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Assessment of influencing factors and mechanisms to engage the private sector in promoting conservation agriculture production systems in Cambodia

Punlork Men[a,b,c], Lyda Hok[a,b], Panchit Seeniang[a], B. Jan Middendorf[d], Fidero Kuok[c] and Rapee Dokmaithes[a]

[a]Department of Agricultural Extension and Communication, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom, Thailand; [b]Center of Excellence on Sustainable Agricultural Intensification and Nutrition, Faculty of Agricultural Education and Communications, Royal University of Agriculture, Phnom Penh, Cambodia; [c]National Institute of Science, Technology, and Innovation (NISTI), MISTI, Phnom Penh, Cambodia; [d]Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL), Kansas State University, Kansas, USA

ABSTRACT

Engaging the private sector in extension services and their direct interaction with farmers contributes to conservation agriculture production systems (CAPS) promotion. This study was conducted to assess influencing factors and mechanisms to engage private sector actors and to rank them to perform their engagement with farmers in an agricultural extension model designed to promote CAPS in Cambodia. The sample size for the survey instrument consisted of 481 randomly selected households, including both CAPS and non-CAPS farmers. For focus group discussions, a purposive sample of 28 participants was used. The positive factors influencing CAPS farmers' engagement with the private sector included gender, number of fields, off-farm income, farm experience, familiarity with the private sector in a commune and government subsidies. In contrast, total land size of main crops, and farmers' perceptions of utilization of private services including a distance of service and increase in profit had a negative impact. Subsidy and incentive programs from the government emerged as highly effective mechanisms for encouraging private sector engagement with farmers. Access to financial institutions was a key priority when engaging the private sector with CAPS farmers. Providing subsidies and incentives is a short-term economic benefit for smallholder farmers that could impact the long-term adoption.

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1. Introduction

The private sector plays a crucial role in promoting conservation agriculture production systems (CAPS). The private sector engagement in driving CAPS through agricultural extension services and working with farmers should lead to enhanced agricultural productivity outcomes (Glover, 2007). The agricultural private sector promotes CAPS by disseminating technology and materials to farmers, while service providers offer machinery support and land preparation services (Pauschinger & Klauser, 2022; Tho et al., 2021; Van Loon et al., 2020). Cover crop integration is another main component of CAPS because it provides organic materials for soil health improvement (Bergtold et al., 2019; Fageria et al., 2005). The cost of cover crops proves to be a challenge for smallholder farmers to practice CAPS. Funding support from financial institutions (FIs) is a promising mechanism for promoting CAPS (Bergtold et al., 2019; Brown et al., 2020; FAO et al., 2022; Gonzalez-Sanchez et al.,

CONTACT Rapee Dokmaithes agrrpd@ku.ac.th Department of Agricultural Extension and Communication, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom 73140, Thailand

2015). FIs are primary providers of agricultural loans for common farming-related activities such as purchasing agricultural inputs (Adjognon et al., 2017; Mafongoya et al., 2016; Martin & Clapp, 2015). Numerous studies have reported that smallholder farmers use credit from the private sector to improve their farm productivity. Farmers with access to credit demonstrated a 25.20% increase in maize productivity compared to those without access to agricultural credit. Agricultural credit positively impacts farmers' income by increasing yields (Assouto & Houngbeme, 2023; Nordjo & Adjasi, 2020). Yet, farmers face various challenges when accessing agricultural credit such as high interest rates, lengthy document processes and undeveloped business plans (Balana & Oyeyemi, 2022; Hussain & Thapa, 2012; Khanal & Wilson, 2019; Men et al., 2024; Widhiyanto et al., 2018). If farmers cannot access credit, succeeding in agricultural technology transfer can be challenging for CAPS practices (Van Loon et al., 2020). Limited funding support is the main challenge to farmers' decision to practice CAPS due to costs involved in paying for agricultural machinery, services and cover crops (Carlisle et al., 2022). This shows the important role of FIs in breaking down barriers and promoting CAPS.

Conservation agriculture (CA) is a sustainable farming approach characterized by three core principles: (1) minimal mechanical soil disturbance by directly seeding and/or placing fertilizers helps to minimize soil erosion and protect soil organic matter; (2) permanent soil organic cover, maintained by ensuring that cover crops and plant biomass cover at least 30% of soil surface; and (3) species diversification, implemented through varied crop rotations and combinations that involve at least three different types of crops (FAO, 2024). CAPS helps reduce soil disturbance and improve soil fertility, which can lead to increased productivity (Fisher et al., 2018; Freitag et al., 2024; Mitchell et al., 2017; Rodenburg et al., 2021). Farmers are drawn to adopting CAPS because of the potential for higher income; however, their access to agricultural inputs and technological resources, including machinery and CAPS training, remains constrained (Derpsch et al., 2016; Sassenrath et al., 2008; Tufa et al., 2023).

Research on and adoption of CA began in the United States in the 1960s; however, in Cambodia, the initiative started in 2004 as a Research for Development (R4D) project supported by Agence Française de Développement (AFD) and Centre de Coopération Internationale en Recherché (CIRAD), with a focus on cover crop preservation practices in Bos Khnor, Kampong Cham (Lal, 2015; Tho et al., 2021). The World Bank (2024) and FAO et al. (2022) reported that in 2021, Cambodia's agricultural land comprised about 6,099,100 ha (around 34%) of the total agricultural land area, but only approximately 0.12% was managed according to full or partial CAPS principles. The number of farmers who adopt or practice CAPS is slow because the expected cost of CAPS inputs and high interest rates have become major challenges for promoting CAPS in Cambodia (FAO et al., 2022; Men et al., 2024). To overcome these challenges, the government of Cambodia has implemented multiple stakeholder policy dialogues to promote CAPS by engaging farmers with the private sector, non-governmental organizations (NGOs) and other stakeholders, ensuring that CAPS will surely expand to benefit more farmers across the country (FAO et al., 2022).

Private sector engagement in the agricultural extension model might address some of these challenges to promote CAPS. A community engagement model was integrated in order to connect the private sector closely with farmers' needs to promote new technologies supported by public actors (Abbott, 2012; Batidzirai et al., 2021). The connection of this model promotes their products including agricultural machinery and cover crops (Mandari et al., 2017; Muyanga & Jayne, 2008; Tang et al., 2015). In Cambodia, the private sector engagement in the agricultural extension model demonstrates that farmers are interested in connecting with CAPS practices. To increase engagement between the private sector and farmers, the Royal Government of Cambodia through the Ministry of Agriculture, Forestry and Fisheries launched the MetKasekor (MK) Agricultural Extension Model in 2018, which translates to 'farmers' friends' in Khmer. The main activity of the MK model is to conduct a field showcase to promote appropriate technologies for CAPS that reduce negative environmental impacts, including improved soil health that enables smallholder farmers to increase their productivity and family income (Phann et al., 2021). This allows an opportunity for the private sector and farmers to discuss challenges they face and recommend products or services to increase productivity and improve CAPS benefits with support from the government and NGOs (Dimitri & Baron, 2020; Ferroni & Castle, 2011; Relf-Eckstein et al., 2019; Tufa et al., 2023).

Direct engagement of the private sector with farmers shows a positive impact and provides an

opportunity to sustainably promote CAPS and to understand unique needs and constraints of farmers (Florini & Pauli, 2018; Kishioka et al., 2017; Managanta, 2021). High agricultural machinery costs, driven by limited local supply, are further exacerbated in the mechanization of CAPS due to the limited price premium for CAPS crops and the expected cost of CAPS inputs. Connecting the private sector with farmers requires attention since farmers need information on CAPS from the private sector, extension agents and service providers (FAO et al., 2022). In Cambodia between 2015 and 2018, the CAPS initiative invested in and engaged with the private sector in appropriate-scale machinery and cover crop seeds, while simultaneously focusing on policy dialogue and cross-sector collaboration. The private sector played a significant role in promoting CAPS, supported by an incentive mechanism for a service-based approach to encourage private sector engagement (Tho et al., 2021). The private sector helps increase accessibility of key elements for promoting CAPS such as providing agricultural inputs like machinery and cover crop the engagement requires a thorough understanding and consideration of various influencing factors and mechanisms (Glover et al., 2016; Tho et al., 2021). The limited engagement of the private sector in the agricultural extension model to promote CAPS production systems in Cambodia remains a major concern.

Farmers' demographic and socioeconomic factors contribute to farmers' decisions to use private services in agricultural practices (Khoza et al., 2019; Manocha et al., 2023; Tatis Diaz et al., 2022). Previous studies provided multiple factors affecting farmers' decision to engage with private services including gender, number of farms, on-farm income, farmers' experience, familiarity with local private sector, farmers' interest in government subsidies, distance of services and use of services to increase family income (Alizamir et al., 2018; Elias et al., 2016; Nyongesa et al., 2016; Quaye et al., 2019; Teff-Seker et al., 2022; Tey & Brindal, 2012; Upadhaya & Arbuckle, 2021). Gender also impacts farmers' decision to accept or reject new technologies. For instance, males might be willing to learn new knowledge of CAPS compared with females (Carnegie et al., 2020). Farm size is considered as another factor as farmers with small fields might not be interested in using these services, while those with large-scale fields are more likely (Upadhaya & Arbuckle, 2021). On-farm cost impacts on-farm income; if farmers spend more on agricultural input, net income might decrease farm income (Nyongesa et al., 2016). There is limited focus on diverse factors, including the total land size of main crops, off-farm income, the price of services, duration of off-farm engagement, main crop production and the amount of primary crop income. These factors would influence engagement between the private sector and farmers to promote CAPS in Cambodia.

