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Heterogeneity in farmers' stage of behavioural change in intercropping adoption: an application of the Transtheoretical Model

Thanh Mai Ha[1,3*], Gordana Manevska-Tasevska[1], Martin Weih[2] and Helena Hansson[1]

*Correspondence:
thi.thanh.mai.ha@slu.se

[1] Department of Economics, The Swedish University of Agricultural Sciences, Box 7013, 750 07 Uppsala, Sweden
[2] Department of Crop Production Ecology, The Swedish University of Agricultural Sciences, Box 7043, 750 07 Uppsala, Sweden
[3] Faculty of Economics and Rural Development, Vietnam National University of Agriculture, Gia Lam, Hanoi 100000, Vietnam

Abstract

Despite its potential economic and environmental benefits, intercropping adoption remains limited in Europe. Drawing upon the Transtheoretical Model, this paper views adoption decision as stages of behavioural change. The paper aims to investigate socioeconomic, behavioural, and policy factors associated with stage of change in intercropping adoption in Sweden. Exploratory factor analysis and generalized ordered logit regression were performed on data from a nation-wide farmer survey conducted in 2021 with 388 usable replies. Results show that farmers with better knowledge of intercropping, a higher evaluation of financial benefits and ease of intercropping, and ley growers were more likely to progress to higher stages of the adoption process. Farmers who have higher perceived seed separation costs, a lower education level, and are older tend to remain at lower stages. Perceived environmental benefits of intercropping, household income, and instrumental values of farming could turn non-adopters into either potential adopters or actual adopters. We found no significant association between policy support and stage of change in intercropping adoption. Policy implications aimed at fostering intercropping adoption were discussed.

Keywords: Adoption determinants, Farmer behaviour, Intercropping, Stages of change, Sustainable farming

Introduction

Intercropping means the cultivation of two or more crops in the same field at a given time (Glaze-Corcoran et al. 2020). This practice can enhance the environmental sustainability of crop production systems. Given its potential to improve plant biomass production, enhance vegetation cover, and support robust root systems, intercropping systems can provide additional plant residues to the soil and reduce water runoff and soil erosion (Glaze-Corcoran et al. 2020). Moreover, well-designed crop mixtures can contribute to enhanced biodiversity, strengthen crops' resistance to pests, and thereby might reduce pesticide use (Bedoussac et al. 2018). Although intercropping has proven to increase and secure yield and yield quality in many cases (Raseduzzaman and Jensen 2017), the effect

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on yield stability is highly context dependent (Weih et al. 2021). While further research is needed to identify the optimal conditions for intercrops to increase crop yields and yield stability, crop diversification, including intercropping, is considered an important adaptation strategy of farmers to spread production and income risk over a wider range of crops (FAO et al. 2018). Particularly, growing grain legumes and cereals in a mixture can improve soil nitrogen and thus reduce the need for synthetic fertilizers (Jensen et al. 2020). This can contribute to the success of Common Agricultural Policy (CAP) aiming at reducing nitrogen fertilizer use in agriculture in Europe (Ladha et al. 2020).

Despite its sustainability potential, the adoption of intercropping practice remains limited in Europe (Bonke and Musshoff 2020) due to a number of constraints. The combination of crops with differential maturity times and harvest products challenges the management of intercropping systems (Kiær et al. 2022). Though intercropping can enhance yield stability compared to sole crops, such stabilizing effect is strongly context dependent (Weih et al. 2021). Intercropping adoption is also hindered by farmer's lack of training on crop diversification, the absence of a market for mixed seed yield, technological hurdles (Jensen et al. 2020), and the limited recognition of intercropping in public policy as an essential agricultural practice for ecosystems (Mamine and Farès 2020). Initial steps taken in CAP 2023–2027 and the recognition that intercropping is among potential agricultural practices are supported by Eco-schemes[1] in Europe (European Commission 2021) might increase adoption rate. However, the uptake of intercropping, like other sustainable agricultural practices, can be influenced by not only economic incentives but also behavioural drivers (Dessart et al. 2019). To optimize the effectiveness of public policy instruments aimed to support intercropping adoption, a systematic understanding of farmers' motivations and barriers towards intercropping uptake is crucial. For instance, if farmers' limited knowledge is found to form a misperception towards intercropping and thus hinders the adoption, policy interventions supporting farmers' knowledge can also be considered.

This study addresses three following research gaps. First, the determinants of intercropping adoption at the farm level are greatly under-researched in Europe with only two studies from Germany by Bonke and Musshoff (2020) and Lemken et al. (2017) and one in Sweden (Ha et al. 2023). This prevents efficient public and private policy formulation due to insufficient knowledge regarding farmers' adoption behaviour in European countries. Related studies are not lacking in the Global South and have provided rich insights into factors influencing farmers' adoption decision (Nguyen and Drakou 2021; Romyen et al. 2018; Tapsoba et al. 2023). Since the determinants of intercropping adoptions are contexts specific (Brannan et al. 2023; Ha et al. 2023) more studies are needed to address research gaps in Europe.

Second, empirical studies on the determinants of agricultural technology adoption often assume adoption decision as a binary choice (Weersink and Fulton 2020) and thus focus on only two groups of farmers: adopters and non-adopters. However, we argue that the adoption of a new practice like intercropping should be viewed as a process that unfolds through a sequence of stages of change, as suggested by the Transtheoretical

[1] Intercropping solely is not supported but can be utilized in eco-schemes as part of the diverse crop rotation in CAP 2023—2027.

Model (Prochaska et al. 2015). Drawing upon the Transtheoretical Model, this paper accounts for three farmer groups, namely "pre-contemplation", "contemplation", "action and maintenance", who are at different levels of readiness to change in the intercropping adoption process. The stages of change in intercropping adoption can be also conceptualized by AKAP framework (Awareness-Knowledge-Adoption-Production) (see De Rosa et al. (2014)) or Diffusion of Innovation Theory (Rogers 2010). In this study, we chose Transtheoretical Model since it proposes a clearer division across the stages of changes than Diffusion of Innovation. Moreover, it distinguishes two groups of adopters "Action" and "Maintenance", which are relevant to intercropping, but not considered by AKAP framework. These ways, the current study can improve our understanding of farmers' underlying drivers of sustainable farming uptake and draw relevant policy implications to address each stage of change.

Third, relying on the assumption that rational farmers strive for profit maximization, empirical studies by economists mainly use economic-related variables to explain farmers' adoption decision (Weersink and Fulton 2020). However, multidisciplinary research points to the heterogeneity in farmers' objectives, which can be economic and non-economic orientations (Pannell et al. 2006). Research shows that both profit maximization and social preferences are likely to influence farmers' adoption of conservation technologies. Particularly, a proportion of farmers feel large social and environmental responsibilities, willing to forgo profit to help others, who are poorer (Streletskaya et al. 2020). The standard economic approach thus fails to capture such multiple dimensions in farmers' personal goals, particularly those linked to behavioural factors that are also important in the adoption of sustainable farming practices (Dessart et al. 2019). This results in an incomplete understanding of farmers' motivations and barriers to adoption. This study fills this gap by incorporating socioeconomic, behavioural, and policy factors as potential underlying drivers of farmers' readiness to shift to intercropping.

