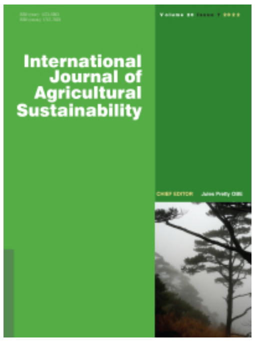

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Farmers' intention towards intercropping adoption: the role of socioeconomic and behavioural drivers

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ABSTRACT

The adoption of intercropping, a sustainable agricultural technology, is limited in Europe. This paper investigates factors driving the intention to intercrop in Sweden. Factors included in the analysis are participation in private certification schemes, interactions with peers and agricultural advisors, attitude, knowledge, innovativeness, perceived intercropping attributes and perceived behavioural control. The first two reflect potential socioeconomic determinants and the last four are possible behavioural drivers. For the first time, the theory of planned behaviour (TPB) and diffusion of innovation theory were integrated to understand farmers' adoption of sustainable farming practices like intercropping . Structural equation modelling was applied to understand the behavioural drivers, whereas logit regression was employed to identify the socioeconomic determinant of adoption intention. The paper highlights the important role of knowledge in fostering intercropping adoption. Knowledge was associated with innovativeness ($B = 0.18$, $p < 0.001$) and influenced perceived attribute ($B = 0.395$, $p < 0.001$) and attitude ($B = 0.268$, $p < 0.001$) towards intercropping. Sufficient knowledge strengthens farmers' confidence in implementing intercropping and subsequently facilitates adoption intention ($B = 0.287$, $p < 0.05$). Participation in private certification schemes and interactions with peers, a bonding social capital, also stimulates adoption intention ($\beta = 0.91$ and $\beta = 0.70$, $p < 0.05$). Policy implications to support intercropping were discussed.

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Intercropping; agricultural innovations; knowledge; social interaction; theory of planned behaviour; diffusion of innovation

1. Introduction

Intercropping, the cultivation of two or more crop species simultaneously on the same field at a given time (Wang et al., 2014), is widely acknowledged as a sustainable agricultural technology (Maitra et al., 2019). The practice can provide environmental benefits by minimizing the need for chemical input, particularly pesticides and herbicides (Glaze-Corcoran et al., 2020). Greater heterogeneity in mixed-crop species could increase and stabilize yields and enhance soil fertility, biodiversity and ecosystem services while using resources efficiently (Brooker et al., 2015; Glaze-Corcoran et al., 2020). In drylands, intercropping systems, which are diversified by nature, can offer natural insurance against the failure of a crop (Maitra et al., 2021). In the face of changing climate and the fluctuating agricultural commodity market, intercropping systems, with their species-richness and superior soil water retention, have a great potential to enable farmers to better adapt to climate irregularities while reducing market risks compared to sole cropping (Maitra et al., 2021; Pham et al., 2020). There is ample evidence worldwide demonstrating how growing crop mixtures has the potential to

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increase farmers' income, food and nutritional security, as well as food safety (Lopez-Ridaura et al., 2021).

However, the potential benefits of intercropping are often context-dependent (Weih et al., 2021). Intercropping increases the complexity of crop production supply chains (Kiær et al., 2022), and the mixed yields generated by intercrops are often not favoured by food processors and retailers.

In recent years, a growing interest in intercropping has been observed in developed agriculture regions due to increasing concerns over sustainability and soil health associated with conventional agriculture (Maitra et al., 2021). Given its great potential to enhance economic and environmental sustainability, intercropping is in the list of agricultural practices to be supported by Eco-schemes of Common Agricultural Policy, as indicated by the European Commisson in 2021). Since intercropping adoption is slow in Europe (Bonke & Musshoff, 2020), the implementation of Eco-schemes is expected to increase the adoption rate of intercropping among European farmers. Economic incentives can motivate the short-term shift to intercropping, but without other measures implemented in conjunction, long-term behavioural changes might not be achieved (Bonke & Musshoff, 2020). The reason is that farmers' adoption of agricultural innovations is driven by not only economic incentives but also social and behavioural factors (Dessart et al., 2019; Hansson et al., 2020).

To support the transition to intercropping, a comprehensive understanding of farmers' motivations and barriers to intercropping adoption becomes increasingly important. However, those motivations and barriers are currently not well-understood in the worldwide literature with Kangogo et al. (2021) and Bonke and Musshoff (2020) being two exceptions. While Bonke and Musshoff (2020) focused on farmers' intentions to intercrop in Germany, Kangogo et al. (2021) examined the adoption of smart climate-farming practices, including intercropping in Kenya. Behavioural factors are increasingly recognized as important drivers of farmers' adoption decisions and, therefore, have been included in international policy documents (Chavas & Nauges, 2020). However, those factors are overlooked in studies on the determinants of farmers' adoption of sustainable farming (Foguesatto et al., 2020). Noticeably, the focus of previous studies is either socioeconomic or behavioural determinants of the adoption (Foguesatto et al., 2020), leading to an incomplete understanding of its overall barriers and motivators.

In this paper, we, therefore, investigate the influence of socioeconomic and behavioural factors on farmers' intention towards intercropping adoption. Behavioural factors of consideration are the subjective norms, perceived behavioural control, attitude, perceived intercropping attributes, farmers' innovativeness and knowledge. Socioeconomic factors of interest include participation in private certification schemes and interaction with peers and production advisers. The empirical application is made to the Swedish agriculture.

This paper contributes to the existing literature in two distinct aspects. First, it adds to the scarce literature in Europe that examines both socioeconomic and behavioural factors driving farmers' adoption of sustainable farming practices. Second, the paper merges the Theory of Planned Behaviour (TPB) (Ajzen, 1991) with the Diffusion of Innovation (DOI) theory (Rogers, 2010) to understand how behavioural factors connect to each other and influence intercropping intention both directly and indirectly. TPB is a psychological framework to understand individuals' intention to perform a behaviour and/or the actual behaviour, using attitude, subjective norms and perceived behavioural control as behavioural drivers. DOI, as a sociological theory, explains how individuals' characteristics, together with innovations' characteristics and communication strategies, influence the adoption of an innovation. Since a single approach is unable to cover all important factors driving farmers' intention to adopt a particular agricultural innovation like intercropping, the combination of the two theories would result in a better understanding of farmers' behaviour and inform policy that aims at scaling up intercropping adoption in Sweden. Context-specific studies on behavioural factors of intercropping adoption like this study are needed. This is due to the fact that the potential benefits of intercropping and barriers to crop diversification are context-dependent, being influenced by many factors (Brannan et al., 2023; Weih et al., 2021).