Substantial costs and limited availability of inputs – including agricultural machinery, agricultural production costs, market opportunities, education and training, promotional resources and collaboration among stakeholders and farmers – are identified as major challenges to the expansion of CAPS in Cambodia (FAO et al., 2022; Tho et al., 2021). Beyond high costs of inputs, Cambodian farmers encounter limitations in educational opportunities, hindering their capacity to comprehend the application and execute CAPS effectively. The private sector also encounters various challenges in engaging in the agricultural extension models to promote CAPS, including high cost of inputs, uncertain returns on investment, policy and regulatory challenges, and limited information and awareness (Alam Hossain Mondal et al., 2010; FAO et al., 2022; Maulidia et al., 2019; Niino et al., 2022). To address these challenges, government subsidies and incentive programs can serve as effective mechanisms for improving farmers' exposure to these technologies, as limited financing and knowledge often prevent farmers from testing CAPS (Khatri-Chhetri et al., 2019; Scheyvens et al., 2016). El Bakali et al. (2023) stated that government subsidies are categorized under social factors, as they influence farmers by enhancing income and reducing production costs, thereby expediting the integration of environmentally friendly agricultural technologies. These types of subsidies should be provided by the government including fertilizer subsidy, improved seed and fertilizer transportation. Instead of providing this monetary assistance indirectly to farmers through the governments and NGOs, it should be done directly to the private sector, and then the private sector can engage directly with farmers through discounted services and input prices (Hellin et al., 2009; Intriago Zambrano et al., 2023).

Government incentives are used to promote CAPS by supporting the private sector including both direct and indirect incentives, i.e. cost-sharing arrangements, price control, training assistance, facilities of liquidity, loan guarantees and tax incentives for

agricultural materials (Brown et al., 2020; Pauw, 2015; Spielman & Ma, 2016). Similarly, Piñeiro et al. (2020) identified three types of incentives for adopting sustainable agricultural practices: market and non-market incentives, regulatory incentives, and cross-compliance incentives. These types of incentives are evaluated to determine how they affect farmers' willingness to adopt such practices. Market dynamics and policy frameworks are integrated influences that impact private sector engagement in promoting CAPS (Pomi et al., 2022). In addressing farmers' demand, regulatory mandates and financial motivations by the private sector, there is significant potential to impact the CAPS expansion. Relevant stakeholders including policymakers, need to establish enabling environments that align private interests with sustainable agriculture goals to foster the broader.

To support this, systemic policy instruments were developed to complement traditional approaches to innovation policy, which primarily address market failures in agriculture (Hermans et al., 2019). Tho et al. (2021) and FAO et al. (2022) proposed various solutions through a multi-stakeholder policy dialogue process to promote CAPS in Cambodia. These include further developing supply chains for CA inputs to reduce their costs, exploring higher-value market opportunities, integrating CA and related agroecological approaches into research, agricultural extension, and education programs, and increasing collaboration and organization among farmers and other key stakeholders. The incentive mechanism also highlights support for the private sector in domestic manufacturing of machinery, the importation of additional machinery, the implementation of an import taxation exemption for relevant agricultural machinery and spare parts for CA, and efforts to improve the quality and quantity of available cover crops (FAO et al., 2022).

Numerous investigations evaluate the significance of interactions among the private sector, extension services and farmers. These research efforts frequently analyse the variables that impact farmers' engagement in extension activities; however, there is a lack of emphasis on socioeconomic determinants that influence the depth of their involvement with extension agencies (Dimitri & Baron, 2020; Maake & Antwi, 2022; Qwabe et al., 2022; Rana et al., 2023; Reimer et al., 2023). Moreover, some of the research in sub-Saharan Africa, South Asia, Latin America, Peru and Australia related to connecting the private sector with farmers used a qualitative approach for data collection (Faure et al., 2017; Nettle et al., 2018; Van Loon et al., 2020). There is still limited focus on a mixed-method design that combines both qualitative and quantitative methods. Therefore, while qualitative methods have been prominent in previous studies, there is increasing acknowledgment of the value of mixed-method approaches in linking the private sector with farmers to promote CAPS, as these designs offer a more thorough understanding of the complex dynamics involved in these interactions. The exploration of engagement between the private sector and farmers to promote CAPS using a mixed-method approach, particularly in empirical studies conducted in Cambodia, will be conducted. The research goal is to fill a knowledge gap on limited funding and limited farmer knowledge available to practice CAPS in the MK agricultural extension model, promoting CA through private sector engagement. The research results are expected to shed light on successful approaches for private sector engagement in an agricultural extension design, providing critical insights to policymakers, agricultural experts and researchers who are engaged in sustainable agricultural intensification development.

By understanding mechanisms and priorities that drive private sector engagement, we can optimize extension services to enhance the adoption of CAPS, thereby fostering a more sustainable resilient agricultural industry in Cambodia. The research findings can serve as a blueprint for other regions grappling with similar challenges, contributing to a global movement towards more sustainable and resilient agricultural systems. This study aimed (i) to assess influencing factors and mechanisms to engage private sector actors and (ii) to rank private sector actors to perform their engagement with farmers in the agricultural extension model to promote CAPS in Cambodia. To carry out this research, we formulated three research questions: (1) What are factors influencing the private sector engagement with farmers to promote CAPS? (2) What are mechanisms underlying the private sector engagement with farmers to advance CAPS? (3) Who are the private sector actors having the potential to interact directly with farmers to promote CAPS?

2. Materials and methods

2.1. Study areas

The research was conducted in Cambodia, Battambang (BTB) and Preah Vihear (PHV) provinces,

which are found in the country's northwest and north, respectively (Figure 1). The multistage method was used to identify village targets for investigation. The difference between the two provinces was the duration of how CAPS was introduced: 2010 in BTB and 2020 in PHV (Stéphane et al., 2010; Tho et al., 2021). BTB has a CAPS demonstration site, while PHV does not, and all CAPS outreach needs to be done on-farm.

2.2. Sampling techniques and sample size

A purposive sampling technique was applied to select the study areas in BTB and PHV provinces. A multistage sampling strategy was adopted based on the population's natural clustering patterns to acquire a representative sample for analysis. This technique required three steps of random sampling from both provinces including district selection, commune selection, and village selection. Three districts in BTB were selected out of the total 13, districts including Ratanak Modul, representing the upland ecosystem, and Banan and Sangke representing the lowland ecosystem. One commune was chosen in Sangke and Banan districts named Kampong Preang and Phnom Sampov, respectively. One hundred and fifty-four farmers attended training with CAPS field showcases in BTB. Among the eight districts in PHV, one district (Rovieng), a lowland area was selected because CAPS had been introduced. Three villages (Pal Hal, Bos and Doung) in the Riek Reay commune were selected in this district, where 88 farmers attended training with the CAPS field showcase in PHV.

The data collection procedure was separated into two sections that included the survey instrument and focus group discussions (FGDs). Secondary information was obtained from relevant stakeholders including village chiefs, Provincial Department of Agriculture, Forestry and Fisheries (PDAFF) representatives, CAPS implementers, and the private sector. The primary data were collected through a household survey. The survey employed in-person interviews with target populations for CAPS and non-CAPS farmers in BTB and PHV. CAPS farmers attended technical training under the MK model's activities, while non-CAPS farmers did not participate in any training. For more details about CAPS farmers and the MK model, see Men et al. (2024). This research, approved by the Ethics Committee of Kasetsart University in Thailand (COE No. COE66/019), ensures that farmers' personal information is kept confidential and is not disclosed to the public, and the results are reported in an aggregate form.

The questionnaire was designed to meet the research objectives. The number of CAPS samples was determined using the formula (Minister of Industry, 2010):

The initial sample size is shown in Equation (1):

$$n_1 = \frac{Z^2 \hat{p}(1 - \hat{p})}{e^2} \quad (1)$$

where n_1 is the first estimation of the sample size (n_1 = 384), e is the target level of precision or the error margin (5%), Z^2 is the Z value or test of statistics for confidence levels, and 1.960 = 95%, p is the population's estimated percentage of an attribute (50%).

The population size was adjusted according to Equation (2):

$$n_2 = n_1 \frac{N}{N + n_1} \quad (2)$$

where n_1 is the first estimation of sample size (n_1 = 384), N is the population size (180 and 90 households in BTB and PHV), n_2 is the population size adjusted at $n_{2\,(BTB)} = 123$, $n_{2\,(PHV)} = 72$, $n_2 = 123 + 72 = 195$. The sample size is defined in Equation (3):

$$n_3 = deff \times n_2 \quad (3)$$

where *deff* denotes the intended result, this research typically used *deff* qual 1 (simple random sampling design). To determine the final sample size, n, the response is adjusted as shown in Equation (4):

$$n_4 = \frac{n_3}{r} \quad (4)$$

where n_3 the design effect ($deff = 1$), $n_3 = 195$, n_4 select the appropriate sample size, r is the anticipated response rate; 90% of r would be used in this study, a total of 242 households practising CAPS were included, accounting for a reserved 12% equal to 25 households.