This study aims to investigate factors associated with farmers' stage of change in intercropping adoption process. We used Sweden's agriculture as a case study and applied the Transtheoretical Model developed by Prochaska and Velicer (1997) to identify farmers' stages of change. Drawing upon a multidisciplinary approach, we examined a range of possible factors associated with the stages of change. These factors are farmers' self-reported knowledge, the values of farming that are important to them, perceived intercropping benefits, perception of management technology, market issues linked with intercropping, public policy support, farmers' demographics, and farms' characteristics. The paper provides an essential analysis of the complexity of farmers' adoption of sustainable farming and the interplay between their values, resources, wider market, technological, and policy environment where their farming is operated. From a policy perspective, this study adds to the question: how do we encourage non-adopters and potential adopters of intercropping to become actual adopters? The answer informs communication interventions for intercropping and/or the design of eco-schemes for crop diversification. Thus, policymakers, farmer organizations, and extension service can use the results.

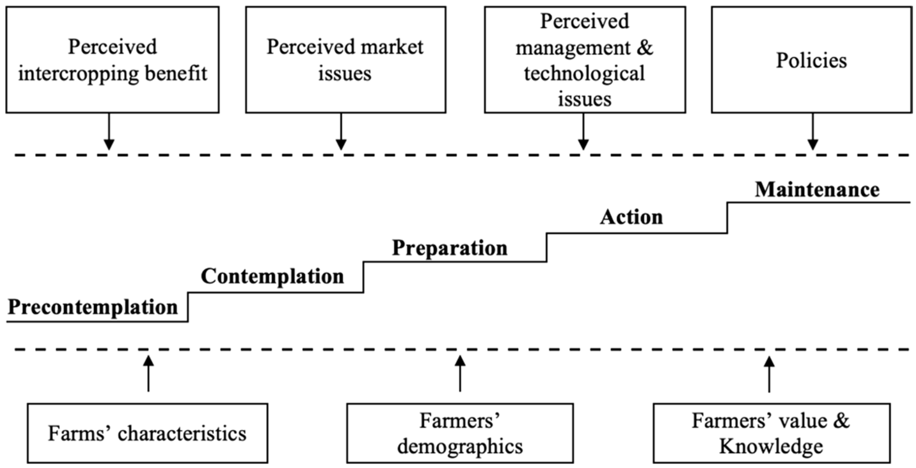

Fig. 1 Theoretical framework explaining farmers' stages of change in intercropping adoption

Theoretical framework

The Transtheoretical Model (TTM) developed by Prochaska and Velicer (1997) is an useful psychological framework to understand behavioural change. In particular, TTM views changes in behaviour as a process of five sequential stages, each reflecting a corresponding level of readiness to change. These stages include (1) pre-contemplation, (2) contemplation, (3) preparation, (4) action, and (5) maintenance. Since there is a clear difference across the stages in TTM, as described later on, it is easy to map respondents' current stage of adoption by using survey instruments. An alternative of TTM is Diffusion of Innovation (Rogers 2010), which has been used by previous studies (Goldberger et al. 2015; Lavoie et al. 2021) to understand individuals' innovation-decision process. However, in Diffusion of Innovation, five stages in the adoption process including knowledge, persuasion, decision, implementation, and confirmation are likely to be more intuitive to identify. For instance, Rogers (2010) defined that knowledge stage is where individuals "are exposed to the innovation's existence and gains some understanding of how it functions." It is unclear at which level of understanding a respondent would pass this stage. From a policy perspective, since TTM shows a clearer distinction across stages, it might be easier to tackle stages of change conceptualized by TTM, compared with those conceptualized in Diffusion of Innovation. TTM has previously been used by Lemken et al. (2017) and been confirmed to be valid for studying farmers' adoption of intercropping.

Applying TTM to intercropping adoption (Fig. 1), there are five sequential stages in intercropping adoption. Farmers in stage 1 (pre-contemplation) are not at all interested in intercropping and thus do not intend to intercrop in the future. They can therefore be called "non-adopters". Possible reasons for their behaviour include they are uninformed about intercropping's benefits or they have switched to intercropping in the past but not successfully. In the next step (contemplation), farmers have intention to intercrop in the future but have not yet practised it and they are still evaluating the perceived costs (cons) and benefits (pros) of adoption. Farmers at stage 3 (preparation) start to take small steps towards change, for example, having a concrete plan for intercropping adoption. Farmers categorized at stages 2 and 3 therefore can be considered "potential adopters".

Farmers in stage 4 (action) have already intercropped for a short time, i.e. within 2 years, while farmers in stage 5 (maintenance) have adopted the practice for a longer period (more than 2 years). Therefore, farmers belonging to stages 4 and 5 are "actual adopters".

According to TTM, individuals weigh perceived costs (cons) against perceived benefits (pros) to make a decision on whether to change their current behaviour. Perceived costs of adopting a new practice decrease while perceived benefits increase when individuals move from stage 1 to stage 5. In addition, to progress to the action stage, perceived benefits should be higher than the perceived costs of adoption (Prochaska et al. 2015). According to Pannell et al. (2006), the adoption of a new agricultural technology is dependent on whether the technology enables farmers to achieve their personal goals which can be economic, environmental, and/or social dimensions. Therefore, it can be argued that different farmers might view the benefits of an agricultural technology through different angles. Thus, the term "perceived benefits" used in TTM can refer to economic and non-economic benefits of intercropping.

From a theoretical perspective, viewing intercropping adoption as a process of sequential stages of change would reveal more information of the adoption behaviour. Indeed, the adoption decision is not simply a binary choice (adopt or not) and thus is more accurately modelled by the TTM. As suggested by TTM, there is a possibility that a proportion of farmers are in the transition stages (contemplation and preparation stages)—somewhere between binary non-adoption and adoption. From a policy perspective, segmenting farmers into different stages of change would allow specific interventions for intercropping to be tailored for each segment.

Furthermore, we grouped potential predictors of stages of change into seven themes including (i) perceived intercropping benefits, (ii) perceived market issues, (iii) perceived management and technological issue, (iv) farmers' value and knowledge, (v) farmers' demographics, (vi) farms' characteristics, and (vii) policy for intercropping. While the first four themes reflect behavioural factors, the middle two represent socioeconomic drivers, and the last captures institutional aspects. This systematic approach fully captures the heterogeneity of farmers' stages of change in intercropping adoption.

In this study, intercropping is defined as the cultivation of any two or more crops in the same field at a given time (Glaze-Corcoran et al. 2020). Based on this definition, the mixture of commercial crops such as legumes and cereal, the intercropping between grass and other crops in green fodder production, and the intercropping between undersown crops and others are all included in this study. Under the current conditions in Sweden, all of these intercropping types are used for feed and thus are similar. In this way, adoption behaviour is relatively specific.