2. Theoretical framework to explain intercropping adoption intention

2.1. Socioeconomic drivers of intercropping intention

2.1.1. Farmers' and farms' characteristics

Previous studies showed mixed results on the influence of farmers' characteristics. A review by

Foguesatto et al. (2020) concludes that the association between age and the adoption of sustainable farming practices can be positive or negative. Higher education level increases the adoption of crop diversification in Wang et al. (2021) but is not associated with intercropping adoption in the study by Bonke and Musshoff (2020). Farm characteristics, such as farm size and income, might shape intercropping intention, as suggested by the literature on sustainable farming adoption (Foguesatto et al., 2020). However, we did not hypothesize the direction of influence of the factors above due to the lack of consistent evidence in previous studies.

2.1.2. Participation in private certification schemes

The relationship between farmers' participation in private certification schemes (e.g. organic) and their decision to adopt sustainable farming practices has been documented. Thompson et al. (2022) reported the positive association between being organic farmers and the adoption of various sustainable crop management practices, including crop diversification in Europe. Similarly, Bonke and Musshoff (2020) found that organic farmers were more likely to adopt intercropping in Germany. The argument is that organic producers might be more interested in intercropping to optimize its potential in reducing pesticide use, improving pest management and creating natural nitrogen for the soil (if intercropping with legume) which are all crucial to organic production. Extending previous works above, this study examines whether participation in private certification schemes including organic, Swedish Seal of Quality and Arlagården (sustainable milk production) influences farmers' intercropping adoption behaviour. Based on the literature above, the following hypothesis is formed:

> H1: Participation in private certification schemes is associated with a higher intention to intercrop

2.1.3. Interaction with peers and agricultural advisers to exchange production information

On-farm adoption of new farming practices requires knowledge and access to information (Cofré-Bravo et al., 2019). As such, farmers with better learning ability and information access are more likely to be early adopters of innovations (Chavas & Nauges, 2020). The social networks that farmers are integrated into play an important role in providing them with such information and knowledge (Cofré-Bravo et al., 2019). Research shows that farmers can receive production information and other support via different actor networks such as family members, friends and peers, agricultural extension services, banks and government authorities (Cofré-Bravo et al., 2019). However, little research has been done on how the frequency and purpose of interactions might affect the adoption of sustainable farming, particularly intercropping. To fill this gap, we will test the following hypothesis:

> H2: Intercropping intention is positively associated with frequentinteractions between farmers and their peers (H2a) and agricultural advisors (H2b) for farming purposes.

2.2. Behavioural constructs from the TPB: attitudes, subjective norm and perceived behavioural control

The TPB (Ajzen, 1991) has been widely used to explain individuals' behaviour. A recent review highlights that there are 124 applications of TPB to understand farmer behaviour in crop management, livestock management and agricultural business development from 2006 to 2020 (Sok et al., 2021). Applying TPB in the context of intercropping, farmers' intentions to intercrop are jointly determined by (i) attitude towards this practice, (ii) perceived behavioural control and (iii) subjective norm. Here, attitude refers to farmers' evaluation of intercropping practice, such as how good or bad it is. Attitude, therefore, reflects their level of appreciation and understanding of the values that intercropping offers. Subjective norms present social influences, for example, farmers' belief in whether their peers, families and friends believe that they should intercrop. Perceived behavioural control refers to farmers' confidence in their ability to apply intercropping practice. In general, farmers with a more favourable attitude, a higher subjective norm and a greater perceived control over intercropping would have a higher intention to adopt this practice.

> H3: Intention to adopt intercropping is influenced by (a) subjective norm, (b) attitude towards intercropping and c) behavioural control.

TPB, though is a powerful framework to predict behaviour, does not cover some key drivers of the adoption of agricultural technologies, such as farmers' innovativeness and perceived attributes of the technology. As such, it is essential to extend the original TPB by adding such variables. Sok et al. (2021), in their review, reported that extended TPB could explain a higher proportion of variance in intention than the original TPB across former studies. In this study, DOI (Rogers, 2010) appears particularly relevant to explain farmer intention towards intercropping, which is a new concept for many European farmers. Thus, in this paper, we propose to augment the original TPB model by adding the relevant elements of DOI (Rogers, 2010).

2.3. Behavioural factors from DOI: farmers' knowledge, innovativeness and perceived attributes of intercropping practice

Rogers (2010) defined innovation as an idea or practice that is perceived as new by an individual or organization. Intercropping systems of commercial crops is uncommon in Europe and, therefore, will be seen by the majority of European farmers as an agricultural innovation. DOI (Rogers, 2010) seeks to explain the process, in which an innovation spreads over time, thus adding a relevant argument to the TPB in understanding farmers' behaviours in the adoption of intercropping practices. DOI, as one of the highest cited theories in social science (Peshin et al., 2019), has been intensively used to understand farmer's adoption of various agricultural practices, ranging from climate change adaptation (Moerkerken et al., 2020) to digital farming technologies (Shang et al., 2021). However, the application of DOI in intercropping adoption studies is limited. Given the scarce literature on behavioural drivers of intercropping adoption, further research on this topic is required.

2.3.1. Perceived attributes of intercropping as an agricultural innovation

According to DOI, the adoption rate of an innovation is dependent on the innovation's perceived attributes including (i) relative advantage, (ii) compatibility, (iii) complexity, (iv) triability and (v) observability. Applying to intercropping, the relative advantage is the degree to which intercropping is perceived as superior to sole cropping systems. Relative advantages might include economic, social or other aspects that are important to farmers. Compatibility is the perception of how well intercropping fits with farmers' existing values, past experiences and needs. Complexity means the perceived difficulty in understanding and implementing intercropping. Observability refers to the ability for the results of intercropping to be visible to others and trialability reflects the degree to which intercropping may be experimented. The decision to adopt agricultural technology may involve large investments and uncertainties (Dessart et al., 2019). A higher level of complexity, therefore, links to a higher level of uncertainty which hinders intercropping adoption. In contrast, high relative advantage, compatibility, trialability and observability will reduce such uncertainties, thereby facilitating the adoption.

2.3.2. Relationship among perceived attributes of intercropping, perceived behavioural control and intention to intercrop

Merging the DOI with TPB, we posit that the perceived attributes of intercropping (a construct derived from DOI) influence perceived behavioural control (a construct from TPB) and subsequently shape intercropping intention. It is plausible to assume that farmers would feel higher confidence to intercrop (higher perceived behavioural control) if they perceive that intercropping is associated with a lower cost (relative advantage), consistent with their current farming experiences (compatibility), easier to apply (complexity) and has been experimented successfully (trialability) with observable results (observability), compared to sole cropping. High perceived behavioural of control in turn will lead to higher adoption intention. This argument leads us to the following hypothesis:

> H4: Perceived attributes of intercropping will indirectly influence adoption intention via perceived behavioural control.

