the credibility of the content." (IDF1); "I pick information that I can truly apply and that suits my preferences." (IDF17); "I try it first; if it does not work, I find new information." (IDF1, IDF2); "I compare multiple sources before deciding." (IDF9, IDF11)	SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action)
6	Utilization of information	After selecting suitable information, farmers apply it in practice. They often begin by testing on a small scale before expanding. The goals are to solve problems, improve product quality, upgrade production standards, and promote sustainable development.	"I used it to solve insect and pest problems." (IDF1, IDF2, IDF21, IDF22, IDF23); "I used the knowledge to improve vegetable cultivation and solve soil and pest problems." (IDF13); "I applied it to improve my cultivation plots." (IDF24)	SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 17 (Partnerships)
7	ISC	Farmers share their experiences and knowledge through face-to-face community	"I exchange ideas with neighbors once a month." (IDF1); "I talk in	SDG 4 (Quality Education), SDG 8 (Decent Work and Economic

(continued on next page)

Table 2 (continued)

No.	IBP	Description	References	Relevant SDGs
		exchanges and online platforms such as LINE groups. Sharing promotes empowerment and expands knowledge throughout the community networks.	the farmers' LINE group." (IDF14, IDF15, IDF17, IDF19, IDF20, IDF23); "I share methods for setting up irrigation systems and vegetable growing techniques on LINE." (IDF23)	Growth), SDG 17 (Partnerships)
8	Reflecting on the process	After utilizing information, farmers assess the outcomes. If the information fails to address problems accurately or goals are not met, they return to redefining information needs, thus starting a new IS cycle. Reflection involves both interim and post-use evaluations to improve future processes. This reflective practice is crucial for continuous self-assessment, strategic adjustment, lifelong learning, and enhancing sustainable agricultural practices.	"I must try first; if it is not effective, applying it on a large scale could cause significant damage." (IDF24); "After using it, if it doesn't work, I need to seek new information and start again." (IDF17)	SDG 4 (Quality Education), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 17 (Partnerships)

4.2.4. Browsing and exploration (BE)

BE involve identifying sustainable alternatives. This stage allows farmers to explore and compare information from various sources, enabling them to select farming practices that are context-specific and environmentally appropriate. The process empowers farmers to shift from reliance on harmful chemical inputs to more environmentally friendly methods such as biologically based pest control. One notable practice involves the use of smartphone-operated smart traps, which supports SDG9 and SDG12 by promoting innovation and sustainable agricultural systems.

4.2.5. Information selection and evaluation (ISE)

ISE are critical stages for enhancing effective decision-making. The ability to evaluate and choose high-quality, credible information that aligns with the agricultural context reflects a contribution to SDG12 and SDG13. Farmers in this study integrated smart farming knowledge such as IoT-based crop monitoring, precision irrigation systems, smart pest traps, and fertigation systems to sustainably develop their farms. The evaluation process was driven by alignment with individual needs and informed by pre-existing knowledge to support appropriate information judgment and usage.

4.2.6. Utilization of information

Information use (IU) is the central element of the IBP, translating

knowledge into practical applications. It moves beyond mere understanding to tangible actions. Without implementation, information yields little value. In this study, IU involved the actual adoption of agricultural technologies such as solar energy systems and drought-resistant crop varieties leading to cost reduction, increased productivity, and more efficient resource use. These outcomes align with SDG2, SDG12 and SDG13.

4.2.7. Information sharing and communication (ISC)

ISC contribute to strengthening the resilience of farming communities. Peer-to-peer knowledge exchange, such as teaching pesticide-free vegetable cultivation techniques or sharing methods for installing smart irrigation systems, supports SDG17 and SDG1. In practice, these interactions often occur informally during farming activities, fostering trust, mutual respect, and a sense of belonging. This informal communication reinforces cooperation and promotes local self-reliance and community sustainability.