Farmers' values and knowledge

Bardi and Schwartz (2003) defined values as what people consider personally important and what guides them in life such as tradition, freedom, and achievement. According to an influential work by Gasson (1973), a better understanding of farmers' personal values would enable a better prediction of their economic behaviours. The authors indicated "since people continually strive to gratify values in order to repeat pleasurable experiences, values impose a certain regularity on behaviour". Gasson (1973) classified farmer values of farming into instrumental, social, expressive, and intrinsic. Moreover, Maybery et al. (2005) identified lifestyle, economic, and land conservation as value categories influencing farmers' behaviour in land conservation. Farmer value typology varies across studies but occasionally overlap (e.g. instrumental value in Gasson (1973) and economic value in Maybery et al. (2005). Ferguson and Hansson (2013) discovered a positive correlation between farmers' business value and their plans for business expansion as well as plans to exit agriculture. Since intercropping has potential economic and environmental benefits (Raseduzzaman and Jensen 2017), farmers who highly evaluate instrumental/economic and land conservation values of farming would be more interested in this practice. Here, instrumental values imply that farming is viewed as a means of obtaining income and security with pleasant working conditions (Gasson 1973). Land conservation values refer to farmers' view about the important role of farming in preserving the land and environment (Maybery et al. 2005).

Knowledge, an important human capital of farmers, can reduce uncertainties associated with intercropping. Changing from sole cropping to intercropping could induce production uncertainties. According to Chavas and Nauges (2020), when confronted with a new farming practice, farmers are often unaware of its compatibility with their farming operation conditions nor effective management in advance. To reduce such uncertainties, obtaining knowledge of the new practice becomes crucial. Knowledge can be obtained via a "social learning process" in which farmers acquire information, learn from others and their own experiences. Uncertainties might be even higher for intercropping systems due to their management complexity (Kiær et al. 2022) and thereby high level of knowledge required is crucial (Glaze-Corcoran et al. 2020). Having sufficient knowledge of intercropping is likely to reduce farmers' perceived complexity and uncertainties, which will in turn foster uptake.

Perceived benefits of intercropping

Perceived benefits, as mentioned previously, are among the core constructs of TTM. Perceived benefits of agricultural technologies have been proven as a strong driver of technology adoption (Chavas and Nauges 2020). Given the variation in information access across individuals, there exists a great heterogeneity among farmers regarding the importance and the nature of perceived benefits associated with a specific agricultural technology (Chavas and Nauges 2020). In terms of economic benefits, intercropping has a potential to improve profitability due to yield advantages. Nevertheless, profitability also depends on other factors such as crop choice (Nie et al. 2016), output price, and the cost of inputs including labour (Rosa-Schleich et al. 2019). As such, the profitability of intercropping might be also context-dependent. Some farmers might intercrop because of the economic advantages of intercropping such as increased yield while others might be motivated by environmental benefits such as pesticide reduction and biodiversity improvement. The review by Dessart et al. (2019) pointed out various empirical evidence on the positive relationship between perceived financial and environmental benefits and organic adoption. In general, perceived benefits towards their farms, the environment or both are one of the strongest motivations for farmers to adopt sustainable practices (Piñeiro et al. 2020). Therefore, it is reasonable to expect that farmers' stages of change in intercropping adoption will be correlated with their perceived financial and environmental benefits of intercropping.

Perception of management, technology, and market issues

Perceived ease about intercropping relates to the perception about management aspect of intercropping systems. According to Diffusion of Innovation theory (Rogers 2010), the adoption rate of an innovation is determined by decision makers' view of its difficulty in implementing innovations. Innovations with easier applications will have a higher adoption rate. Regarding intercropping adoption, perceived ease reflects the extent the practice is compatible with farm's available resources such as land, labour, and machinery. Intercropping systems might require more farm's resources since they are associated with management complexity (Jensen et al. 2020). As such, resource-poor farmers might perceive difficulty in implementing intercropping and thus are at lower stages of change in the adoption process.

Farmers with a lower expectation of market potential for intercropping products and higher perceived costs of seed sorting technologies would be discouraged to progress towards higher stages of change. If intercropping products are marketed for human consumption, the use of seed sorting machinery is necessary, which imposes additional costs for farmers. For instance, the sorting cost for bean-wheat mixture in France is about 15€ per ton which includes both separating pure products from the mixture and the loss of peas that were not separated from wheat (Mamine and Farès 2020). Another possible barrier is the lack of market opportunities for intercropping products in the supply chain. Making the food market recognize and accept innovative foods from intercropping products (Mamine and Farès 2020) remains a considerable challenge in the food industry.

Policy support, farms' characteristics, and farmers' demographics

Policy instruments that favour mono-cropping are hurdles against intercropping uptake in Europe (Jensen et al. 2020). Although intercropping-specific policy measures take place with CAP 2023–2027 programme, other policies that promote crop mixtures might also be of relevance (Himanen et al. 2016). In that regard, public policy support provided within CAP for, for example, protection zones and grassland ley, also encourages intercropping in Europe, especially in nitrogen-sensitive areas where waterways and lakes are sensitive to nitrogen pollution caused by agriculture (Swedish Board of Agriculture 2022).

Demographic factors such as education and farming experience represent farmers' important human capital. According to Chavas and Nauges (2020), such human capital determines the compatibility of a new agricultural technology for a particular farm and this subsequently shapes adoption decision among farmers. It has been shown that farmers with higher education levels are more likely to adopt crop diversification (Wang et al. 2021). Farming experience could positively or negatively affect the adoption of new farming practices. More experienced farmers might have more resources to implement conservation practices. But they are generally older and may be hesitant towards changes to farming due to shorter planning spans in the future (Prokopy et al. 2019).

Previous studies point to the association between the adoption of sustainable farming and farms' characteristics (Wang et al. 2021). For instance, farms with equipment ownership and higher income are more likely to adopt minimum tillage (Grabowski et al. 2016). Farms that engage in livestock production were found to have a higher likelihood to diversify their crops to serve livestock production (Wang et al. 2021). Production factors such as access to land and equipment and the presence of livestock production might play an important role in farmers' stages of change in the adoption of intercropping.

Material and methods

Data

Data were collected via an online farmer survey conducted in Sweden during the winter of 2021. The survey targeted full-time farmers who are involved in crop, livestock production, or both. Online surveys are comfortable and inclusive for Swedish farmers as more than 90% of them are internet users (Helsper and Reisdorf 2017). At the time of data collection, Sweden had roughly 60,000 farms including about 26,700 smallholders and 33,300 commercial farms, according to national statistics. Smallholders are defined as those that devote less than 400 working hours to farming per year; otherwise, they are called commercial farms. Among commercial farms, 21,586 had a registered email address in the official register. Based on our previous experience, response rates of recent farmer surveys are low in Sweden, ranging from 15 to 20%. Thus, from the list of registered farms, we randomly selected 2000 farms to achieve at least 300 complete replies and to avoid burdening farmers more than necessary. For the sample size calculation, we adopted a standard error of 5%, a confidence interval level of 95%, an expected prevalence of intercropping adoption of 20%, and population size of 33,300. The minimum sample size that satisfy the requirements was estimated to be 244 respondents. We collaborated with a marketing research company to implement data collection. This company programmed the survey designed by the project team, dispatched, and collected data according to our instructions. The survey link was sent out to the sample via respondents' email or mobile phone. After 3 reminders, 700 replies were received. After removing incomplete replies, we retained 388 useable replies for this study, equivalent to a 19% effective response rate.