2.3.3. Famers' innovativeness and intercropping knowledge

DOI points out that how early innovation is adopted by an individual is dependent on individual's degree of innovativeness. First adopters are assumed to be the most innovative individuals who are venturesome, open to new ideas and willing to take risks. Diffusion studies show that early adopters with a higher degree of innovativeness seek information about innovations more actively, possess greater knowledge of innovations and have a more favourable attitude towards innovation (Rogers, 2010). The variability in information seeking, knowledge and attitude among adopters is most likely attributable to the heterogeneity in learning abilities.

According to Chavas and Nauges (2020), agricultural innovations are associated with uncertainties as farmers often do not have sufficient information about the innovation at the early stage. To reduce such uncertainty, farmers start with the discovery of new knowledge, learning from others and/or from their own experiences. This social learning process-differs across individuals due to their heterogeneity in learning ability. Applied to intercropping, we posit that farmers with a higher level of innovativeness will have a stronger motivation to learn and better learning ability. Subsequently, they will have better knowledge, a more favourable attitude towards intercropping and a higher inclination to adopt it. Morever, knowledge of intercropping means that farmers are aware of its attributes. Equipped with sufficient knowledge, farmers can reduce the perceived uncertainty from intercropping, resulting in better perceived behavioural control and stronger intention to intercrop. Accordingly, we propose the following hypothesis:

H5: Farmers' innovativeness will indirectly influence intention via knowledge of intercropping

H6: Knowledge of intercropping will be positively associated with attitude (a), perceived behavioural control (b), perceived attributes of intercropping (c) and (d) intention

H7: Knowledge will affect intention indirectly via attitude (a), perceived behavioural control (b) and perceived attributes of intercropping (c)

2.4. Summary of the theoretical framework

The framework illustrates the intention to intercrop (dependent variable) and its eight hypothesized underlying drivers. Two of them, including participation in a private certification scheme and interactions with peers and production advisers (social interaction), are socioeconomic factors. The remaining six are behavioural factors. Participation in private certification schemes and frequent interactions with peers and advisors increases the intention to intercrop (H1, H2). Intention is directly influenced by subjective norm (H3a), perceived behavioural control (H3c), attitude (H3b) and knowledge (H6d). Perceived attributes of intercropping indirectly influence intention via perceived behavioural control (H4). Innovativeness also affects intention indirectly via knowledge. Knowledge directly determines attitude (H6a), perceived behavioural control (H6b) and perceived attributes of intercropping (H6c). Knowledge indirectly shapes intention via attitude (H7a), perceived behavioural control (H7b) and perceived attributes (H7c). While hypotheses H3, H4, H6 and H2 present direct effects, the remaining illustrate indirect effects (Figure 1).

3. Material and methods

3.1. Farmer survey

Data were collected via an online survey delivered during November 2021. Since the majority of Swedish farmers are internet users (Helsper & Reisdorf, 2017), an online survey is relevant and convenient. From a population of 60,000 farmers registered nation-wide by Statistics Sweden, a pool of 2000 farmers were randomly drawn and invited to participate in the survey. Survey participants must be full-time farmers who are specialized in crop production, livestock production or both. Crop-specialized farms occupied about 50% of the total pool. We included livestock and mix farms in the sample because livestock farmers might use the intercropping output (e.g. mixed seed yield) for their livestock. Our survey shows that ley is the most commonly grown crop, being grown by 80% of respondents. This suggests that most of the surveyed farms are either livestock or mixed farms. The overrepresentation of livestock or mixed farms is a primary limitation of this study. Livestock or mixed farms might differ from crop-specialized farms in terms of the utilization of intercropping products. For instance, mixed farms might intercrop ley with other crops to provide fodder to farm animals while crop-specialized farms would mainly use mixed seed yields for sale.

The online survey was administered by a market research company. The survey questionnaire was designed by researchers and then programmed in the survey tool by the market research company. This is a web-based survey from a Swedish company called Research Automators. The surveys are made by responsive design so it is adaptable to different screen sizes and platforms such as computers, tablets and mobile phones to deliver a good survey experience for the respondents, regardless of the device. The respondents can leave the survey and return to finish the parts they haven't completed even if they start responding on a device and then switch to a different one later. The survey link and invitation were sent to the selected sample of 2000

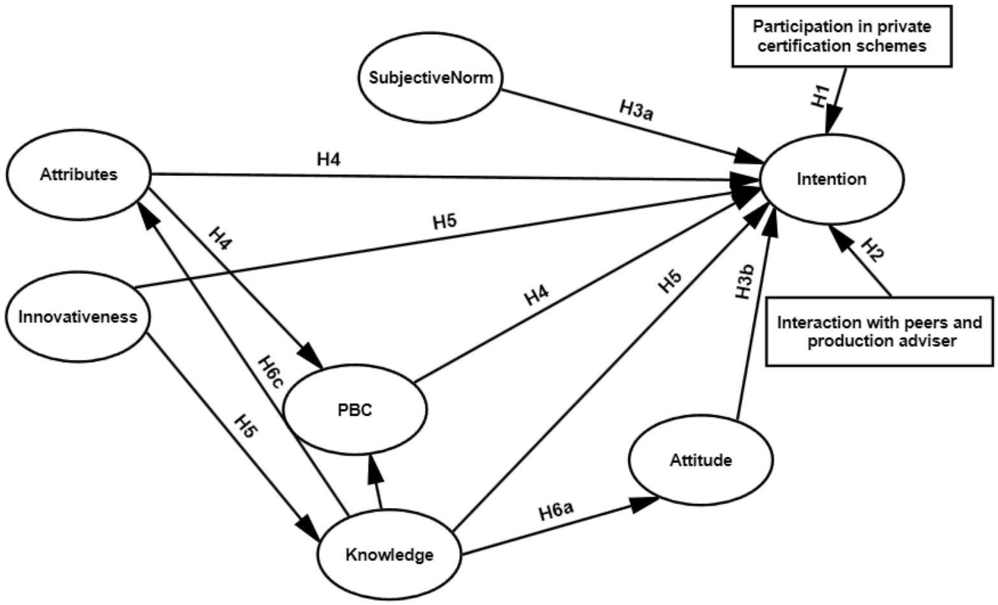

Figure 1. Theoretical framework explaining intention towards intercropping adoption. Note: PBC denotes perceived behavioural control. For simplicity, hypotheses H3c, H6b, H6d and H7 are not presented.

farmers mainly via email. After 3 reminders, about 700 replies were received, of which 378 were completed and useable replies, giving an effective response rate of 18.9%.