2.3. Data source

This study followed a mixed-method design. Consistent with the research goal, a literature analysis and researchers' prior extensive experience in the fields, a structured questionnaire was created. These quantitative results were complemented by FGDs with qualitative data collected. FGDs collected qualitative data from multiple stakeholders including government officers, private sector representatives, NGO staff,

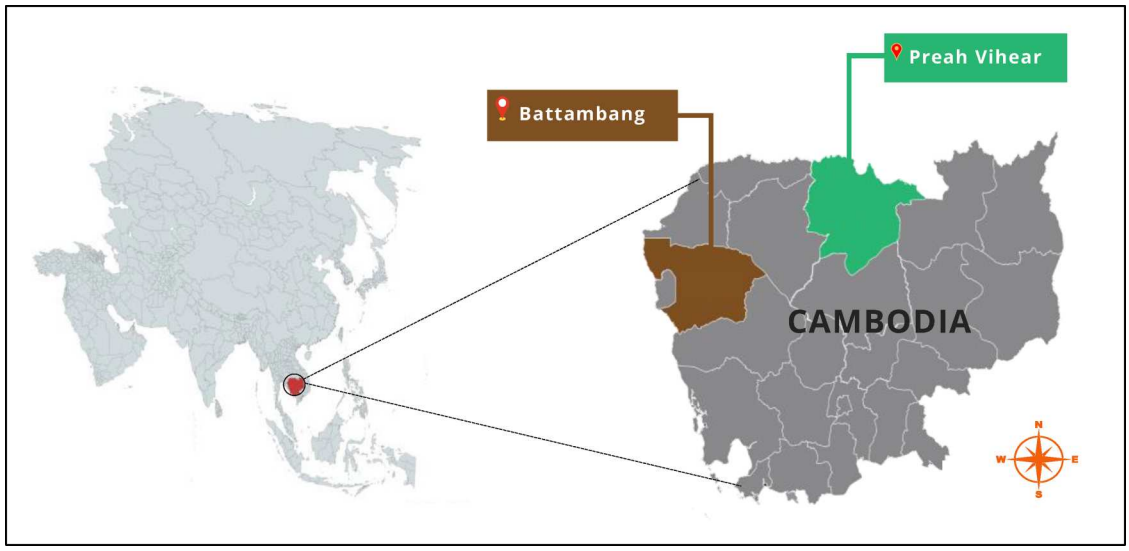

Figure 1. The location map of study areas, Battambang and Preah Vihear provinces, Cambodia.

and farmers engaged with the MK model to promote CAPS (Table 1). It aimed to collect problems and solutions, to identify a mechanism to engage the private sector with farmers in the agricultural extension model, and to validate the information from the survey instrument. FGDs were divided into two groups: one at BTB and another at PHV.

2.3.1. Focus group discussion method

The qualitative data gathered from the focus group dialog supplemented the qualitative findings of researchers (ten at a government level, six at a private sector level, eight at a farmer level, and four at an NGO level in BTB and PHV), allowing us to triangulate the survey's findings with farmers' observations and reflections as well as perspectives of the government and the private sector (Table 1). FGDs assisted researchers in collecting new information and gaining clarity on problems and solutions from stakeholders' perspectives to find an appropriate mechanism to engage the private sector with CAPS farmers who assist the government. Stakeholders identified problems, solutions and appropriate mechanisms to engage the private sector in the agricultural extension model to promote CAPS in the country.

FGDs were conducted in three steps: preparation, implementation and analysis. The preparation step included the invitation of each participant extended by staff members of the MK model, who were employed at the local study site. After the team's final decision during the discussion, the staff were provided with a list of participants to invite for the FGDs. The participants were furnished with discussion topics, objectives, locations, timing and data about the FGDs. The implementation step related to requesting permission from the participants for all activities, including the use of a sound recorder, script notes and photography before starting the FGDs. Information about participants was kept

Table 1. Summary of data collection methods.

	Provinces		
Collection methods	BTB	PHV	Total sample size
Survey instrument			
CAPS farmers	154	88	242
Non-CAPS farmers	155	84	239
Total sample size (HH)	309	172	481
Focus group discussions (FGDs)			
Local government ($n = 10$)			
PDAFF	2	2	4
Village chiefs	3	3	6
Private sectors ($n = 6$)			
Service providers	1	1	2
Cover crop suppliers	1	1	2
Financial institutions	1	1	2
Farmers ($n = 8$)			
CAPS farmers	2	2	4
Non-CAPS farmers	2	2	4
NGOs ($n = 4$)			
MetKasekor model implementers	2	2	4
Total sample size (HH)	14	14	28

HH = household head; PDAFF = provincial department of agriculture, forestry and fisheries; n = number of observations; CAPS = conservation agriculture production systems; BTB = Battambang province; PHV = Preah Vihear; NGOs = non-government organizations.

confidential and was not revealed to the public. For this step, FGDs focused on three main themes: (1) problems, (2) solutions and (3) mechanisms for practising CAPS. During the analysis step, we transcribed the audio, condensed the data, and identified and analysed emerging themes after the discussions. We also reviewed the script notes and audio recordings to ensure they aligned with the main discussion themes. The sound recorder was distilled and placed into text, and thematic analysis was conducted. Script notes and audio recordings were translated into English.

An open-ended questionnaire was administered to collect additional data from participants. FGDs were conducted by purposive sampling with three types of questions, namely, engagement questions, exploration questions and exit questions. FGDs were conducted with the 3EQ-PSM model, encompassing engagement, exploration and exit questions (3EQ), alongside open-ended inquiries designed to collect qualitative data on problems, solutions, and mechanisms (PSM). This approach aimed to encourage the private sector's involvement in the agricultural extension model, fostering the promotion of CAPS in Cambodia. The 3EQ-PSM model was implemented to discern problems, solutions and mechanisms from participants. Three sections were employed for conducting FGDs. Section one referred to engagement type questions (introduction questions), while section two focused on the exploration question (focus questions with problems, solutions, and mechanisms). Section three included an exit question that pertained to a summary section capturing participants' perceptions. The open-ended questions are shown in Figure 2.

2.3.2. Survey instrument

The quantitative data were collected by using an in-person survey. A total of 481 households in two provinces of Cambodia were randomly selected for the research, and structured questionnaires were distributed in 2023 to collect information about general practices of CAPS and its geographic locations. Primary data from the survey were collected on types of agricultural private sectors, private sector activities, the importance of farmers' perceptions of the private sector, and subsidies. The samples from BTB and PHV provinces were separated into two respondent groups (CAPS = 242 observations and non-CAPS = 239 observations) (Table 1). The sample size of non-CAPS farmers was assumed to be equal to that of CAPS farmers' respondents. A structured questionnaire was developed, drawing on several items identified from literature reviews, including household demographics, socioeconomic factors,

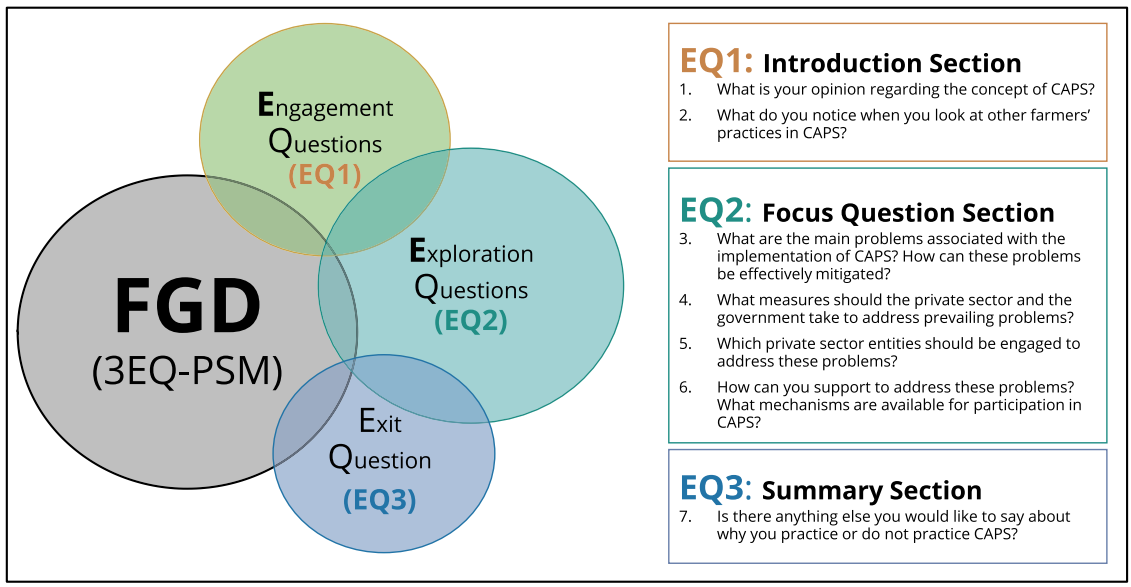

Figure 2. Focus group discussions (FGDs) by using the 3EQ-PSM model for qualitative data collection. 3EQ-PSM = engagement, exploration, and exit questions, alongside open-ended inquiries designed to collect qualitative data on problems, solutions and mechanisms; CAPS = conservation agriculture production systems.

and the level of private sector engagement with farmers. Household demographics included: gender, age, education level, family labour, number of fields, farm experience and familiarity with the private sector in a commune. Socioeconomic factors included: off-farm income, duration to engage off-farm, on-farm income, amount of primary crop income, total land size of main crops, main crop production, government subsidies, distance to services, price of services and using services to increase in profit. A 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = moderate, 4 = agree, 5 = strongly agree) was used to measure the rank of the private sector engagement with CAPS farmers. The validity of the question items was assessed through a pretest with 10 farmers who were not part of the total sample size. The questionnaire was revised based on the pretest results.