Data description and variable measurement

Table 1 shows respondents' descriptive statistics and their farms' characteristics, which are independent variables. These independent variables were compared across three stages: pre-contemplation, contemplation, and action and maintenance. Detailed information about how the three groups were categorized is presented in Table 2. 85% surveyed farm managers were male and the mean age of the whole sample were 56 years old. According to Swedish Board of Agriculture (2023), 83% of farm mangers in Sweden were men and one in three farm managers were older than 65. The mean age of pre-contemplation group was statistically significantly lower than the two remaining groups. Action and maintenance group had a lower percentage of male managers but a higher proportion of ley growers, compared to the first two groups. About 38% of respondents had a university degree. The average household income of the whole sample was at the scale of 5, ranging from 450,000 SEK to 700,000 SEK/year. It is relatively close to the national average household income of full-time farms, which is about 590,000 SEK in 2021 (Swedish Board of Agriculture 2023). Compared across subgroups in our sample, household income was higher for the contemplation and action and maintenance groups., 62%

Table 1 Descriptive statistics of farmers' and farms' characteristics by stages of change

	Whole sample	Pre-contemplation ($n=97$)	Contemplation ($n=153$)	Action and maintenance ($n=138$)
I. Farmers' characteristics				
Age (respondent's mean age)	55.95	61.36[a]	55.38[b]	52.78[b]
Male (% of male respondents)	85.31	89.69[a]	89.54[a]	78.99[b]
UniversityDummy (% of respondents have university or higher degree)	38.65	30.93[a]	41.18[b]	41.30[b]
II. Farms' characteristics				
Arable land (ha)	105.91	73.65[a]	131.09[b]	100.73[a]
Ley (% of respondents growing ley)	79.90	69.07[a]	77.12[a]	90.58[b]
ContractworkDummy (% of respondents hired equipment and drivers)	70.10	68.04[a]	68.63[a]	73.19[a]
HHincome (Household income/year level 1–9)	4.70	4.13[a]	5.04[b]	4.65[c]
III. Policy supports				
GrassProtectionSupport (% respondents received either ley farming support or protection zone support)	77.84	73.20[a]	79.80[a]	79.71[a]

HHincome ranged from 1 (Less than 150 000 kr) to 9 (Between 1050 000 kr and 1200 000 kr). Values within a row with different superscripts [a,b,c] are different in either mean or percentage at 5% significance level, using Chi-square test (for the percentage) or t-test (for the mean)

of all arable land in Sweden are operated by companies larger than 100 hectares. In our sample, farms with more than 100 hectares occupied 64% of the total arable land holding of the sample (Swedish Board of Agriculture 2023). 80% of respondents grew ley and the percentage of ley growers was highest in action and maintenance group. Policy support variables refer to the support provided for grassland ley and protection zones. This policy support does not directly target intercropping but indirectly promotes crop diversification including intercropping. For instance, to receive support for protection zones, farmers need to grow grass and/or a mixture of grass with other crops (Swedish Board of Agriculture 2022). The variables concerning policy support and farms' and farmers' characteristics were treated as either dummy or continuous variables.

Table 2 illustrates the descriptive statistics of the dependent variable and behavioural factors. Prior to the questions about stages of change, surveyed farmers were given a detailed definition of intercropping. Respondents were then asked whether they were currently practising it. Farmers with a positive response were asked about the number of years they have intercropped. Respondents who have intercropped for less than 2 years were categorized as "action", while those with more than 2-year experience were labelled "maintenance".

Respondents who have not intercropped were required to select one of three options: (i) "I have not intercropped, and I will not do it in the future", (ii) "I have not intercropped yet but I am thinking of doing it in the future", and (iii) "I have not intercropped yet but I have a concrete plan to do it soon". Those selecting the first, second, and third options were categorized as "pre-contemplation", "contemplation", and "preparation" groups, respectively.

Two categories "preparation" and "action" had a few counts (9 for "preparation", 18 for "action"). Since there were a few respondents in the "preparation" stage and this

Table 2 Descriptive statistics of the dependent variable and behavioural factors

Variables	Mean or %	SD
Dependent variable: adoption stage		
Pre-contemplation (% of respondents)	25.00	N/A
Contemplation (% of respondents)	39.43	N/A
Action and Maintenance (% of respondents)	35.57	N/A
Independent variables: *I. Farmers' value in farming and intercropping knowledge*		
LandConsevValue (Perceived importance of environmental issues in farming)		
Keep farming land for future generations*	4.35	0.75
Improving soil condition*	4.06	0.76
Work and live in nice surroundings*	4.36	0.72
Farming in a pro-environmental way*	3.90	0.77
InstrumentalValue		
Supporting the family from farm income*	3.48	1.14
Expanding the farm business*	2.82	1.09
Maximizing profits from farming: important value*	3.64	0.97
Meeting challenges from farming*	3.22	1.06
Intercropping knowledge (self-reported)		
Optimal timing of harvest*	2.49	1.01
Crop variety performance*	2.45	1.06
Crop management*	2.49	1.12
Characteristics of crop varieties*	2.63	1.10
II. Perceived Benefit of intercropping		
EnviBenefit (Perceived environmental benefits)		
Intercropping helps farmers adapt to climate change better*	3.32	0.80
Intercropping is environmentally friendly*	3.41	0.82
Intercropping buffers crop failure from changing climate*	3.39	0.80
Intercropping increases agroecosystem biodiversity*	3.74	0.89
FinanceBenefit (Perceived financial benefits)		
Intercropping reduces fertilizer and pesticide cost*	3.39	0.82
Intercropping creates a higher profit*	3.11	0.82
Intercropping makes the land fully used in a growing season*	3.44	0.80
Intercropping increases crop yield*	3.32	0.82
III. Perception of management, technical, market issues		
ApplyEase (Perceive ease in implementing intercropping)	3.07	1.04
MixedSeedAnimal (Perceived ability of using mixed seed yield as livestock fed)	2.90	1.40
SeedSeparationCost (Perceived cost of mixed seed separation)	3.39	1.08
MarketIssues (Perception of market issues)		
Demand for mixed seed yield*	2.24	1.00
Price for mixed seed yield*	2.31	0.96
The availability of seed separation technology*	2.51	1.11

Survey items with a star * are subjected to exploratory factor analysis. *N/A* not applicable

stage is close to "contemplation" in meaning, we merged "preparation" and "contemplation" into one group, namely "contemplation". Given the similar reason, we combined "action" with "maintenance" into one group "action and maintenance". These three identified categories were coded from 1 (pre-contemplation), 2 (contemplation), and 3 (action and maintenance).