3.2. Data analysis

This study employed logit regression and structural equation modelling (SEM). Logit regression was used to identify the relationship between socioeconomic variables and intercropping intention. SEM was applied to reveal the influence of behavioural factors on intention. SEM is more suitable for latent constructs, which cannot be directly observed such as innovativeness, attitude and knowledge. Socioeconomic variables, such as age, gender, education and participation in private certification schemes, are not latent constructs and thus should not be analysed by SEM. Therefore, we used two separate analytical approaches: logit regression for socioeconomic variables and SEM for behavioural variables.

3.2.1. Socioeconomic variables and logit regression

Socioeconomic variables are presented in Table 1. About 40% of the surveyed farmers had higher education. The majority of farms are managed by men and the average age of the surveyed farmers is 59. These results are comparable to the Swedish Board of Agriculture's 2020 statistics on the population, which indicated that one-third of farmers are older than 65 and 40% of agricultural labourers are females (Swedish Board of Agriculture, 2021). The

Table 1. Surveyed farmers' socioeconomic characteristics.

Variables	Variable description	Mean (SD) or %
Age	Respondent' age	56.0 (12.12)
University	University education, dummy; 1 if yes, 0 if no	39.2
Male	Male respondent (=1 if female; 0 if male)	85.50
Landholding	Arable land holding (ha)	104.93 (193.65)
HighIncome	Annual household income more than 750 000 SEK/year, dummy; 1 if yes; 0 if no	30.95
Certificate	Participation in private certification schemes (e.g. organic production), dummy; 1 if yes, 0 if no	31.48
PeerInteract	Exchange production information with peers frequently, dummy; 1 if contact daily or weekly, 0 if no	61.11
AdvisorInteract	Exchange production information with agricultural advisors frequently, dummy; 1 if contact daily or weekly, 0 if no	20.11

Source: authors' data.
Note: 1 SEK = 0.097 USD.

average arable land per surveyed farm is 104 ha which is higher than the national average of 43 ha (ibid). A possible explanation is that our sample mainly includes professional/full-time farmers while data from the Swedish Board of Agriculture contain both full-time and part-time farmers and smallholders. One-third of the surveyed farms have upper levels of household income, more than 750000 SEK/year. About 60% of the respondents are in regular interactions with their peers to discuss production issues. Only 20% of the farmers frequently contact production advisers.

The variable 'intention', the dependent variable, was measured by three items capturing the propensity to adopt intercropping within the next 5 years. Responses are on a 5-point Likert scale, ranging from 1 (very unlikely) to 5 (very likely). The Cronbach's alpha coefficient of the three items is 0.97, suggesting that they are highly related to each other. For the regression purpose, the average score of these three items was transformed into a dummy variable ($=1$ for high intention if the average score ≥ 4, $=0$ for low intention if the average score < 4). The covariates included in logit regression are shown in Table 1.

A binary logistic regression model was employed with the dependent variable (Y) having two outcomes: high intention ($Y=1$) and low intention to intercrop ($Y=0$). This model is constructed as follows:

$$P(Y=1) = \frac{e^{\beta_0+\beta_1*Certificate+\beta_2*PeerInteract+\beta_3*AdvisorInteract+\gamma*Control+\varepsilon}}{1+e^{\beta_0+\beta_1*Certificate+\beta_2*PeerInteract+\beta_3*AdvisorInteract+\gamma*Control+\varepsilon}} \quad (1)$$

where $P(Y=1)$ is the probability of having high intention, *Certificate*, *PeerInteract*, *AdvisorInteract* are independent variables described in Table 1, *Control* is the vector of control variables including age, education, biological sex, land holding and income (see Table 1), β_0 is a constant, β_1, β_2 and γ are the corresponding coefficients and ε is the error term.

3.2.2. Behavioural variables and SEM

3.2.2.1. Behavioural constructs. Each behavioural construct was measured by at least 3 observed indicators or survey items (see Figure 2). Since these constructs are complex and multi-faceted in nature, multiple observed indicators will allow for better measurement of the constructs. Attitude items measured farmers' evaluation of intercropping's yield, profit, chemical input use and land use, compared to monocrop. These items were developed, based on the findings from studies on farmers' perception of intercropping systems (Himanen et al., 2016; Nnadi & Nnadi, 2009). Subjective norm items were adapted from Bonke and Musshoff (2020) and Gowda et al. (2021), capturing the extent other people important to a farmer support his/her adoption of intercropping. There are three items for perceived behavioural control, with responses indicating the level of agreement with given statements. The intention was operationalized by three items, which were adapted from Daxini et al. (2019). All behavioural items were measured on scales ranging from 1 to 5 with a higher score representing a higher level of agreement or intention.

Based on the ideas from DOI and the findings of Nnadi and Nnadi (2009), we developed attribute items that convey respondents' rating of the ease in conducting trial and in implementing intercropping, the suitability of their land for intercropping and the similarity between intercropping and current farming practices. Knowledge scales reflect various knowledge components of intercropping management, as shown by Himanen et al. (2016). 'Innovativeness' items were adapted from Ferguson and Hansson (2013) that present characteristics of an innovative farmer such as being the first adopter and a challenge taker. All constructs and their reflecting indicators are depicted in Figure 2.

Table 2 shows descriptive statistics for observed indicators of behavioural constructs. Respondents' evaluation of intercropping attributes was moderate, ranging from 2.9 to 3.2 out of 5. Attitude towards intercropping was relatively favourable, with the main scores between 3.10 and 3.40. Noticeably, self-reported knowledge of intercropping was below the mid-point of the scale for all aspects. The mean score for all items measuring intention and perceived behaviour of control was higher than 2.7.