4.2.8. Reflecting on the processes

Farmers engage in personal cognitive processes to assess whether each step effectively addresses their needs. If a process fails to meet expectations, they return to earlier stages to revise their strategies. Reflection occurs in two forms: (1) concurrent reflection during the process, allowing for mid-course adjustments; and (2) post-process reflection after completing an information-seeking cycle. Some farmers actively reviewed their strategies and evaluated the quality and effectiveness of the IU, leading to improved approaches in future cycles. This process supports SDG4, SDG12, and SDG13 by enabling ongoing learning and adaptive responses to environmental challenges.

The findings demonstrate that IB is not merely a mechanism for acquiring knowledge to boost productivity. Rather, it serves as a systemic process that fosters a continuous cycle of learning, informed decision-making, and the development of agricultural resilience in the face of environmental and economic changes. The systematic implementation of these eight stages provides a foundational structure that supports multiple Sustainable Development Goals particularly SDG1, SDG2, SDG4, SDG8, SDG9, SDG12, SDG13, and SDG17 as illustrated in Fig. 3.

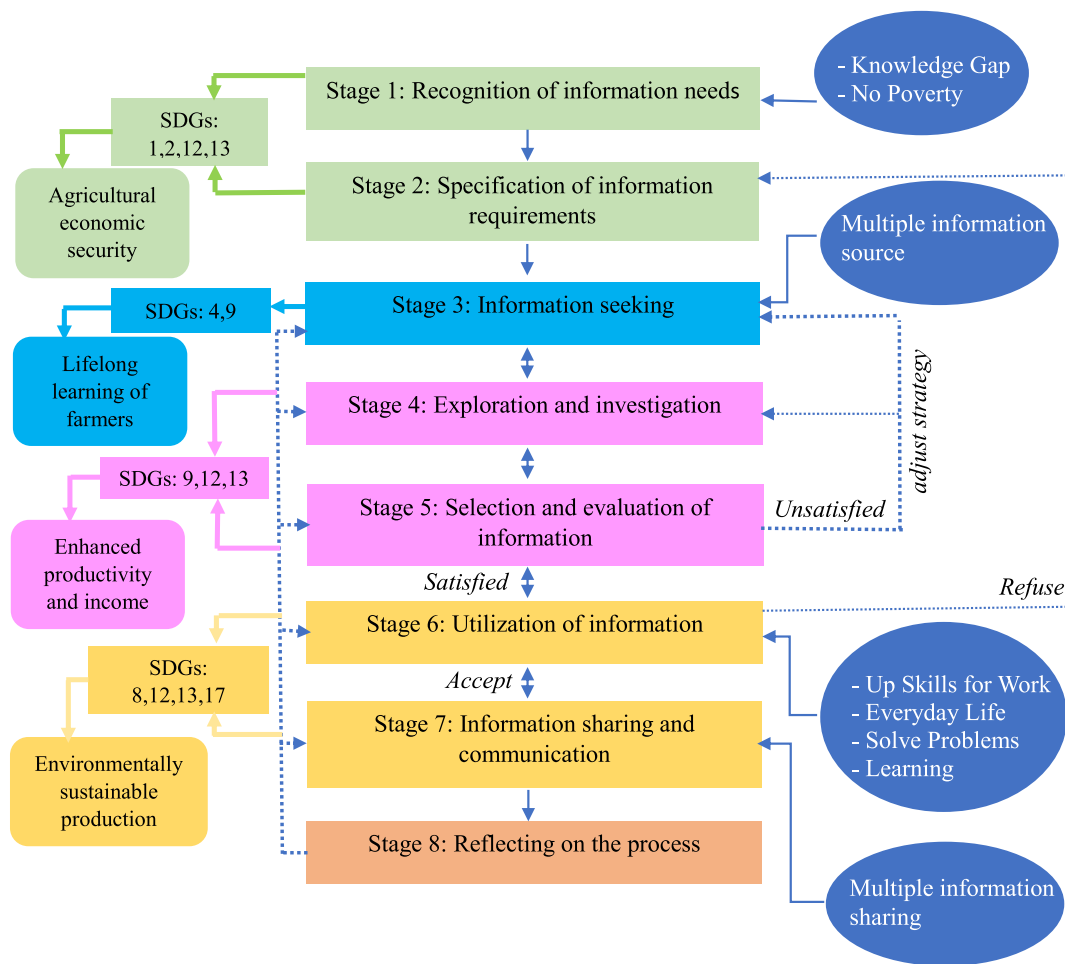
5. Discussion

5.1. From western models to new knowledge in IB for developing countries

This research proposes an eight-stage IB model developed in the context of Thai rural farmers, which significantly differs from internationally recognized models such as Wilson [38,39], Ellis [16], Dervin [18], and Savolainen [17]. Unlike traditional models that emphasize individual or specialized contexts, this model highlights "practice-based" and "participatory learning" aspects that are less pronounced in Western frameworks.

Wilson's [39] model, which describes IN and responses, does not adequately address post-use behaviors, such as practical application and evaluation crucial for Thai farmers, who frequently experiment in real settings. Farmers in this study not only seek and select information but also implement and adapt it or reject and search again if unsatisfactory. The eight-stage model addresses this gap by incorporating the stages of "selection and evaluation," "IU," "sharing," and "reflection," emphasizing hands-on trial before acceptance or rejection reflecting a deeper experiential learning cycle than Wilson's framework. This aligns with Pengtiang [20], who found that Thai farmers adapt through practice and outcome-based learning. Furthermore, Seenuankaew and Vongprasert [12] noted that state actors, community leaders, and peer exchange are central to information dissemination and decision-making a point reinforced by this model's focus on sharing and reflection.

Ellis [16] focuses on sequential scholarly IS activities, which are less relevant for farmers who use information through discussion,