Since behavioural constructs like perception, values, and knowledge are likely to be multifaceted, we used multiple survey items to measure these constructs when possible. The responses to these items were coded on a 5-point Likert scale (1–5), with the higher score reflecting a higher level of agreement or importance. Instrumental value, land conservation value in farming, and knowledge each were measured by four survey items adapted from Ferguson and Hansson (2013) and Himanen et al. (2016).

Items measuring the perceived financial and environmental benefits of intercropping were adapted from Himanen et al. (2016) with responses presenting the level of agreement (1 = strongly disagree, 5 = strongly agree). To assess the perception of market-related issues, we used the statement: "Regarding seed-related issues, please evaluate demand/price for mixed seed yield, and the availability of seed sorting technologies". Responses ranged from 1 (very low) to 5 (very high).

Data analysis

There are two steps in data analysis: exploratory factor analysis and generalized ordered logit regressions.

Exploratory factor analysis (EFA)

Exploratory factor analysis (EFA) was performed on 23 survey items measuring farmer value, knowledge, perceived benefits, and perception of market issues (items with a * in Table 2). The purpose was to capture underlying latent constructs and assess their discriminant validity. Via EFA, 6 latent constructs identified were Knowledge, EnviBenefit, FinanicalBenefit, InstrumentalValue, LandConsevValue, and MarketIssue (See Table 4 "Appendix"). These latent constructs capture farmers' perception of (1) their intercropping knowledge, (2) environment benefits of intercropping, (3) financial benefit of intercropping, (4) instrumental value in farming, (5) land conservation value of farming, and (6) market issue, respectively.

The Kaiser–Meyer–Olkin (KMO) value that measures the proportion of variance in the 23 survey items to be explained by latent constructs was 0.862, far above the acceptable level of 0.5 (Watkins 2018). The significant Bartlett test of sphericity (Chi-square = 4965.78, $df = 267$, $p < 0.001$) implies that these 23 survey items are correlated and thus suitable to EFA. We used maximum likelihood estimations and Promax with Keiser Normalization as the rotation method to allow possible correlations among latent constructs. The Cronbach's Alphas of all constructs ranged from 0.73 to 0.92, indicating good construct reliability (Tavakol and Dennick 2011). Guttmann lambda 2, an alternative of Cronbach's Alphas, was used for the robustness check of scale reliability. The result shows Guttmann lambda 2 values ranged from 0.70 to 0.93, reconfirming good scale reliability of latent constructs. Regarding the convergent validity, 5 out of 23 observed variables had factor loadings less than 0.7, the recommended level (Hair et al. 2017), but is still far above the cut-off 0.4 suggested by Howard (2016) (See Table 4 "Appendix" Factor analysis result). For discriminant validity, items measuring EnviBenefit and FinanicalBenefit are cross loading, suggesting the correlation between the two constructs.

Generalized ordered logit regression

Stage of change was regressed on factor scores obtained from EFA for the latent constructs and remaining independent variables (*ApplyEase, SeedSeparationCost*, policy-related variables, farmers and farms' characteristics) (see Table 2 for descriptions of variables and latent constructs).

Since stages of change have ordinal nature, ordered logit regression (ologit) is the most suitable (Long and Freese 2006). Proportional odd, a key assumption of ologit assumes the regression coefficient associated with any covariate to be identical across parameter thresholds. As the data violated this assumption (Chi-square = 81.94, $df = 36$, $p < 0.001$, Brant test), we used generalized ordered logit regression (gologit) (Williams 2006). We performed partial proportional odds models, where the proportional odd constraint is relaxed for the variables that violate the assumption (*Knowledge, EnviBenefit, InstrumentalValue, SeedSeperateCost, HHIncome*). To fit this model, we used Stata 17.0 with gologit2 command. Adapted from Williams (2006), the gologit model for stage of change in intercropping adoption is presented as following:

$$P\left(Y_i > j\right) = \frac{\exp(\alpha_j + X_i\beta_j)}{1 + \left[\exp\left(\alpha_j + X_i\beta_j\right)\right]}, j = 1, 2$$

where Y is the stage of change, Y =1 for pre-contemplation, = 2 for contemplation, and = 3 for action and maintenance stage. P is the probability of having outcome Y, j is the cut point. There are two cut points for three stages of change in this study), α_j is a constant associated with cut point j, β_j is a vector of parameters to be estimated (coefficients) at cut point j, X_i is a vector of independent variables for farmer i including *Knowledge, EnviBenefit, FinanicalBenefit, InstrumentalValue, LandConsevValue, and MarketIssue, ApplyEase, SeedSeparationCost, PolicySupport*, farm's and farmers' characteristics (see Tables 1 and 2). Note that positive coefficients indicate that higher values of the independent variable are associated with higher stages of change, comparing to the current one. In contrast, negative coefficients suggest that higher values of the independent variable increase the likelihood of being in the current or a lower stage of change.

We examined the correlation among independent variables, using the cut point of 0.7 as high coefficient correlation (Dormann et al. 2013). We revealed a strong association between two variables "*EnviBenefit*" and "*FinanceBenefit*" (coef. correlation = 0.73). This confirmed the EFA result on cross loading of items measuring the two variables. Accordingly, the interaction term between the two was included in the regression model.

We conducted three robustness checks to validate the results. First, we compared between the full model with a simpler model to assess whether the predictive power of the full model is meaningful (Hicks et al. 2019). The full model includes all covariates shown in Tables 1 and 2 and the simpler model contains only perception-related variables (psychological variables). Second, to evaluate the stability of the results on the influence of policy support, we compared the full model with its alternatives where variables *GrasslandLeySupport* and *ProtectionZoneSupport* are transformed, or one of them is excluded. Third, we assessed the measurement error of the two behavioural variables: *ApplyEasy* and *SeedSeparationCost*, each was measured by single survey item only.

Results and discussion

As shown in Table 2, 25% respondents were at the "pre-contemplation" stage, where farmers were not at all interested in intercropping. Around 40% of surveyed farmers were at "contemplation" stage, who were potential adopters. About 36% of them were at "action and maintenance" stage, who were actual adopters.