3.2.2.2. Modelling behavioural influence on intention. To test complex associations between intention and its behavioural predictors, we employed SEM. SEM is a system of multiple regression analyses used for examining a set of relationships between independent variables and dependent variables (Ullman & Bentler, 2012). Our data have no missing values but are slightly non-normal, as most of the skewness and kurtosis values are less than 0.4 and 1.0, respectively (Lei & Lomax, 2005). Therefore, we performed bootstrap resampling in AMOS on 2000 bootstrap

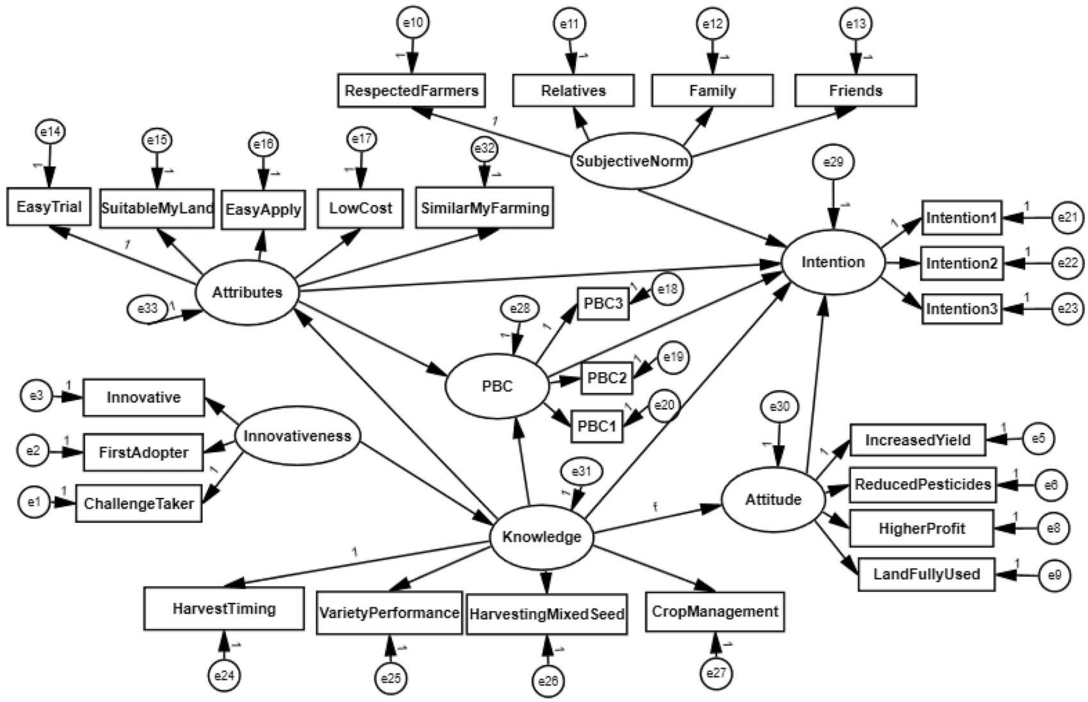

Figure 2. Hypothesized structural model of intention towards intercropping.

samples, which is a potential solution for estimating Chi-square *p*-values and parameter standard errors for non-normal data (Nevitt & Hancock, 2001).

SEM analysis involves the assessment of the measurement model and structural model. The former captures the relationship between latent constructs (or latent variables) and their reflecting observed indicators, using confirmatory factor analysis. The latter presents the relationship among latent constructs. This study has six latent constructs including two exogenous (Subjective norm and Innovativeness) and four endogenous constructs (Attributes, Knowledge, PBC and Intention) (Figure 3).

According to Kline (2016, p. 227), the measurement model involves a system of measurement equations for observed indicators of exogenous constructs (Equation (2)) and endogenous constructs (Equation (3)):

$$x = \Lambda_x \boldsymbol{\xi} + \boldsymbol{\delta} \tag{2}$$

$$y = \Lambda_y \boldsymbol{\eta} + \epsilon \tag{3}$$

where *x* is a vector of observed indicators for exogenous constructs and *y* is a vector of observed indicators for endogenous constructs, $\boldsymbol{\xi}$ is the vector of exogenous constructs, $\boldsymbol{\eta}$ is the vector of endogenous constructs, Λ_x is the matrix coefficient for observed indicator *x*, Λ_y is the matrix coefficient for observed indicator *y*, $\boldsymbol{\delta}$ is the vector of error terms associated with *x* and ϵ is a vector of error terms associated with y.

The structural model is defined as a system of structural equations as follows:

$$\boldsymbol{\eta} = \Gamma \boldsymbol{\xi} + \mathrm{B} \boldsymbol{\eta} + \zeta \tag{4}$$

where Γ is the matrix coefficient for the direct effect of exogenous constructs on endogenous constructs, $\boldsymbol{\xi}$ is the vector of exogenous constructs, B is the matrix coefficient for direct effects between endogenous constructs, $\boldsymbol{\eta}$ is the vector of endogenous constructs and ζ is the vector of disturbance of endogenous constructs.

The goodness of fit will be assessed for each model via a set of common fit indexes. AMOS 26 was used to perform SEM. Hypotheses that include direct and indirect effects were tested via the structural model. We employed the bootstrapping method, based on a 2000 bootstrap sample to obtain confidence intervals for specific indirect effects as it is the most powerful and reasonable method for this purpose (Preacher & Hayes, 2008). Since the estimation of specific indirect effects is unavailable in AMOS, we used AMOS user-defined estimand developed by Gaskin (2016).

Table 2. Descriptive statistics of observed indicators measuring behavioural constructs.

Construct, observed indicator	Indicator description	Mean (SD)
Subjective norms		
Friends	Friends' approval of farmer's intercropping	2.37 (0.89)
Family	Family's support of farmer's intercropping	2.52 (0.96)
Relatives	Relatives' approval of farmer's intercropping	2.71 (0.91)
RespectedFarmers	Other respected farmers support one's intercropping	2.89 (0.89)
Attributes of intercropping		
EasyTrial	The ease of conducting trial	3.03 (0.95)
SuitableMyLand	The suitability of farmland for intercropping	3.14 (1.05)
EasyApply	The ease of conducting trial	3.07 (1.04)
LowCost	The cost of implementing intercropping	3.07 (0.92)
SimilarMyFarming	Intercropping is a similarity to one's current farming practice	2.90 (1.16)
Attitude		
IncreasedYield	Intercropping could increase yield	3.32 (0.83)
ReducedPesticides	Intercropping could reduce pesticide use	3.39 (0.83)
HigherProfit	Intercropping could lead to a higher profit	3.11 (0.82)
LandFullyUsed	Intercropping could make the land fully used	3.44 (0.80)
Innovativeness		
Innovative	The importance of being innovative	3.17 (1.09)
FirstAdopter	The importance of being the first people to try agricultural innovations	2.49 (1.05)
ChallengeTaker	The importance of meeting challenges from farming	3.23 (1.05)
Knowledge		
HarvestTiming	Knowledge of optimal harvesting time	2.49 (1.01)
VarietyPerformance	Knowledge of varieties' performance	2.46 (1.06)
HarvestingMixedSeed	Knowledge of harvesting mixed seeds	2.48 (1.12)
CropManagement	Knowledge of crop management	2.49 (1.12)
Perceived Behavioural Control (PBC)		
PBC1	Feel easy to intercrop within the next 5 years	2.90 (1.21)
PBC2	Feel confident to intercrop within the next 5 years	2.83 (1.21)
PBC3	Feel capable to intercrop within the next 5 years	2.90 (1.25)
Intention		
Intention1	Intention to adopt intercropping within the next 5 years	2.79 (1.30)
Intention2	Effort to intercrop within the next 5 years	2.85 (1.29)
Intention3	Plan to intercrop within the next 5 years	2.71 (1.34)