**Fig. 3.** Model of farmers' information behavior for enabling smart farming towards Sustainable Development Goals (SDGs)

**Note:** This model was validated for appropriateness and consistency through a focus group discussion involving five information experts, five smart agriculture experts, and three farmers.

experimentation, and group sharing. The eight-stage model introduces "practice-oriented IB," consistent with the lived reality of farmers, including knowledge exchange, trying new methods, and reflective evaluation, echoing Du [47] and Seenuankaew et al [48] who emphasized the importance of experiential learning and social networks in effective information use. The model advances these concepts by explicitly incorporating practical action and reflection.

Dervin's [18] Sense-Making theory, emphasizing "knowledge gaps," is like the initial stages of this model, but does not develop structures for reflection post-gap-closure. The current model addresses this by adding information sharing and reflective adaptation behaviors grounded in actual rural practice and continuous change. Importantly, the model is consistent with Savolainen's [17] concept of "everyday information practices," which sees information as embedded in daily life. This research extends Savolainen's ideas by showing that Thai farmers actively "create" and "adapt" information in cycles of experimentation and reflection, expanding the ELIS concept to encompass climate change and economic vulnerability.

Thus, the eight-stage IBP model does not merely adapt Western concepts but extends knowledge and offers a new framework suitable for Thai agricultural communities focusing on collaborative learning, reflection, and adaptive practice. This contribution is particularly relevant to the development of theoretical frameworks for developing countries and agricultural sectors facing constant change.

### 5.2. The influence of Thai context and adaptation from western models

The development of this model is not simply an application of Western ideas, but a contextual reinterpretation shaped by the unique conditions of Thai society. Three key contextual factors influence farmers' IB :

#### 5.2.1. Social context

Collaboration, community participation, and leadership-centered information exchange create collective, rather than individual, IB contrasting with Western models. Thai farmers engage in group learning and community-based knowledge management, as supported by Chongchorhor [49], who found collaborative IB among local rice experts.

#### 5.2.2. Cultural context

Thai agricultural communities are characterized by mutual support and information exchange through hands-on practice and collective problem-solving, rather than textbook knowledge. This is consistent with Savolainen's [17] view of "routinized everyday practices." Community culture that fosters information sharing is a core and distinctive feature reflected in this model. Seenuankaew et al [48] also highlighted the importance of social networks and informal communication channels, while studies from other developing contexts (e.g., Diemer et al [13], on Ugandan farmers) confirm that cultural and practical factors strongly shape IB .