2.4. Statistical analyses

A mixed-methods approach was used in this study. Both quantitative and qualitative data were gathered, and R-program (version R.4.3.2) was employed to process the acquired data using descriptive statistical techniques and statistical modelling. The quantitative data were analysed using a binary logistic regression model to identify influencing factors of engagement from the private sector with farmers in promoting CAPS. Kendall's *W*-test was used to rank the private sector engagement with CAPS farmers. Thematic content methodologies were used to examine qualitative data from FGDs.

2.4.1. Variables and measurement

An examination of general information was conducted using descriptive statistics. A binary logistic regression model was employed to analyse the association between a binary variable indicating whether farmers have to engage in training to promote CAPS and a set of explanatory factors that describe the socioeconomic characteristics of farmers and the accompanying institutional features (Ullah et al., 2020). Dependent (outcome) and independent (explanatory) variables were collected. This model provides factors that can influence how the private sector can engage with CAPS farmers in the agricultural extension model. The logistic distribution model is excellent for examining categorical data. Attendance in CAPS training was a dichotomous dependent variable. The variable takes values 1 or 0 if a farmer has attended or has not attended CAPS training, respectively. The following is the model formulation with several independent variables impacting CAPS and non-CAPS availability:

$$P(Y=1)=\frac{1}{1+e^{-(\beta_0+\beta_i X_i)}} \tag{5}$$

$$P(Yi=1)=\frac{1}{1+e^{-Z_i}} \tag{6}$$

where $P(Y=1)$ is the probability of CAPS farmers attending training, Z_i is a function of a vector of n explanatory variables, e is the base of the natural logarithm, $P(Y=0)$ is the probability of non-CAPS farmers not attending to CAPS training. If $1-P(Y=1)$ is a probability of CAPS farmers occurring, and if $1-P(Y=0)$ is a probability of non-CAPS farmers occurring.

$$1-P(Yi=1)=1-\frac{1}{1+e^{-Zi}}+\frac{1}{1+e^{Zi}} \tag{7}$$

Therefore, the formulation can follow:

$$\frac{P(Y=1)}{1-P(Y=1)}=1-\frac{1+e^{Zi}}{1+e^{-Zi}}=e^{Zi} \tag{8}$$

Equation (8) is the odds ratio, which is the probability that a farmer who joined the CAPS training field (CAPS farmer) would engage with the private sector services to practice CAPS. In contrast, non-CAPS farmers did not attend CAPS training.

$$\begin{aligned}\text{Logit}&=\ln\left(\frac{P(Yi=1)}{1-P(Yi=1)}\right)Z_i\\&=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_{17}X_{17}+\varepsilon_i\end{aligned} \tag{9}$$

where logit is the log of the odd ratio, which is linear not only for the independent variables but also for the other parameters. Where β_0 is a constant, β_1 *to* β_{17} is the coefficient of logistic regression, ε_i is an error term, and X_i is a relevant factor of respondents (explanatory variables), including X_1 = gender, X_2 = age, X_3 = education level, X_4 = family labour, X_5 = number of fields, X_6 = total land size of main crops, X_7 = main crop production, X_8 = off-farm income, X_9 = duration to engage off-farm, X_{10} = on-farm income, X_{11} = amount of primary crop income, X_{12} = farm experience, X_{13} = familiarity with the private sector in a commune, X_{14} = government's subsidy, X_{15} = distance of service, X_{16} = price of service, and X_{17} = increase in profit. These variables were found to have a positive and negative significant

influence on the engagement of private sector with farmers for promoting CAPS (Table 2).

2.4.2. Kendall's W-test

Nonparametric statistic results from straightforward normalization of the Friedman test and swings between 0 (disagreement) and 1 (whole agreement). This demonstrates that given the respondents' unanimity, $W = 1$ if each farmer ranked the list of concerns in the same order; $W = 0$ if there was no consensus among interviewers; hence, respondents' answers were chosen at random (Dhehibi et al., 2020). The following equation was used to compute Kendall's statistical test:

$$W = \frac{12S}{p^2(n^3 - n) - pT} \tag{10}$$

Table 2. The statistical variables and measurement of farmer information.

Variables Farmers respondent (outcome variable)	Unit of measurement Dummy: CAPS = 1; Non-CAPS = 0	Expected sign
Independent (explanatory variables)		
Gender	Male = 1; Female = 0	+
Age	Households' age (years old)	+
Education level	Education year (years)	–
Family labour	Family member (number of family member)	+
Number of fields	The number of filed (field/s)	+
Total land size of main crops	Number of harvested areas recent year (ha)	–
Main crop production	Number of main crop production (ton per ha)	–
Off-farm income	Yes = 1; No = 0	+
Duration to engage off-farm	Number of farmers engaged with off-farm (months)	+
On-farm income	On-farm income per year (USD per year)	+
Amount of primary crop income	The primary crop income per year (USD per year)	+
Farm experience	Number of farm experience (years)	+
Familiarity with the private sector in a commune	Yes = 1; No = 0	+
Government's subsidy	Farmer's perception of subsidy (Yes = 1; No = 0)	+
Farmers' perception of using private services		
Distance of service	Yes = 1; No = 0	–
Price of service	Yes = 1; No = 0	+
Increase in profit	Yes = 1; No = 0	–

(+/–) indicates a positive or negative relationship with the dependent variable; USD = U.S Dollar; CAPS = conservation agriculture production systems.

where n demarcated of concern number, p is the number of judges quantified, and T has developed a coefficient to break ties in ranks.

The average of rank sums over squares is used to calculate S. In this way, the following can be deduced from Kendall's W-test:

$$S = \sum_{i=1}^{n} (Ri - R)^2 \tag{11}$$

W-statistic was an evaluation of the row sums of rankings divided by Ri's variance by the widest range of variance values (R). When all responses (CAPS and non-CAPS) are in complete agreement, this might be feasible; hence, $0 \leq W \leq 1$. As a reason, the three enhanced service providers used to promote CAPS by connecting with the private sector in a model of agricultural extension were classified using the aforementioned Kendall's W-test. Ranking was conducted to assess private sector engagement with CAPS farmers. The importance of the private sector included service providers, cover crop suppliers and FIs. Kendall's W-test showed that the private sector prioritized engaging with farmers to promote CAPS.

3. Results

3.1. Descriptive statistics of explanatory variables

Almost 60% of households that practiced CAPS and 38% of those who did not practice CAPS (non-CAPS farmers) were headed by men (Table 3). On average, both CAPS and non-CAPS farmers were approximately 50 years old. The education level of both farmer groups was primary school education (i.e. grades 1–6, education system in Cambodia (Marshall & Ung, 2022; Pellini & Bredenberg, 2015). Adult labourers in a family were similar between the two farmer groups (approximately 3 people). Adult labourers' age is referred to as working age by the International Labour Organization in Cambodia (15–64 years) (Kanol et al., 2013). The number of fields was 2.08 and total land size of main crops was 3.98 ha on average for CAPS farmers while 2.42 fields and 4.46 ha for non-CAPS farmers. The main crop production for both groups of farmers was around 6 tons per hectare. Off-farm income was money earned through paying for work done away from one's farm. CAPS farmers had off-farm income of 75.25%, whereas 61.92% of non-CA farmers had off-farm

income. The duration to engage off-farm was 77 months for CAPS farmers, compared to 91 months for non-CAPS farmers. Approximately, 6027 USD per year and 7497 USD per year was generated as on-farm income by CAPS and non-CAPS farmers, respectively. CAPS farmers' average amount of primary crop income was 4954 USD per year, while non-CAPS farmers received 7298 USD per year. Farm experience was 19.30 years on average for CAPS farmers, while non-CAPS farmers had 23.90 years of engaging in agricultural activities. Similarly, approximately 99% of CAPS and non-CAPS respondents were familiarity with the private sector in a commune. Both groups of farmers showed approximately 99% interest in government subsidies. Farmers' perception of using private services included distance of service, which affected approximately 83% of CAPS farmers and nearly 89% of non-CAPS farmers. Similarly, the price of service was 71% of CAPS farmers and about 64% of non-CAPS farmers. The utilization of private sector services to increase in profit was similar between CAPS and non-CAPS farmers, with approximately 95% in both groups.