The effect of perceived knowledge was statistically significant and positive across both panels with a larger effect observed in the second one. This finding suggests that farmers with a higher level of knowledge about management issues in intercropping are more likely to progress to the higher stages of the adoption process. Note that in the second panel, knowledge exerts the largest effect. This implies that knowledge enhancement would be most effective in moving farmers from the pre-contemplation (non-adopters) and contemplation stages (potential adopters) to action and maintenance stages (actual adopters). In line with our study, research from Asia also pointed out that intercropping knowledge was one of significant determinants of intercropping adoption (Romyen et al. 2018). Additionally, our study shows that farmers' knowledge of intercropping was relatively low (all knowledge items had a mean score less than 3, neutral level, Table 2). This is expected since intercropping is knowledge intensive (Bybee-Finley and Ryan 2018). To optimize its potential benefits, farmers are required to have a greater understanding of ecology and an integrated knowledge of different crop species. Our findings suggest that farmers' limited knowledge of management issues in intercropping presents a considerable barrier to intercropping adoption. Our finding is close to that of Vecchio et al. (2022), which show that non-adopter perceive management complexity as one of barriers to adopt precision farming among Italian farmers. Turning to our study, our results also suggest the limited availability of knowledge about intercropping. This questions the transfer of knowledge between scientists and farmers. While there is a number of scientific studies on intercropping, it appears that not much of this scientific information has been translated into practical knowledge at farm level. In line with Vecchio et al. (2022), this study confirms the existence of knowledge hurdles in adoption of agricultural technologies. The strong association between knowledge and stage of change implies that removing such knowledge hurdle can lead to a boost in the adoption rate.

In this study, the perceived benefits of intercropping were considered through financial and environmental dimensions. We found that perceived financial benefits of intercropping were positively associated with stages of change with a common magnitude across cut points. In other words, the propensity of moving to higher stages of change increases for respondents who perceived a higher financial benefit of intercropping. This result supports economists' assumption that a technology is adopted when it provides perceived financial gains (Chavas and Nauges 2020). This also reflects the presence of "rational farmers", who are engaged in intercropping to maximize profit.

The regression coefficient of perceived environmental benefits of intercropping was positive and significant in the first panel but non-significant in the second panel. Particularly, among variables used, perceived environmental benefits have the second highest effect in the first panel. This means farmers who are more aware of the environmental sustainability of intercropping were more likely to be potential adopters (contemplation stage) or actual adopters (action and maintenance stage). Together with the result above, this study suggests that farmers were interested in not only the economic but also environmental aspects of intercropping. As such, the assumption of profit maximization is relevant but insufficient to understand farmers' motivations behind intercropping adoption decision.

Perceived benefits are likely to depend on information available to farmers (Chavas and Nauges 2020). This stresses the important role knowledge and information play in farmers' adoption decisions. To increase the adoption rate of intercropping, information about intercropping should be made available and accessible to farmers. However, we argue that to support farmer's decision-making, such information should be neutral, containing not only potential benefits but also risks and uncertainties associated with management issues in intercropping adoption. As stated by Jensen et al. (2020), there is a lack of farmer education about intercropping and advisory service engagement. To foster intercropping adoption, farmer education should be prioritized.

Instrumental value in farming caused a significant and positive effect in the first cut point and a negative and non-significant effect in the second cut point. The result suggests that farmers, who acknowledge the income-generating role of farming, were more likely to progress to contemplation or action and maintenance stages. According to Huss et al. (2022), intercropping systems are climate resilient since due to their resource use efficiency and ability to control insect pests, pathogens, and weeds. All of these increase farmers' profitability, despite the management complexity and higher labour demand of intercropping (Huss et al. 2022). Potential and actual adopters might realize the economic benefits above and thus had a higher adoption tendency to achieve their instrumental value in farming occupation.

Surprisingly, farmers who appreciate conservation values in farming were less likely to move to a higher stage of intercropping adoption. Farmers with high perceived conservation values might be concerned about technical uncertainties associated with intercropping or are not fully aware of its conservation benefits, resulting in their reluctance to intercrop. Given the lack of education on intercropping in Europe (Jensen et al. 2020), it is arguable that farmers are uninformed or under-informed about intercropping's attributes, especially its conservation component. This might explain the lack of awareness about that aspect of intercropping among farmers, who care about conservation and the environment in farming. According to Dessart et al. (2019), the association between farmers' perceived personal values with the adoption of sustainable farming is under-researched. Examining the relationship between farmers' values in farming and stages of change in intercropping adoption, this study contributes to addressing the research gap mentioned above.

Another surprising result is that the perception of market issues was negatively associated with stages of change. Respondents who perceived a lower demand and price for intercropping products were more interested in intercropping. The data used in this study shows that most intercropping farmers grew ley (91%) and at least 50% of them intercropped to have animal feed. For them, selling intercropping products on the market would not be a way forwards due to market issues (Jensen et al. 2020) such as the low price and demand for intercropping products. However, intercropping with the intention to feed animals remains relevant to their farm's operation. In other words, their decision to intercrop might not be driven by the market price of intercropping products but by the need for mixed seeds from intercropping to feed farms' animals. This argument is supported by the following result on the association between ley cultivation and intercropping adoption.

Ley growers were more ready to adopt intercropping, compared to those without ley cultivation. Since growing ley is an indication of livestock production, the result implies that livestock farmers were more interested in intercropping. Adoption of sustainable farming depends on farmers' utilization of their own agricultural products (Kiær et al. 2022; Wang et al. 2021). Wang et al. (2021) found that farmers who integrated livestock into their cropping system were more likely to diversify their crops. We argue that livestock farmers in Sweden might be motivated by the usage of mixed seeds as animal feed and are thereby more interested in intercropping. This might result in a more positive attitude towards intercrops in general and especially when intercropping products are used for feed, where harvest issues (of different seed sizes and maturity timing) become unimportant. This way, the use of intercropping outputs can be a solution to establish the link between food and feed systems within livestock farms and buffer farmers against the volatilities of the feed market.

Famers with a higher perceived ease to practice intercropping were more likely to be in a higher stage of change. Perceived ease captures farmers' perception about the technical aspects of intercropping. Specifically, perceived ease relates to farmers' belief in their confidence in implementing intercropping or perceived behavioural control, which is one of the key constructs in Theory of Planned Behaviour (TPB) (Ajzen 1991). According to (TPB) (Ajzen 1991), perceived behavioural control influences not only intention to perform a behaviour but also the actual behaviour. TPB also postulates that perceived behavioural of control is dependent on perceived presence or absence of requisite resources and opportunities that facilitate or inhibit the behaviour. Research shows that the adoption of intercropping, in particular, is resource intensive (Khanal et al. 2021). The complex management of intercropping systems means they require more skills, knowledge and change in machinery and infrastructure. All of these result in higher production cost of intercropping, comparing to mono-cropping (Khanal et al. 2021). Resource-constrained farmers therefore would perceive a low level of confidence to implement intercropping and thus are at lower stages of change. Using Theory of Planned Behaviour, Bonke and Musshoff (2020) also found a positive association between German farmers' perceived behavioural of control (conceptually similar to perceived ease) and intention to intercrop. A similar result is also found by Nguyen and Drakou (2021), which investigates intercropping intention in Vietnam.

The association between the stages of change and perceived seed separation cost was negative and significant. This implies that farmers who perceived a higher cost for seed separation technologies were more likely to be in a lower stage. Mixed seed yield needs to be separated after harvest to be marketable. However, the high cost associated with sorting would reduce the economic gains obtained from the increased yields of intercropping systems (Jensen et al. 2020) and discourages intercropping adoption. This technical hurdle is also perceived by studied farmers in Germany (Lemken et al. 2017). Like this study, Lemken et al. (2017) found that perceived technical barriers relating to mixed seed sorting and practical knowledge hindered intercropping adoption. Together with previous intercropping studies (Jensen et al. 2020; Lemken et al. 2017), this study confirms that the issue of seed sorting technologies remains a considerable obstacle to intercropping adoption.