### 5.2.3. Economic context

Income vulnerability distinguishes this model from those in other countries. Thai farmers must maximize the value of information through practical trials and continuous evaluation, which is critical for survival and sustainable development. The eight-stage model not only addresses theoretical concerns but connects directly to real-life economic decision-making. This is in line with Qiu et al [50], who found that Chinese farmers' adoption of smart agriculture technology is driven by economic value and return on investment, and with Huang et al [14], who showed that internet-based IB can alleviate poverty among smallholder farmers by reducing information asymmetry and increasing development opportunities. Economic context is thus a central driver of adaptive, outcome-oriented IB.

### 5.3. CC as a catalyst for an adaptive IB model

Frequent and unpredictable climate events—such as unseasonal rainfall, flash floods, and droughts have forced farmers to continuously adapt and learn. As a result, their IB is not a linear process of IS or use (as in Western models like Wilson or Ellis) but rather a cyclical process involving constant reflection and adjustment. Thai farmers, especially in the study area, must experiment with new methods (e.g., IoT irrigation systems, adjusting organic inputs) and use seasonal outcomes to inform future decisions. This reflects a "cyclical learning loop" that goes beyond Dervin's sense-making theory by emphasizing ongoing meaning-making and experiential accumulation in response to recurring climate shocks. Such adaptive, reflective cycles are also highlighted in research on Farmer Field Schools [32] and in studies of adoption barriers in smart agriculture elsewhere [34]. The model thus demonstrates how continuous experimentation and reflection help bridge knowledge gaps and overcome obstacles to climate adaptation, confirming the necessity of cyclical learning in uncertain environments.

### 5.4. Linking IB to SDGs

Farmers' IB is critical in driving the transition toward SSA, with clear connections to the SDGs:

First, the pressures of CC, unstable yields, and labor shortages compel farmers to adapt, starting with IN recognition and leading to the pursuit of new knowledge and technology [6]. This process directly supports SDG2, SDG12 and SDG13, as adaptive information seeking helps farmers manage environmental and quality standards.

Second, integrated collaboration among academics, policymakers, practitioners, and markets strengthens each step in the IBP. Such partnerships constitute a "knowledge-enabling environment" that supports SDG1 and SDG8, in line with Makate [30], who emphasized the value of local institutions and indigenous knowledge.

Third, fostering trust and awareness in information sources is essential for effective adoption and lifelong learning. The transition from reliance on interpersonal sources to digital platforms accelerates the dissemination of reliable information [13,48], supporting SDG4 and long-term rural economic sustainability [14].

The proposed eight-stage Adaptive IB model, therefore, offers a novel framework for understanding and enhancing farmers' learning, adaptation, and community collaboration, especially under intensifying CC. It fills theoretical gaps left by Western models and provides practical pathways aligned with SDGs including SDG1, SDG2, SDG4, SDG12, SDG13, and SDG17 by emphasizing self-directed learning, community participation, and ongoing adaptation.

### 5.5. Scalability and knowledge transfer to other developing countries

Although this research was conducted within the specific context of Thai farmers in the southern region, the developed eight-stage adaptive IB model possesses significant potential for scalability and conceptual transferability to other developing countries facing similar challenges.

These challenges include climate uncertainty, the vulnerability of smallholder farmers, and limitations in digital infrastructure.

The core strength of this model lies not in any specific type of technology, but rather in its "process logic," which emphasizes cyclical learning, real-world experimentation, and continuous reflection for adaptation. This logic serves as a fundamental mechanism for rural resilience and can be applied in resource-constrained contexts—such as East Africa, South Asia, or Latin America without the need to directly replicate Thailand's technical models.

From a policy perspective, scaling this model should be implemented through four systemic mechanisms:

**Community-level digital infrastructure:** Investment in accessible high-speed internet, local information centers, and digital agricultural platforms is a foundational condition that enables the IB cycle to function efficiently.