4. Results

4.1. Logit regression

Table 3 presents the results of logit regression. Age, gender, participation in private certificate schemes and frequent interactions with peers were the significant determinants of high intention to intercrop. Older respondents and male respondents were less likely to report a high intention to intercrop. Participation in private certification schemes and frequent interaction with peers for farming purposes were both positively associated with intercropping intention, providing support for hypotheses H1 and H2a. Note that the association between intention and interactions with peers was the strongest. The probability of having a high intention to intercrop increases by 0.12 for respondents who remain in regular contact with their peers, compared to those with irregular interactions. The relationship between intention and interactions with production advisers was negative, but non-significant. Thus, hypothesis 2b was unsupported.

4.2. Structural equation modelling

4.2.1. Measurement model and structural model

The measurement model gained a good model fit. CFI (Comparative Fit Index) and NFI (Normal Fit Index) values are 0.971 and 0.941, respectively, higher than the 0.9 threshold suggested by Bentler and Bonett (1980). Root Mean Square Error of Approximation (RMSEA) (0.048) and Standardized Root Mean Square Residual (SRMR) (0.0492) are fairly good (Hu & Bentler, 1999). Construct validity and reliability were established since variance extracted (AVE) higher than 0.5, no cross-factor loading, Cronbach's alphas, composite reliability (CR) and factor loading larger or nearly equal to 0.7 (Table 4) (Hair et al., 2017).

Figure 3 presents the standardized estimate of the structural model. Five behavioural drivers including subjective norm, perceived attributes, perceived behaviouralcontrol, knowledge and attitude can explain 76.5% of the variance in intention. Attributes and knowledge were strong predictors of the

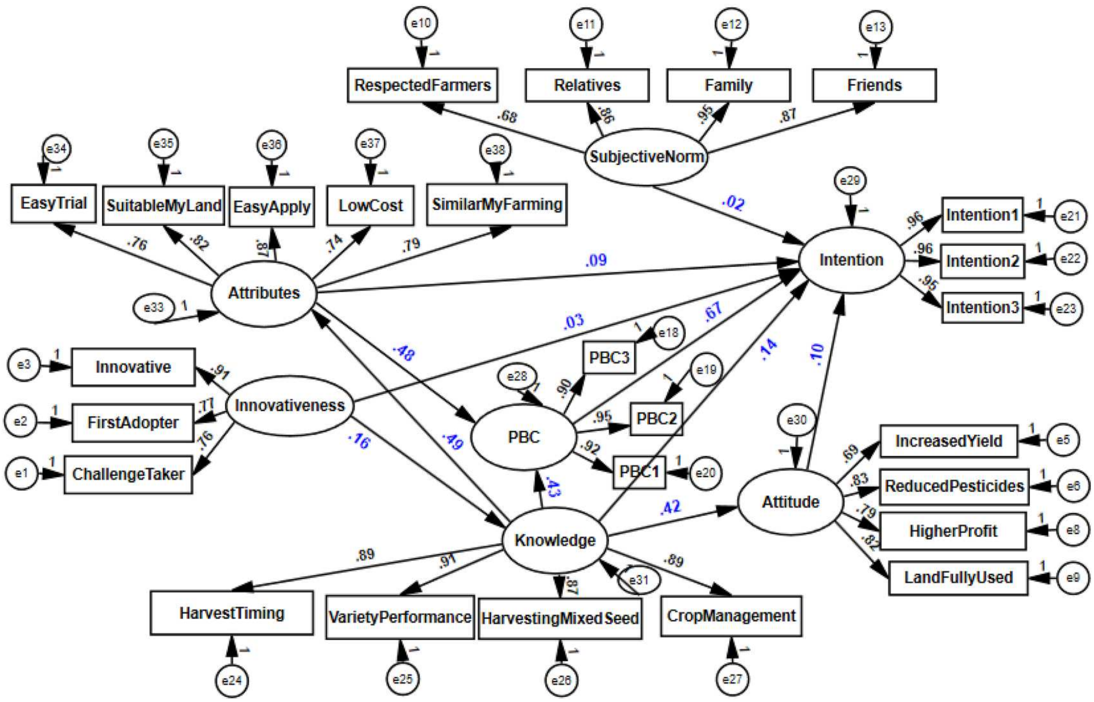

Figure 3. Results of a structural model, standardized estimate. Note: Numbers in black are factor loadings. Numbers in blue are standardized coefficients.

Table 3. Socioeconomic determinants of intercropping intention.

Variable	Coefficient (SE)	Marginal effect (SE)
Age	−0.030*** (0.011)	−0.005*** (0.001)
Female	0.646** (0.321)	0.111** (0.054)
University	0.223 (0.267)	0.038 (0.045)
Landholding	−0.001 (0.000)	−0.000 (0.000)
HighIncome	−0.082 (0.279)	−0.014 (0.048)
Certificate	0.915*** (0.264)	0.157*** (0.043)
PeerInteract	0.704*** (0.284)	0.121*** (0.047)
AdvisorInteract	−0.210 (0.335)	−0.036 (0.057)
cons.	−0.802 (0.802)	
Likelihood ratio $\chi^2(8)$	38.54	
p value χ^2 test	0.000	
pseudo-R2	0.891	
Count	0.743	

Note: ***, ** denotes *p*-value ≤ 0.01 and ≤ 0.05, respectively.

perceived behaviour of control, explaining 61.8 per cent of its variance. R^2 of attitude, perceived attribute and knowledge is 17.7%, 24.4% and 2.6%, respectively.

4.2.2. Hypothesis testing

Table 5 presents the results of testing hypotheses 3 and 6 that present direct effects. Among these hypotheses, only H3a, the influence of subjective norm on intention was non-significant (B = 0.046, $p > 0.05$). Hypotheses H3b and H3c were confirmed as evidenced by the significant effects of attitude and perceived behavioural control on intention (B = 0.210, B = 0.725, respectively and $p < 0.05$). Moreover, H6a, b, c and d were supported, confirming the role of

Table 4. Construct validity and reliability.