Concerning demographic variables, the review by Campos (2022) shows that high age and low education are constraints to the adoption of sustainable farming practices. Similarly, in this study, respondents with a university degree and respondents at a younger age were more likely to be at a higher stage of change, compared to those who do not hold a university degree and are younger. A possible explanation for our finding in relation to age is that older farmers are constrained by their well-established habits of practising monoculture, which is common in Europe, and are therefore reluctant to change their current cropping systems. Moreover, older farmers might have a shorter planning horizon (Prokopy et al. 2019) and thus are not interested in long term investment associated with intercropping such as machinery and equipment.

Regarding farms' characteristics, crop diversification research shows mixed finding regarding the effect of land size. For instance, Adjimoti et al. (2017) found that farm size was inversely correlated proportional with the number of crops grown and the Simpson Diversity Index in Africa. In contrast, Silberg et al. (2017) reported that larger farms in Malawi were more likely to intercrop. Similar to a study from Europe by Bonke and Musshoff (2020), the current paper did not find a significant association between farm size and intercropping adoption. Income exerted a significant and positive effect in the first regression panel but a non-significant and negative effect in the second panel. This suggests that farmers with higher household income were more likely to be in the contemplation stage and action and maintenance stage.

Policy support provided within CAP for protection zones and ley farming did not motivate intercropping adoption in Sweden. Support for protection zone and ley farming do not directly target but was expected to increase the adoption of intercropping and various crop mixtures in Sweden. However, this study shows that these policy instruments did not deliver such expected outcome. Our results are in line with research showing that EU policies that are favourable to sole crops (Jensen et al. 2020) and/or the lack of policy measures specific to crop diversification has hampered intercropping uptake.

Applying TTM, this study does not account for farmers who have quitted intercropping. It is assumed that some farmers are disadopters of a technology due to the disappointment with its low performance or the influence from other disadopters (Grabowski et al. 2019). This limitation should be addressed by future research. However, since the adoption of intercropping, particularly intercropping between commercial crops is new

Table 3 Generalized ordered logit regression results

Variables	1st stage vs. (2nd and 3rd stages)	(1st and 2nd) stages vs. 3rd stage
	Coefficient (SE)	Coefficient (SE)
Knowledge	0.491*** (0.179)	1.217*** (0.193)
EnviBenefit	0.754*** (0.252)	0.338 (0.224)
FinanceBenefit	0.604*** (0.206)	0.604*** (0.206)
EnvixFinanceBenefit	0.034 (0.107)	0.034 (0.107)
InstrumentalValue	0.537*** (0.198)	− 0.115 (0.190)
LandConsevValue	− 0.370** (0.157)	− 0.370** (0.157)
MarketIssue	− 0.366** (0.150)	− 0.366** (0.150)
ApplyEase	0.390*** (0.138)	0.390*** (0.138)
SeedSeperateCost	− 0.026 (0.144)	− 0.393** (0.154)
Age	− 0.039*** (0.010)	− 0.039*** (0.010)
UniversityDummy	0.438* (0.247)	0.438* (0.247)
HHIncome	0.160*** (0.060)	− 0.043 (0.057)
ContractWorkDummy	− 0.306 (0.254)	− 0.306 (0.254)
Ley	0.665* (0.355)	0.665* (0.355)
LogLand	0.042 (0.042)	0.042 (0.042)
GrasslandLeySupport	0.249 (0.301)	0.249 (0.301)
ProtectionzoneSupport	− 0.082 (0.309)	− 0.082 (0.309)
_cons	1.223 (1.004)	0.750 *** (1.037)
Pseudo-R^2	0.293	
Cragg-Uhler/Nagelkerke R^2 0.530		

1st stage (pre-contemplation), 2nd stage (contemplation), 3rd stages (action and maintenance). ***, **, and * indicate significant level at 0.01, 0.05, and 0.1, respectively

in Sweden, it is arguable to expect that the disadoption rate is also low. If this assumption is held, only a small number of disadopters are not considered by this study. Moreover, using TTM to reveal farmers' stage of change in the adoption process, this study can provide more information on adoption behaviour, compared to adoption studies that focus on binary choice of adoption outcomes.

Robustness checks

We inspected the stability of the association between behavioural variables and the stages of change. Comparing the full model (Table 3) with the nested model with only behavioural covariates (Table 6, "Appendix"), we found the full model had a greater predicting power (pseudo-R2 of 29.3 versus 23.6). Moreover, the exclusion of variables on policy supports, farmers and farms' characteristics did not affect the association between behavioural factors and adoption stage (Table 6, "Appendix"). This is the evidence for the stability of the findings on the influence of behavioural factors.

To evaluate the stability of the result on policy support, we performed three additional regressions like the one shown in Table 3 but differed from that in policy-related covariates (Table 5, "Appendix"). In Table 5, the first model (5a) and the second (5b) included only one of the two variables on policy supports (grassland ley, protection zone) and the third one (5c) included the variable on support for either grassland ley or protection zone. The results of these three models were similar to those shown in Table 3 and thus the stability of the results on policy support is confirmed.

Lastly, via EFA, the measurement error of 23 survey items measuring the latent constructs (item with * in Table 2) has been handled (Hicks et al. 2019). However, measurement error might be an issue for the other two behavioural variables measured by single survey items including ApplyEase and SeedSeparationCost. Therefore, a robust check for the measurement error of these two variables is required. Adapted from Finger and Möhring (2022), we transformed the two into dummy variables: perceive a low and high levels of ease in intercropping or seed separation cost (Table 7 "Appendix"). We found similar results between this modified model (Table 7, "Appendix") and the full model in Table 3. We therefore conclude that ApplyEase and SeedSeparationCost did not face any measurement issues and in general, our results are stable.

Conclusions and policy implications

Drawing upon the Transtheoretical Model (Prochaska and Velicer 1997), this study considered intercropping as a process of sequential stages of change and aimed to reveal their determinants in the context of Sweden's agriculture. Based on the data collected and the Transtheoretical Model, surveyed farmers were categorized into three stages of behavioural change in intercropping adoption including pre-contemplation, contemplation, action, and maintenance with higher stages reflecting higher readiness to intercrop. Using multidisciplinary approach, a wide range of socioeconomic, behavioural, and policy factors associated with stages of change was uncovered via the application of behavioural insight in conjunction with economic principles.

The result shows that farmers with better knowledge of intercropping, a higher evaluation of its financial benefits and ease of use, and ley cultivation were more likely to progress to the higher stages of the adoption process. In contrast, the higher perceived cost of seed separation technologies and farming experience were associated with lower stages in the intercropping adoption process. Perceived environmental benefits of intercropping, household income, and farmers' instrumental values in farming are factors that can act as pushing forces to turn non-adopters (pre-contemplation stage) into either potential adopters (contemplation stage) or actual adopters (action and maintenance stage).