3.2. Influencing factors to engage private sector in promoting CAPS

The binary logistic regression model revealed a good fit for the survey instrument, with nine out of 17 explanatory variables having statistically significant positive and negative coefficients at the 1% level ($p < 0.01$) (Table 4). The factors that positively influenced the engagement of CAPS farmers with the private sector included gender, number of fields, off-farm income, farm experience, familiarity with the private sector in a commune, and government subsidies (Table 4). Gender, number of fields, off-farm income, and government subsidies were significant influencing factors at the 1% level, with the odds ranging from 1.430 to 8.469. Farm experience and farmers' familiarity with the private sector in a commune were also significant at the 5% level.

Negative influencing factors in the engagement of CAPS farmers with the private sector included total land size of main crops, farmers' perception of using private services including distance of service, and increase in profit (Table 4). Farmers' perception of using private sector services from distance of service and increase in profit were significant influencing factors at the 1% level, whereas the total land size of main crops was significant at the 5% level. The odd ratio was ranked from 0.417–0.915.

3.3. Mechanisms for private sector engagement in promoting CAPS

The 3EQ-PSM model was performed to validate the survey procedure, and FIs were priority of private sector to connect directly with CAPS farmers in the agricultural extension model (Figure 3). Participants

Table 3. Description of descriptive statistics of explanatory variables for CAPS and Non-CAPS farmers ($n = 481$).

Explanatory variables	CAPS farmers ($n = 242$)		Non-CAPS farmers ($n = 239$)		Expected sign
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	
Gender (1/0)	0.38	0.49	0.53	0.50	+
Age (years old)	45.00	13.00	49.60	12.10	+
Education level (years)	5.68	3.86	5.25	3.27	–
Family labour (person)	2.29	0.53	2.30	0.54	+
Number of fields (fields)	2.08	0.95	2.42	1.41	+
Total land size of main crops (ha)	3.98	5.90	4.46	4.87	–
Main crop production (ton per ha)	5.84	7.91	6.34	10.30	–
Off-farm income (1/0) (%)	75.25		61.92		+
Duration to engage off-farm (months)	77.10	141.00	91.00	204.00	+
On-farm income (USD per year)	6027.00	10,227.00	7497.00	11,628.00	+
Amount of primary crop income (USD)	4954.00	9787.00	7298.00	19,993.00	+
Farm experience (years)	19.30	12.70	23.90	12.20	+
Familiarity with the private sector in a commune (1/0) (%)	99.00		99.00		+
Government's subsidy (1/0) (%)	98.76		90.65		+
Farmers' perception of using private services					
Distance of service (1/0) (%)	83.47		89.54		–
Price of service (1/0) (%)	71.07		64.44		+
Increased in profit (1/0) (%)	96.28		94.56		–

(+/–) indicates a positive or negative relationship with the dependent variable; *SD* = standard deviation; CAPS = conservation agriculture production systems; *n* = number of observations.

Table 4. Estimation results of factors influencing private sector engagement with farmers for promoting CAPS ($n = 242$).

Explanatory variables	Estimate	Odd ratio	*SE*	*z* value	*p*-value
Intercept	−6.067**	0.002	1.651	−3.676	0.000
Gender	0.589**	1.802	0.222	2.645	0.008
Age	0.022	1.023	0.011	1.917	0.055
Education level	−0.023	0.977	0.032	−0.718	0.472
Family labour	0.031	1.032	0.193	0.161	0.871
Number of fields	0.357**	1.430	0.106	3.367	0.000
Total land size of main crops	−0.089*	0.915	0.039	−2.272	0.023
Main crop production	−0.006	0.994	0.011	−0.531	0.595
Off-farm income	0.665**	1.945	0.236	2.816	0.004
Duration to engage off-farm	0.000	1.000	0.000	0.636	0.524
On-farm income	0.000	1.000	0.000	0.413	0.679
Amount of primary crop income	0.000	1.000	0.000	0.709	0.478
Farm experience	0.022*	1.022	0.011	1.973	0.048
Familiarity with the private sector in a commune	2.431*	11.368	1.128	2.154	0.031
Government's subsidy	2.136**	8.469	0.700	3.049	0.002
Farmers' perception of using private services					
Distance of service	−0.857**	0.424	0.305	−2.808	0.004
Price of service	0.380	1.462	0.221	1.717	0.086
Increase in profit	−0.874**	0.417	0.339	−2.578	0.009

* and ** denote significance at the 5% level ($p < 0.05$) and 1% level ($p < 0.01$), respectively;
SE = standard error.

were categorized into four groups: farmers, private sector, government officers, and NGOs. Sub-stakeholders of participants, including those at the farmer level, were divided into CAPS and non-CAPS farmers. Private sector had three sub-stakeholders: service providers, cover crop suppliers, and FIs. The government level was separated into two subgroups: PDAFF and village chiefs. NGOs were staff of the MK model or CAPS implementers. Three main themes of FGDs, including problems, solutions, and mechanisms, were discussed.

The majority of respondents confirmed the problems of participants, including limited funding, farmers' knowledge, price of agricultural machinery, animal control, farmers' engagement, price of cover crops, limited information, limited labour, limited time to attend CAPS training, CAPS input cost, farmers' confidence, CAPS newly-introduced practices, limited of private services and small-scale farms (Figure 3).

Participants of FGDs in both provinces, BTB and PHV, revealed that:

> We encounter challenges with CAPS practices, including issues related to financial support for inputs, varying levels of farmer knowledge, animal management, farmer engagement, the cost of cover crops, limited access to information, labor shortages, restricted time for training participation, expenses associated with service providers, and specific difficulties faced by small-scale farmers. (FGDs with all actors, Table 1)

> We will practice CAPS if we secure funding for land preparation, cover crops, and agricultural machinery. We lack knowledge and information about CA technology, which prevents us from practicing it. Having necessary information is indispensable for making decisions about adopting CAPS. We also wanted to practice CAPS but did not have the funds to purchase agricultural inputs. Credit accessibility is essential for addressing the issue of practicing CAPS. Document for credit accessibility should be easy to access, and credit information should be shared with us. (FGDs with farmers, Table 1)

> Farmers have limited knowledge about practicing CAPS because this technology may be new to them. Additionally, many farmers face labor shortages and have limited time to attend training sessions. Challenges such as managing animals, farmers' confidence, and the newly introduced CAPS practices further discourage some farmers from adopting CAPS. (FGDs with the local government and NGOs, Table 1)

> Most farmers operate small-scale farms, which affects the cost of services like land preparation. For instance, service providers who use tractors charge more for smaller farms due to the economies of scale. Collective formation of groups by farmers to share services can lead to a reduction in costs. Additionally, the high price of services is partly due to the limited availability of service providers. During the planting season, such as for maize, the demand for services spikes because many farmers plant simultaneously, leading to service bottlenecks. (FGDs with service providers, Table 1)

> Accessing credit necessitates an agricultural business plan and ownership of production land, which presents

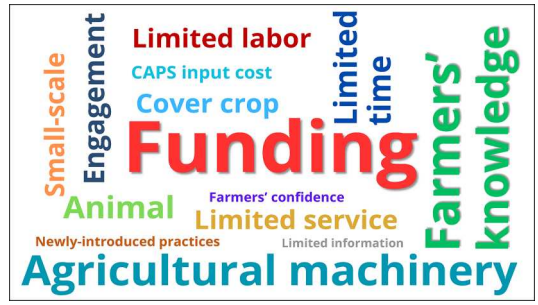

Figure 3. Problems identified by participants in focus group discussions (FGDs) using the 3EQ-PSM model for conservation agriculture production (CAPS). 3EQ-PSM = engagement, exploration and exit questions, alongside open-ended inquiries designed to collect qualitative data on problems, solutions and mechanisms.

> obstacles for many farmers. The majority of farmers face challenges due to limited knowledge and operate on small-scale farms, which complicates their ability to obtain credit for implementing CAPS. (FGDs with financial institutions, Table 1)

> Funding represents the most significant challenge for implementing CAPS, as some of the agricultural inputs necessary for CAPS, including agricultural machinery, cover crops, and land preparation, are costly. (FGDs with all actors, Table 1)

In addressing constraints raised by relevant stakeholders, there is a need to increase access to agricultural credit. A strong perception from respondents emerged that high interest rates were the main challenge in engaging with the private sector for credit accessibility. Most participants also highlighted the challenge of limited funding as the second most critical factor in practising CAPS, particularly in relation to insufficient financial support for inputs including agricultural machinery, service providers and cover crops as some agricultural inputs are costly.