Constructs	Cronbach's alphas	CR	AVE	1	2	3	4	5	6	7
1. Intention	0.970	0.970	0.916	0.957						
2. Innovativeness	0.797	0.855	0.665	0.187	0.816					
3. Attitude	0.864	0.866	0.618	0.572	0.200	0.786				
4. SubjectiveNorm	0.904	0.908	0.714	0.422	0.163	0.455	0.845			
5. Attributes	0.895	0.897	0.635	0.658	0.146	0.461	0.421	0.797		
6. PBC	0.945	0.947	0.855	0.868	0.170	0.588	0.446	0.691	0.925	
7. Knowledge	0.938	0.939	0.794	0.658	0.153	0.397	0.304	0.486	0.658	0.891

Table 5. Direct effect estimate.

Hypothesis	Path	B	B (SE)	*p*	Hypothesis supported
H3a	SubjectiveNorm → Intention	0.023	0.046 (0.058)	0.432	No
H3b	Attitude → Intention	0.098	0.210 (0.073)	0.004	Yes
H3c	PBC → Intention	0.667	0.725 (0.058)	0.000	Yes
H6a	Knowledge → Attitude	0.420	0.268 (0.037)	0.000	Yes
H6b	Knowledge → PBC	0.431	0.541 (0.057)	0.000	Yes
H6c	Knowledge → Attributes	0.494	0.395 (0.045)	0.000	Yes
H6d	Knowledge → Intention	0.147	0.201 (0.059)	0.000	Yes

Note: β: standardized coefficient, B (SE): unstandardized coefficient (standard error).

knowledge in shaping attitude, perceived behavioural control, perceived attributes of intercropping and intention.

Table 6 shows the estimation of indirect effects. H4 was confirmed, implying that a higher evaluation of the attributes of intercropping strengthens perceived behavioural control, resulting in a higher intention to intercrop. H5 was also supported, suggesting that farmers with higher levels of innovativeness would have better knowledge of intercropping and this thereby increases adoption intention. A higher level of knowledge also results in better perceived behavioural control, which was translated into a higher intention and this provides support for H7b. H7a and H7c were not confirmed, meaning that knowledge did not generate a mediate impact on intention via perceived attributes and attitudes.

5. Discussion

This paper adds to the scarce literature that examines socioeconomic and behavioural motivations behind farmers' adoption of intercropping practices in a European setting. Moreover, TPB (Ajzen 1991) is merged with DOI (Rogers 2010) to understand how behavioural factors influence intercropping intention both directly and indirectly. The insight generated from the paper can advance our current understanding of farmers' decision in adopting sustainable farming practices, using intercropping as an example and inform policy that aims at upscaling intercropping adoption in Sweden. The context dependency of the barriers as well as the potential benefits of intercropping (Brannan et al., 2023; Weih et al., 2021) demonstrates the need for intercropping country-specific adoption studies .

Table 6. Indirect effect estimate.

Hypothesis and Indirect path	B	*P*	β	Support Hypothesis
H4: Attribute → PBC → Intention	0.545	0.000	0.319	Yes
H5: Innovativeness → Knowledge →Intention	0.167	0.000	0.108	Yes
H7a: Knowledge → Attitude → Intention	0.056	0.253	0.014	No
H7b: Knowledge → PBC → Intention	0.287	0.000	0.392	Yes
H7c: Knowledge → Attributes → Intention	0.045	0.161	0.062	No
Total indirect effect: Knowledge → Intention	0.725	0.000	0.531	

Note: B: unstandardized coefficient, β: standardized coefficient.

5.1. Socioeconomic determinants of intercropping intention

We found that age, gender, participation in private certificate schemes and frequent interactions with peers were associated to adopt intercropping systems. Previous research indicates that old age is one of the farmers' personal barriers against adopting sustainable farming practices (Campos, 2022). This is in line with our finding on the negative association between age and farmers' intention to adopt intercropping. Farmers are more risk-averse and less experimental when they become older (Brown et al., 2019). Such personal characteristics and the complexity of intercropping are possible reasons for a lower interest in intercropping among older farmers, as supported by this study. Similar to the study by Bonke and Musshoff (2020), this paper did not find any association between education and intercropping intention. In relation to gender, we found that female managers had higher intentions towards intercropping adoption. This might be due to their higher pro-environmental attitude, compared to male farmers, as suggested by Campos (2022). However, the result in relation to gender should be interpreted with caution since our sample is over-presented by male farmers.

Participation in private certificate schemes, such as KRAV (organic), Swedish Seal of Quality (a trademark for foods and other products) and Arlagården (sustainable milk production), strengthened farmers' intercropping intention. This result is close to the findings from related studies conducted in Europe (e.g. Thompson et al. (2022) and Bonke and Musshoff (2020)). These two studies pointed out that organic farmers were more likely to practise environment-friendly land use measures including crop rotation and intercropping. Intercropping systems can potentially reduce the use of pesticides and increase output quality (Maitra et al., 2021). Intercropping between legum, as a nitrogen-fixing crop and other crop species, can generate natural nitrogen for the soil. All these characteristics of intercropping are particularly important for organic production. Perhaps, farmers that are engaged in the high-quality production and/or sustainable foods have a better awareness of such potential benefits and this translates into their higher adoption intention.

Farmers who have frequent interactions with other farmers had a higher intention to adopt intercropping, compared to those with irregular interactions. These interactions represent their bonding social capital, which refers to the ties that farmers have with individuals with similar backgrounds. It has been shown by previous studies that what farmers benefit from such interactions or bonding social capital are information, knowledge and other supports (Cofré-Bravo et al., 2019). These interactions might also enable a 'social learning process', where farmers learn from others and gain knowledge to eliminate perceived risks and uncertainties associated with new farming approaches, particularly intercropping. As suggested by Chavas and Nauges (2020), that is particularly important to the successful diffusion of new agricultural technologies. Perhaps, farmers, who regularly contact their peers, have obtained more knowledge and information on new agricultural technologies, as shown by the literature on peer effect (Skevas et al., 2022) and bonding social capital (Cofré-Bravo et al., 2019). This facilitates their higher intention towards intercropping adoption.

5.2. Behavioural determinants of intercropping intention

We found that subjective norms did not influence the intention to intercrop. This result implies that the opinions of friends, families and other farmers did not have a significant effect on farmers' intention towards intercropping adoption. More broadly, this also suggests that Swedish farmers tend to be 'independent' in their decision-making towards intercropping and perhaps regarding agricultural technologies in general as well. This might be attributable to the highly individualistic culture in Sweden (Galinha et al., 2016) that places importance on individual independence and freedom.