**Development of information and digital literacy:** Enhancing skills in evaluating data, selecting reliable sources, and utilizing analytical information will mitigate the risks of misinformation and improve decision-making efficacy, thereby concretely supporting SDG 4 and SDG 12.

**Community-Based Learning Systems:** This model demonstrates the critical role of informal information exchange. Therefore, policy design should foster Farmer Field Schools, Smart Farmer Networks, and peer learning mechanisms, which actively reinforce SDG 17.

**Multi-Actor Collaboration:** The integration of academics, government agencies, markets, and farmers helps construct a "knowledge-enabling ecosystem" that supports SDG 1, SDG 2, and SDG 8 by increasing incomes and reducing economic vulnerability.

However, scaling at the national or transnational level should not adopt a "direct replication" approach. Instead, it should strictly adhere to the principle of "contextual adaptation," tailoring the model to align with each country's distinct level of technological access, market structures, and local knowledge-sharing cultures.

## 6. Conclusions and implications

This study presents an eight-stage model of Thai farmers' IB for SSA, covering processes from awareness of information needs, identification of needs, IS, exploration, evaluation, utilization, sharing, to cyclical reflection. This model is distinctive in describing "adaptive IB," reflecting decision-making based on experiential learning and "reflective practice for generating new approaches" that recur in accordance with seasonal cycles and specific, rapidly changing circumstances especially in the context of escalating climate change. The discovered model not only differs structurally from Western IB theories but also proposes a novel perspective for understanding the information processing of smallholder farmers in developing countries, thereby addressing a theoretical gap where prior models lack contextual specificity in complex environments. Moreover, this eight-stage model demonstrates direct alignment with and support for the SDGs, particularly SDG 1, SDG2, SDG4, SDG12, SDG13 and SDG17, by emphasizing self-directed learning, adaptability, and the cultivation of community collaboration for foundational economic security.

Despite providing deep insights and proposing a novel, contributive model, this research has certain limitations. First, the qualitative case study approach focuses on in-depth understanding of phenomena within the specific, climate-vulnerable context of Satun Province, based on 25 participants. Although data saturation was reached, the qualitative nature means the findings may not be statistically generalizable to all Thai farmers, who are diverse in geography, society, and culture. Second, the unique regional and cultural context Satun's climatic challenges and social-economic conditions (such as strong community leadership, mutual support, and economic hardship leading to lifestyle changes and youth outmigration) exerts significant influence on farmers' IB, which may differ from other regions. Thus, direct application of the model elsewhere may require contextual adaptation. Third, potential sampling

bias exists: participants were farmers interested in, experienced with, or actively adopting smart agriculture technologies, and may represent a more proactive and innovative segment than the general farmer population.

From these limitations and findings, several recommendations for future research arise. Quantitative studies should be conducted to test the relationships among the stages of this eight-stage model with larger and more diverse samples, to validate the model's components, causal relationships, and generalizability. Comparative studies across other regions in Thailand or in developing countries with differing cultural, social, and economic contexts are needed to assess the broader applicability of the model and to identify additional contextual factors. Further research should also explore the impact of specific smart farming technologies (e.g., IoT sensors, AI-driven analytics) on IB at each stage, including in-depth analyses of the effectiveness of government policies and development programs in supporting IB s conducive to sustainable smart agriculture.

Although this research provides in-depth understanding and develops a model with substantial theoretical and policy contributions, the reliance on a single-site qualitative case study design with a limited number of informants inherently constrains its broader generalizability. Consequently, the findings primarily reflect this specific context. Therefore, the proposed model should be further tested and expanded into other contexts or regions to strengthen its robustness and generalizability in future studies.

#### CRedit authorship contribution statement

**Unchasa Seenuankaew:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Visit Boonchom:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Romchat Khuntong:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis. **Mumtas Meelaman:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis. **Sukanda Chanthawee:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis.

#### 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.

#### Acknowledgment

The authors are deeply grateful to the farmers in Udol Charoen Sub-district for their participation, their time, and their willingness in granting permission for the survey. This research was supported by the Thailand Science Research and Innovation (TSRI) (grant number 14/2023).

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