Numerous FGD participants in both provinces, BTB and PHV, confirmed that:

> Accessing agricultural credit can help address challenges of CAPS adoption. Despite this, high interest rates pose a significant barrier for smallholder farmers. These farmers may struggle with monthly repayment, making it difficult for them to take on loans. For example, elevated interest rates on agricultural loans can discourage farmers from adopting CAPS practices. (FGDs with all actors, Table 1)

> We might adopt CAPS to practice in our fields if we can access credit with low interest rates and simplified documentation for credit accessibility. Information about agricultural credit should be widely available. For example, when we seek agricultural loans, we often do not know which FIs can support us. (FGDs with farmers, Table 1)

FGD participants addressed challenges including need to make farmers' knowledge easily accessible for CAPS training, and the issue of insufficient funds could be addressed by promoting agricultural loans and subsidies from the government. Agricultural loans should be provided with lower interest rates than other types of loans, while subsidies and incentives should be proposed by the government and relevant NGOs. One form of subsidy supporting this involves offering discounts to farmers interested in practising CAPS, as discounting serves as a mechanism to involve private sector with CAPS farmers, thus promoting this promising farming practice. Stakeholders of FGDs in both provinces, BTB and PHV, pointed out that:

> All stakeholders involved in promoting CAPS should provide support to farmers who want to adopt these practices. NGOs should offer technical support using simple methods that are easy for farmers to understand. This approach should encourage farmers to adopt CAPS. Government support plays a pivotal role in addressing these challenges. The government should share training information with all farmers interested in practicing CAPS. This information should be widely disseminated among farmers. (FGDs with all actors, Table 1)

The mechanism for engaging the private sector in the MK agricultural extension model to promote CAPS was to provide a farming loan with a reduced interest rate and to share information with farmers broadly. Farmers' collateral assets for credit accessibility for agricultural inputs including agricultural machinery, land preparation services and cover crops service payments were required by FIs. CAPS farmers were provided with agricultural business plans to access credit. The government and NGOs should provide some support to farmers such as information on agricultural loans, CAPS techniques, subsidies, and incentive programs. Subsidies from the government and NGOs should be in the form of a discounted method of fifty per cent. Government taxation incentives should be provided to encourage private sector to engage with the agricultural extension model for promoting CAPS in Cambodia (Figure 4).

Multiple stakeholders of FGDs in both provinces, BTB and PHV, stated that:

> Providing agricultural credit with low interest rates is a good mechanism to engage the private sector with farmers to promote CAPS. Information on the CA management practices, and agricultural credit should be shared with farmers. This information will help farmers make better decisions about adoption. For instance, when farmers seek credit, they need to know requirements set by FIs for accessing loans. FIs should provide credit information, while NGOs should support dissemination of the practices. The government should offer subsidies, incentives, and information to promote CAPS. These financial supports are effective mechanisms to encourage farmers. Additionally, tax incentives could help increase the number of farmers implementing CAPS. The government and NGOs should provide a 50% discount on all related services for farmers who wish to adopt CAPS practices. This will encourage farmers to adopt and promote CAPS. (FGDs with all actors, Table 1)

3.4. Ranking of private sector actors engaging in CAPS promotion

The following section addresses outcomes of face-to-face interviews on the type of private score used to

rank private sector actors in connecting with CAPS farmers to promote CAPS in Cambodia. Concordance coefficient (W), there was agreement among farmers, was measured at 0.02 and significant at the 1% level ($p < 0.01$) (Table 5). FIs were considered the most trustworthy agricultural sector for advancing CAPS, with a mean rank of 1.86 and a standard deviation of 0.91. The service provider constituted the second priority among private sector actors, boasting a mean rank of 2.06 and a standard deviation of 0.87. Cover crop suppliers were assigned a third-level ranking, accompanied by a standard deviation of 0.83 and a mean rank of 2.08.

4. Discussion

4.1. Influencing factors of private sector engagement with CAPS farmers

There are both positive and negative significant factors influencing the engagement of the private sector with farmers to promote CAPS (Table 4). Significantly positive influencing factors in engaging farmers with the private sector include gender, number of fields, off-farm income, farm experience, familiarity with the private sector in a commune, and the government subsidies. Gender dynamics significantly influence various agricultural practices and decision-making processes, and they are also key in shaping engagement and determining outcomes within farming practices (Kristjanson et al., 2017; Wekesah et al., 2019). Gender was a positive significant influencing factor on farmers' engagement with the private sector, as gender is more likely to be connected with the private sector promoting CAPS. This finding agrees with Wale and Mkuna (2023), who found that gender positively influenced preferences for channels of agricultural information used to practice a new technology. A corresponding observation was made by Ragasa et al. (2013), who demonstrated that gender positively influenced access to agricultural services. Farmers would discuss with their family members, including both spouses, to collectively make decisions on significant matters such as accessing agricultural loans, utilizing additional services, or adopting new technologies.

The family source, such as the number of fields, was a factor that influenced the gender decision to adopt or engage with using private services in practice CAPS (Kristjanson et al., 2017). According to Fisher et al. (2018), the number of fields influenced the connection between the private sector and farmers. This research also found that the number of fields owned by farmers was a significantly positive influencing factor on farmer engagement with the private sector. This aligns with Derpsch et al. (2016) and Mishra et al. (2022) who concluded farmers who had large-scale agricultural activities (> 20 ha) would be better able to adopt a new technology, whereas farmers who had small-scale agricultural activities (< 2.5 acres equal to 1 ha) may find it more complicated to adopt agricultural technologies. Brinkman (2017), Ntshangase et al. (2018) and Sukayat et al. (2023) also discovered that small-scale farmers are more inclined to accept a modern technology. Consequently, these farmers may more easily adopt CAPS practices as they demand less labour as labour is essential in impacting off-farm income through its influence on the accessibility of time and opportunities for diversifying income (Anang et al., 2020).

Off-farm income was a significant factor positively influencing engagement of farmers with the private sector in promoting CAPS. This reason is corroborated by Nkegbe et al. (2024) and Tudor and Balint (2006), who reported that off-farm involvement by farmers enhances private services. Similarly, Eshetu and Mekonnen (2016) and Li et al. (2021) widely acknowledged in the literature that off-farm income plays a significant role in reducing rural poverty. Higher off-farm earnings increase engagement with this agricultural extension model, as farmers are more likely to practice CAPS when they have off-farm employment since it requires purchasing certain inputs including agricultural machinery, land preparation services, and cover crops. Multiple studies by Anang et al. (2020); Marenya et al. (2017); Myeni et al. (2019) and Ntshangase et al. (2018) indicated that improved farm liquidity reasons in positive private-sector engagement with off-farm revenue, which farmers can use to pay employees and buy supplies. Farmers who had income from off-farm employment were less likely to adopt new technologies, but labour in an agricultural sector was defined as off-farm employment with higher requirements. This data is corroborated by Zakaria et al. (2020). In Cambodia, adult labourers transitioned from agricultural to off-farm employment to enhance their living standards (Alrawashdeh et al., 2023). As discussed earlier, off-farm employment activities might increase the intensity of technology adoption to promote CAPS.

Furthermore, household demographics including farm experience and familiarity with the private

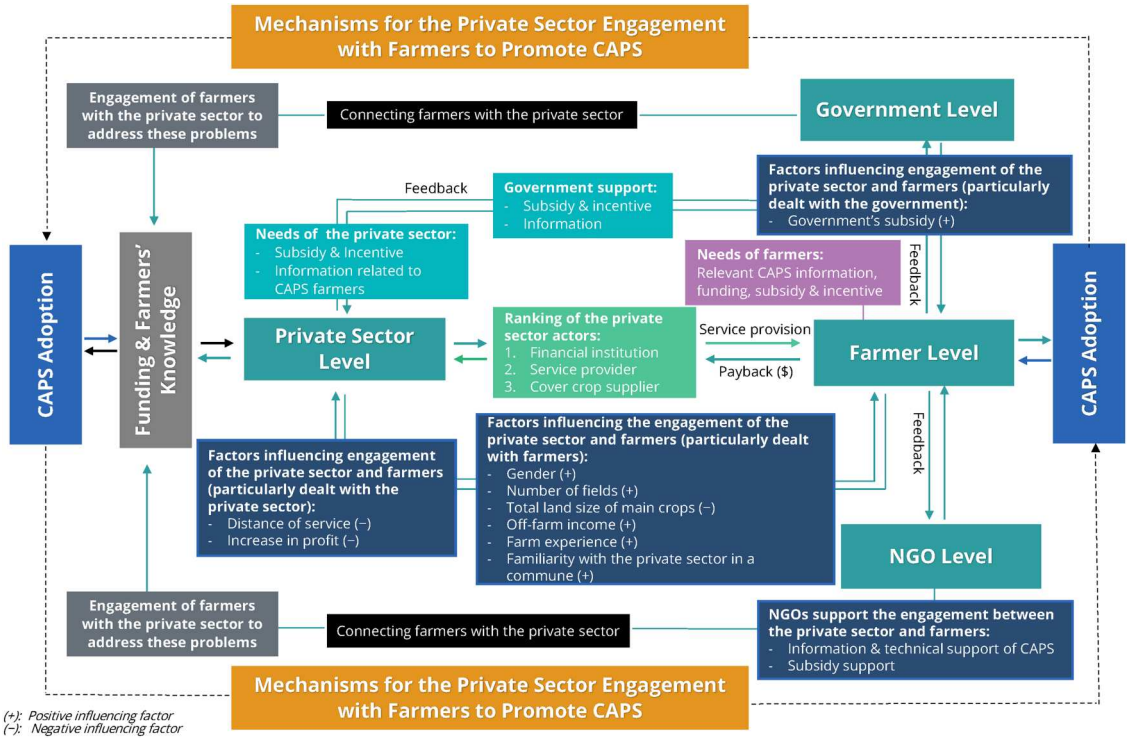

Figure 4. Mechanisms for the private sector engagement with farmers to promote CAPS using the encompassing engagement, exploration and exit questions, alongside open-ended inquiries designed to collect qualitative data on problems, solutions and mechanisms (3EQ-PSM). CAPS = conservation agriculture production systems; NGO = non-governmental organization.