We found that farmers with a more favourable attitude towards intercropping have a higher tendency to adopt this farming approach. This result is also consistent with studies specifically on intercropping adoption (Bonke & Musshoff, 2020; Lemken et al., 2017). While Bonke and Musshoff (2020) report that attitude was the most important driver of intention, we found that the effect of attitude was statistically significant but not large. The differences in construct measurement between our and previous studies might be a reason for this discrepancy. For instance, Bonke and Musshoff (2020) measured attitudes by perceived advantages of intercropping in a broader scene such as economic importance and its role in sustainable agricultural production. Our study captured farmers' attitudes towards specific aspects of intercropping systems such as perceived yield, profit, chemical input use and land use.

Perceived attributes of intercropping generated a mediated effect on intention via perceived behavioural control - the confidence to adopt intercropping. Knowing that intercropping is suitable for their land, consistent with their farming experiences and easy to conduct reduced farmers' perceived uncertainties. Subsequently, they experienced a high level of control over the adoption and this in turn increased their intention towards intercropping adoption. Note that perceived behavioural control was also the most important behavioural driver of intention to adopt intercropping in our study. This finding is in line with that of Bonke and Musshoff (2020), where perceived behavioural control was the second most influential factor affecting German farmers' intention to adopt mixed cropping.

Perceived behaviour of control was determined by knowledge. However, farmers' knowledge of intercropping remains limited, as evidenced by the low mean scores for all knowledge items (Table 2). Successful operation of intercropping systems requires intensive knowledge (Bybee-Finley & Ryan, 2018). Given the context that intercropping between commercial crops not being a tradition in Sweden, farmers' insufficient knowledge in this area is as expected. Such insufficient knowledge lowered farmers' confidence in intercropping adoption, and this in turn hindered adoption intention. In line with Tensi et al. (2022), this study confirms that the lack of practical knowledge remains a big hurdle towards the adoption of sustainable agricultural practices.

Knowledge directly shaped attitude, perceived attributes of intercropping and adoption intention as well. More specifically, a low level of knowledge led to a negative attitude towards intercropping, lowered farmers' evaluation of its attributes and subsequently decreased the tendency to intercrop and vice versa. According to Chavas and Nauges (2020), an innovation is adopted because it creates some perceived benefits. Knowledge about such benefits helps farmers reduce perceived uncertainties around agricultural innovation. However, the magnitude of the perceived benefits differs among individuals, being dependent on the information available to them and their knowledge (Chavas & Nauges, 2020). Similarly, our findings suggest that knowledge forms attitudes towards intercropping systems and perceived management characteristics of intercropping. Uncovering the role that knowledge plays in motivating adoption intention directly and indirectly, this study confirms the validity of DOI and highlights the importance of knowledge in the adoption of a specific sustainable farming practice.

We found that innovativeness, a distinct characteristic of entrepreneurs, indirectly affected intention via knowledge. Farmers with a higher degree of innovativeness posed a higher level of knowledge of intercropping, leading to higher adoption intention. The association among innovativeness, knowledge and technology adoption has been discussed in previous literature. For example, Rogers (2010) states that an innovation adoption decision is an information-seeking and information-processing activity. The variability in information seeking and knowledge among individuals is likely to be attributable to the heterogeneity in learning abilities (Chavas & Nauges, 2020), which is dependent on the degree of innovativeness, as suggested by many diffusion studies (Rogers, 2010). Agreeing with DOI, this study confirms the relationship between knowledge, innovativeness and technology adoption.

6. Conclusions

This paper examined how participation in private certificate schemes and interactions with peers and agricultural advisors, attitude, knowledge, innovativeness, perceived intercropping attributes and perceived behavioural control influence intercropping intention. Considering not only socioeconomic but also behavioural influences, this study is expected to offer a novel and systematic insight into the determinants of farmers' intention towards the adoption of a particular sustainable farming technology from a Swedish perspective. Moreover, this paper, for the first time, merged TPB with DOI to understand how behavioural factors explain the intention to intercrop directly and indirectly.

An important finding that emerges from this study is the role that knowledge plays in intercropping adoption. Farmers' self-reported knowledge of intercropping linked to their innovativeness, influenced their confidence in implementing intercropping, their view of intercropping's attributes and their attitude towards this farming practice. It also determined adoption intention directly and indirectly via perceived behavioural control. However, limited knowledge of intercropping among farmers was found a barrier to farmers' intention towards adoption of intercropping systems. Another important finding is that participation in private certification schemes and regular interactions with peers for farming purposes both were positively associated with higher adoption intention. Peer-to-peer interactions represent bonding social capital, which facilitates social learning among farmers. These are all important to the successful adoption of new farming practices like intercropping.

7. Policy implications

The findings presented in this paper suggest some important policy implications for Sweden's agriculture. Insufficient knowledge of intercropping demonstrates the need to enhance farmers' knowledge of this practice. To do so, policies facilitating the sharing of information and knowledge of intercropping via peer networks can be an effective solution. However, farmers are not the only group facing the issue of having limited intercropping knowledge. Actors such as farm advisors and supply chain actors also face this challenge (Mamine & Farès, 2020). Therefore, their knowledge of intercropping and the effect it might have on intercropping adoption should be investigated in future research. It is also a key role of researchers, in collaboration with extension service, to make research results of intercropping available to interested farmers. Given the improvement in intercropping knowledge, farmers would be more confident to apply intercropping and this also increases their adoption intention.

The relationship between innovativeness, knowledge and intercropping adoption implies the need for policy instruments that encourage innovators to take part in agricultural technology diffusion. Innovators, with their knowledge, could take a leading role in intercropping diffusion, use and creation of new knowledge. They can be role models for other farmers. As such, to increase the intercropping adoption rate, advisory services and scientists could target this group first to keep them informed about scientific evidence on intercropping and encourage them to conduct on-farm experiments. Various intercropping practices and other agricultural innovations can be tested and promoted by the support provided to farmers who are innovators. This also opens up the possibility for the exchange of information and co-production of knowledge among researchers, extension services and farmers not only within but also beyond rural boundaries.

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Data availability statement

Data will be provided upon request.

Ethical statement

This study involves human participation but it is exempted from ethical approval because it uses a survey as a means of data collection and the survey had no sensitive information, according to the Swedish regulation on research ethics. Consent forms were given to participants and it was clearly stated that farmers' participation was voluntary.

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