sector in the commune were also identified as positive influencing factors in engaging farmers and the private sector. Nevertheless, our finding contrasts with Carrer et al. (2017) in Brazil, and Chen et al. (2022) in China. Farmers with more experience are more willing to collaborate with private sector services to promote CAPS (Pilarova et al., 2018). Chalak et al. (2017) and Chowa et al. (2013) stated that farmers' decisions to adopt new technologies were influenced by their farm experience, which in turn serves as a primary factor affecting the likelihood of their engagement with the private sector. It was related to the farmer age (older farmers had greater farming experience than younger farmers) (Chalak et al., 2017). Kernecker et al. (2020) stated that older individuals, who are often more aware and experienced than their younger counterparts, utilize their knowledge to make well-informed decisions about CAPS adoption. Face-to-face interviews also indicated that the average age of farmers was approximately 50 years old. We expect that older farmers would share their farming experience with younger farmers leading to CAPS promotion in their community.

Familiarity with the private sector in a commune would encourage farmers to access private services and adopt agricultural technologies (Meijer et al., 2015). Warner et al. (2022) showed that public-private partnerships are pivotal for increasing the private sector's involvement in providing information services and enhancing the quality of those services.

Table 5. Ranking of private sector actors engaging with farmers to promote CAPS ($n = 242$).

	Ranking of private sector actors		
Private sector actors	Mean rank	*SD*	Ranking
Financial institutions	1.86	0.91	1
Service providers	2.06	0.87	2
Cover crop suppliers	2.08	0.83	3
Kendall's *W*-test	0.02**		
Chi-square (χ^2)	22.20		
Degree of freedom *(df)*	2		
p value	0.00		

Ranking was 1–3, with 1 being the most significant in importance and 3 being the least significant. The means were measured on a 5-point Likert scale (1 = very disagree; 5 = very agree); Kendall's *W*-test = coefficient of concordance; ** denotes significance at the 1% level ($p < 0.01$), respectively; *SD* = standard deviation.

Limited private sector's ability to play a positive role in advancing agricultural knowledge and information systems has been sparked by the increased complexity of the private sector's delivery of agricultural extension services (Kassem et al., 2021). Ngigi and Muange (2022) and Warner et al. (2022) observed that service information was widely considered a factor influencing the adoption of new technologies. There would also be an added benefit that private services including agricultural machinery, cover crops, and FIs would provide programs related to their products to encourage farmers to use their products. In turn, farmers need to pay for all services provided by the private sector.

Socioeconomic factors such as government subsidies would encourage farmers to engage with private services in practising CAPS. The outcome of this investigation revealed that farmers with a positive perception of the government subsidies, approximately 98% of them, were most likely to connect with the private sector to promote CAPS. This finding is in line with a previous study by Liu et al. (2021) that explored impacts of perceived value and the government regulation on farmers' willingness to adopt wheat straw incorporation in China. The government subsidies positively influenced farmers' adoption of new and improved technologies, enhancing yield productivity and living standards, because they were effective in encouraging farmers to use private services. El Bakali et al. (2023) similarly indicated that input subsidies significantly contributed to the promotion and expansion of CAPS. Government subsidy policies announced in the farming sector would impact farmers' willingness to adopt personal services because it was a potential factor for connecting farmers in agricultural technology to promote innovation (Barnes et al., 2019). This would suggest that further government subsidies could positively impact farmers' perceptions of using or connecting with private sector services through the CAPS practice. Household demographics and socioeconomic factors serve as significant influencing factors in engaging the private sector with farmers to promote CAPS.

However, significantly negative factors influencing the engagement of farmers with the private sector to promote CAPS such as total land size of main crops, farmers' perception of using private services including distance of service and increase in profit were reported in this research (Table 4). Giller et al. (2009) stated that the total land size can indicate productivity and scale in agriculture, yet it can also present obstacles to engaging with the private sector. This study also found that the total land size of main crops was a statistically and negatively significant influencing factor of engagement between CAPS farmers and the private sector. This discovery corresponds with the research of Ntshangase et al. (2018), but it contrasts with those of Nahayo et al. (2017) and Kassem et al. (2021), who indicated that land size positively impacts the use of private sector services. As Ntshangase et al. (2018) pointed out, farmers who cultivate their main crops on small-scale farms are interested in adopting new technologies, particularly CAPS. This aligns with Kassem et al. (2021) who emphasized factors influencing farmers' satisfaction with the quality of agricultural extension services in northern Egypt.

Farmers' socioeconomic factors such as distance of service and increase in profit by using the private sector services were negative influencing factors in the engagement of farmers and private services to promote CAPS. Similar evidence was reported by Teklewold et al. (2013) who stated that farmers with a distance of service are less likely to connect with the private sector. Acheampong et al. (2021) also showed that distance negatively impacts farmers using private services. According to Elahi et al. (2018), the effectiveness of agricultural outreach depends on the quality of services provided, including public agricultural advisory and extension services. This necessitates requiring provision of agricultural services to consider the quality and price of services to encourage farmers to use private services to practice CAPS (Stewart et al., 2015). The programme of private services would offer an additional advantage in promoting private services to expand the adoption of CAPS among farmers in Cambodia. CAPS expansion would be accelerated by better cooperation among diverse stakeholders including researchers, extension services, farmers, service providers, agricultural machinery manufacturers, and makers of technologies for technology transfer (Feder et al., 2011; Possner et al., 2022). Farmers' socioeconomic factors, including the total land size of main crops, distance of service, and the use of private services to increase in profit, were negative influencing factors in engaging farmers with the private sector to promote CAPS in Cambodia.

4.2. Mechanisms for private sector engagement with CAPS farmers

The perspectives provided by participants indicates that funding and farmers' limited knowledge were the main problems in promoting CAPS (Figure 3). Participants' strong perceptions emerged regarding high price of land preparation services, and some agricultural inputs including machinery and cover crops for CAPS farmers (Hobbs et al., 2008). Farmers who want to practice CAPS need to pay approximately 35–40 USD per ha for land preparation services at the first stage. This finding agrees with Tho et al. (2021), Hobbs et al. (2008), and Mkomwa et al. (2015), who stated that practising CAPS incurs higher costs during the initial stage, particularly for land preparation, where machinery is required. Participants also raised issues in the early stage of CAPS, where farmers struggle to realize benefits due to challenges in land preparation. The crop yield of CAPS differed during the first 5 years (changes in soil properties during the first year that were followed by the provision of organic materials to improve soil health for the next year) (Hobbs et al., 2008). These financial constraints were a barrier to farmers' decisions to improve their living standards in the early stages because of machinery needs (Brown et al., 2020; Dhar et al., 2018). One way to deal with this challenge is to utilize government subsidies as a more effective mechanism to engage farmers in practising CAPS. It has proven to be more influential for farmers adopting new technologies because farmers receive subsidies from the government for purchasing technology services or agricultural inputs (Groot et al., 2019). This would also involve indirect subsidy methods that should be implemented by the government; if indirect funds were provided to farmers, they would be able to use or lease technologies even after the conclusion of the government subsidies (Groot et al., 2019). Many participants also confirmed that they needed some support from the government or NGOs – 50% of the total price of services. For example, if the price of land preparation was 40 USD per ha, the government needed to pay 20 USD per ha, and farmers paid the remaining. Chinseu et al. (2019) observed that CAPS farmers would not be challenged to practice new technologies if they did not see their benefits such as increased soil fertility and yield production.

The consensus among participants was that the main barrier to practising CAPS was limited funding or loans from FIs. Brown et al. (2017) and Chinseu et al. (2019) also proposed that farmers need to purchase agricultural inputs such as machinery, services and cover crops. They identified funding as the primary challenge to adopting CAPS. In addressing this constraint, there is a need to engage private sector and FIs prioritized to work with CAPS farmers for problem-solving by providing agricultural loans. Previous literature by Chandio et al. (2017); Isaga (2018) and Van Auken and Carraher (2012) suggest that FIs should be encouraged to offer agricultural credit. For instance, these loans could support farmers by allowing them to practice good agricultural methods and farmers need to provide collateral, detailed agricultural business plans and clear purposes for credit accessibility. The farming business plan is an essential document for obtaining agricultural loans (Henning et al., 2019).

Many participants also pointed out that limited farmers' knowledge was an issue in promoting CAPS. Fisher et al. (2018) found that farmers' knowledge significantly influences the quality of information they receive about CA practices. Their adoption is often hindered by limited information and knowledge. Participants were interested in practising CAPS, but non-CAPS farmers lacked critical agricultural information that influences the decision to adopt such agricultural management practices. According to Mahindarathne and Min (2019), farmers actively seek information to make informed decisions and improve their practices, aiming to enhance farm productivity. CAPS farmers, especially those who have undergone technical skill-building, possess enhanced knowledge of practices. This suggests that participating in CAPS training significantly increases farmers' knowledge and skills which is supported by Ataei, Sadighi, Chizari, et al. (2021). To tackle this, there is a need to provide an instructional programme to encourage farmers to practice CAPS by discussing it with relevant private sector. The training programme would also provide a benefit to connect private sector, the government, NGOs and farmers, in the agricultural extension model to promote CAPS. The government and NGOs were fundamental in supporting groups that promoted CAPS by connecting the private sector with farmers (Chalak et al., 2017). Information on CAPS including agricultural loans, training, technical information, and technical support, should reach both the government and NGOs. This is significant for providing information and technical support to farmers

who need agricultural technical information through conventional methods. This necessitates additional farmer-to-farmer (F2F) training because farmers often trust their peers. It provides an opportunity for CAPS farmers to transfer CA technologies to other farmers in the community who require support from the government, NGOs and the private sector (Asprooth et al., 2023; Taylor & Bhasme, 2018).

The majority of participants emphasized the government's essential role in facilitating the connection between private sector and farmers through provision of subsidies and incentives for promoting CAPS. The government subsidies aim to encourage farmers to improve their operations and foster development of agricultural assets. These subsidies have an incentive effect, promoting greater farm investment (Akber et al., 2022). As an example, the government facilitates tax-free importation of irrigation equipment and implements a subsidy programme covering 50% of the investment cost to make irrigation more affordable for farmers, (Fan et al., 2008; Ngango & Hong, 2021). NGOs are encouraged to provide support for information and technical methods tailored to the needs of CAPS farmers, while the government subsidy method could influence private sector engagement. The government should consider offering targeted subsidies to farmers as part of a comprehensive strategy to promote CAPS, as subsidies encourage private sector engagement with farmers, resulting in enhanced farmer knowledge and private sector benefits (Lencucha et al., 2020; Thapa et al., 2023). Providing discounts proved to be a more effective mechanism for connecting private sector with CAPS farmers, and price setting was a value part of promoting new technology. Sims and Heney (2017) pointed out that offering discounts or special offers for new customers was a good way to encourage farmers to adopt or practice new technologies. Sharing cost arrangements between the government and the private sector should be utilized, with the government considering subsidy support as an effective to encourage farmers to practice CAPS. On the other hand, providing subsidies was just a short-term economic benefit for smallholder farmers to adopt or practice new technologies (Piñeiro et al., 2020).

Government incentives for the private sector served as a mechanism to engage them in promoting CAPS. Offering incentives proved to encourage the private sector to directly engage with farmers who required support for private services (i.e. government regulations incentivizing private sector investment in regional service monopolies) (Poulton et al., 2010). This would require policymakers to reduce both direct taxes such as import-export tax incentives, and indirect taxes such as those resulting from an overvalued exchange rate, on agriculture for the private sector. This reduction would indirectly impact farmers practising CAPS. The government should also consider reducing local taxation on agricultural trading activities to facilitate collaboration between private sector and CAPS farmers. Policymakers should emphasize incentive programs to increase the number of farmers practising CAPS, as facilitating engagement between the private sector and CA farmers would serve as a more effective mechanism for promoting CAPS. Moreover, information support was a mechanism through which the private sector connected to work with CAPS farmers. Farmers can convert information from technologies to make decisions into practical CAPS or lease it (Brooker et al., 2016). FIs were identified as a priority for providing agricultural credit for CAPS practices, with a condition that the interest rate should be lower than that for other credits. Documentation for credit accessibility should not be difficult to access and credit information should be shared with all farmers. Agricultural loan information also affected farmers' decision to use private sector services. This would necessitate information support, encompassing agricultural, financial, and service information, provided in an easily accessible manner, to promote CAPS.

Mechanisms of private sector engagement to promote CAPS require active engagement from key actors including support actors (the government and NGOs), service provider actors (private sector), and user actors (farmers). All actors have different roles and activities in advancing CAPS. The government incentives to the private sector can effectively encourage farmers to engage with these entities. This approach is further supported by offering indirect subsidies to committed CAPS farmers. Training programs should also be provided by CAPS farmers, who provide some support from NGOs, the government, and the private sector to improve technical knowledge of other farmers on CAPS. Farmers would contact support actors to receive information and technical support, and farmers' needs should be prioritized by the government and NGOs. Therefore, information on CAPS and agricultural loans would be available, and the private sector would work

directly with farmers. This agricultural extension model should be implemented to promote CAPS by private sector engagement in agricultural extension programs.

4.3. Ranking of private sector actors to directly connect with CAPS farmers

Agricultural financial accessibility helped farmers solve the challenges of practising CAPS (Table 5). Mapanje et al. (2023) and Men et al. (2024) demonstrated that FIs played an essential role in CA promotion among farmers. The service provider, who collaborated with farmers to promote CAPS, faced a major challenge: limited funding to pay for agricultural inputs such as agricultural machinery, cover crops and main crops (Knierim et al., 2017). FIs were private sector's priority because limited access to FIs was the main barrier to adopting CAPS to increase agricultural productivity. Consequently, farmers ranked financial support, specifically agricultural loans, as their top priority because the main challenge they encountered in practising CAPS was limited funding (Maher et al., 2023; Mapanje et al., 2023; Purnomo et al., 2023). Similarly, problems include high expenses for CA equipment and farmers' economic instability, limited support for CA (agricultural loan, and technology support), and input price (some inputs were expensive) (Ataei, Sadighi, Aenis, et al., 2021). Service providers were the second priority for farmers needing private sector support to practice CAPS, specifically for land preparation and land levelling (Haque et al., 2016; Zhong et al., 2023). If farmers do not have their own agricultural machinery; they will need private services so these services are fundamental for encouraging farmers to practice CAPS (Boyd & Spencer, 2022). Cover crop suppliers were the third priority in promoting CAPS because farmers need to grow cover crops, one of the three CAPS principles, before or at the same time as planting main crops (Dunn et al., 2016; Rodenburg et al., 2021). This finding is similar to the data reported by Mason et al. (2015). FIs were ranked first among private sector entities working directly with farmers to promote CAPS in Cambodia, followed by service providers and cover crop suppliers. Policymakers should support engaging FIs to support farmers to promote CAPS. Future research should prioritize exploring the mechanism underlying FIs in provision of agricultural loans, as well as examining the farmers' behavioural intentions.

5. Conclusions

Engaging the private sector with farmers is necessary for advancing CAPS adoption in Cambodia, given the slow uptake of CAPS practices among farmers. Influencing factors that positively and significantly affect the promotion of CAPS included gender, number of fields, off-farm income, farm experience, familiarity with the private sector in a commune, and government's subsidy. In contrast, other factors including total land size of main crops and farmers' perception of using private services (i.e. distance of service and increase in profit) were identified as negative influencing factors on accessing the private sector within the agricultural extension model. Government subsidies and incentives are proven to be highly successful mechanisms for encouraging private sector engagement with farmers. FIs have emerged as the crucial private sector actor that aims to promote CAPS adoption, with subsequent importance attributed to service providers and cover crop suppliers. Policymakers should prioritize the government subsidies and incentive programs resulting in positive impact on farmers' income generation. Despite this, the government subsidies and incentives are beneficial in the short term for supporting farmers but may not be sustainable in the long term. This research has yet to determine how long subsidies and incentive programs should be provided to farmers. Policy support over the next 5–10 years should focus on promoting CAPS through long-term programs. This includes support for farmers' education, farmer-to-farmer programme, farmers' organizations and groups, farmer entrepreneurship and cooperatives. Proactive collaboration with the private sector is expected to enhance these efforts, leading to higher adoption rates of sustainable agricultural intensification practices. The agricultural extension model was essential in connecting the private sector with farmers, but this research was limited by not comparing it with other models that might influence the engagement mechanisms between the private sector and farmers in promoting CAPS in Cambodia.

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Authors' contributions

Punlork Men: Conceptualization, Methodology, Software, Validation, Formal Analysis, Writing – original draft preparation, Writing – review and editing, Visualization, Project Administration, Supervision. **Lyda Hok:** Conceptualization, Methodology, Validation, Writing – review and editing, Visualization, Project Administration, Supervision, Funding Acquisition. **Panchit Seeniang**: Methodology, Validation, Writing – review and editing, Supervision. **B. Jan Middendorf**: Methodology, Validation, Writing – review and editing, Supervision, Funding Acquisition. **Fidero Kuok**: Writing – review and editing. **Rapee Dokmaithes**: Conceptualization, Methodology, Software, Validation, Writing – review and editing, Visualization, Project Administration, Supervision. All authors have read and agreed to the published version of the manuscript.

Ethical approval

This research was approved by the Research Ethics Committee of Kasetsart University, Thailand.

Data availability statement

Data used for the manuscript can be provided on request.

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