The paper found that the existing policy measures expected to encourage intercropping were not translated to a higher intercropping adoption readiness in Sweden. Some proposed eco-schemes of CAP 2023–2027 (European Commission 2021) are new voluntary instruments to directly support crop diversification, including but not exclusive to intercropping. However, since single interventions are less likely to succeed, it is necessary to combine different policy instruments aimed at sustainable farming (Piñeiro et al. 2020). In addition to economic incentives, training and education on intercropping is crucial to move Swedish farmers towards the higher stages of change. Moreover, interventions are likely to be effective if farmers' perception is considered (Gao et al. 2020).

As intercropping adoption is driven by its perceived financial benefits but hindered by farmers' insufficient knowledge of intercropping, the new policy should be implemented in conjunction with enhanced extension services to not only provide economic incentives but also remove knowledge barriers. Creating an enabling environment for implementation of diversification practices (Jensen et al. 2020) including intercropping adoption via improved seed sorting technologies and improved markets for intercropping products might be important to boost the adoption.

This study is constrained by some limitations. First, there is a possibility that some farmers are disadopters, who have relapsed from a higher stage (e.g. action) to a lower stage (e.g. contemplation) in the adoption process, which this study did not account for. However, this limitation is not likely to be a major concern in our case since the disadoption rate is expected to be low because intercropping is a new practice in Sweden. Second, while generalized ordered logit is more interpretable than non-ordinal methods such as multinomial logit, it is sensitive to categories with a small count (Katic and Ellis 2018). Merging categories with a small count to fit the model will result in information loss. There is an opportunity for future research to investigate relapse behaviour in intercropping adoption and explore alternative approaches in data analysis. Third, selection bias is unavoidable in this study. However, this bias is not profound due to two reasons. First, the survey includes both interested and non-interested farmers. 25% of the surveyed farmers in our study were non-adopters and did not have an intention to intercrop in the future, who are indeed non-interested farmers. Second, our sample is close to the national statistics in relation to respondents' age, income, and distribution of large farms. Last but not least, the empirical application on the determinants associated with the stage of change in intercropping adoption is for the agriculture in Sweden only. Future research can consider applying the TTM to compare determinants of intercropping uptake between countries with a similar context like Sweden and other countries in Europe, or between industrialized and developing countries.

Responsible research and innovation (RRI) (Owen et al. 2020) in relation to intercropping is needed to remove barriers of intercropping adoption and contribute knowledge to addressing societal challenges associated with monoculture. The final aim is to improve the sustainability of our food systems. According to Brooker et al. (2015), "a primary challenge for researchers is in understanding the processes and mechanisms underpinning intercropping… Such knowledge could allow manipulation of intercropped systems to maximize desired outcomes (e.g. food production, landscape quality or biodiversity conservation)…. This study used a systematic approach to examine multiple forces pushing and/or pulling farmers' progress towards intercropping adoption. We explored forces induced not only by farms and farmers but also on a societal level. This way, the study can contribute knowledge to address the research challenge mentioned by Brooker et al. (2015) and promote the wider uptake of intercropping, a sustainable farming practice.

Appendix

See Tables 4, 5, 6 and 7.

Table 4 Exploratory factor analysis result

	Knowledge	Envi benefit	Financial benefit	Instrumental value	Land consev value	Market issue
Knowledge in optimal timing of harvest	0.915					
Knowledge in crop variety performance	0.898					
Knowledge in crop management	0.871					
Knowledge of characteristics of crop varieties	0.867					
Intercropping farmers can adapt to climate change better		0.912				
Intercropping is environmentally friendly		0.831				
Intercropping buffers for crop failure during climate irregularities		0.719				
Intercropping increase biodiversity		0.689				
Intercropping reduces fertilizer and pesticide cost			0.838			
Intercropping creates higher profit			0.795			
Intercropping makes the land fully used in a growing season			0.765			
Intercropping leads to the increased crop yield			0.585			
Supporting the family from farm income				0.812		
Expanding the farm business				0.766		
Maximizing profits from farming				0.709		

Table 4 (continued)

	Knowledge	Envi benefit	Financial benefit	Instrumental value	Land consev value	Market issue
Meeting challenges from farming				0.608		
Keep farming land for future generations					0.756	
Improving soil condition					0.708	
Work and live in nice surroundings					0.582	
Farming in a pro-environmental way					0.567	
Demand for mixed seed yield						0.871
Price for mixed seed yield						0.798
The availability of seed separation technology						0.549
Cronbach's alpha	0.920	0.869	0.814	0.741	0.741	0.735
Guttmann lambda 2	0.935	0.888	0.865	0.817	0.746	0.695
% of variance explained	28.489	13.674	11.309	7.220	6.421	4.470
Eigenvalue	6.553	3.145	2.601	1.661	1.477	1.028

Table 5 Results of generalized ordered regressions with different policy-related covariates

Variables	Model with Grassland ley support covariate (5a)		Model with Protection zone support covariate (5b)		Model with covariate being either protection zone or grassland ley support (5c)	
	1st stage vs. (2nd and 3rd stages)	(1st and 2nd) stages vs. 3rd stage	1st stage vs. (2nd and 3rd stages)	(1st and 2nd) stages vs. 3rd stage	1st stage vs. (2nd and 3rd stages)	(1st and 2nd) stages vs. 3rd stage
	Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)	Coef. (SE)
Knowledge	0.492*** (0.180)	1.220 (0.192)	0.487*** (0.180)	1.205*** (0.192)	0.498*** (0.177)	1.193 (0.189)
EnviBenefit	0.755*** (0.251)	0.341 (0.224)	0.744*** (0.250)	0.327 (0.223)	0.857*** (0.246)	0.312 (0.221)
FinancialBenefit	0.607*** (0.206)	0.607*** (0.206)	0.603*** (0.205)	0.603*** (0.205)	0.644*** (0.202)	0.644*** (0.202)
EnvixFinanceBenefit	0.034 (0.107)	0.034 (0.107)	0.037 (0.107)	0.037 (0.107)	0.054 (0.108)	0.054 (0.108)
InstrumentalValue	0.528*** (0.195)	− 0.124 (0.187)	0.526*** (0.198)	− 0.114 (0.190)	0.551*** (0.191)	− 0.222 (0.183)
LandConsevValue	− 0.372** (0.157)	− 0.372** (0.157)	− 0.371** (0.156)	− 0.371** (0.156)	− 0.404** (0.152)	− 0.404** (0.152)
MarketIssue	− 0.365** (0.151)	− 0.365** (0.151)	− 0.352** (0.149)	− 0.352** (0.149)	− 0.368** (0.149)	− 0.368** (0.149)
ApplyEase	0.387*** (0.138)	0.387*** (0.138)	0.399*** (0.138)	0.399*** (0.138)	0.401*** (0.138)	0.401*** (0.138)
SeedSeperateCost	− 0.027 (0.144)	− 0.395** (0.155)	− 0.031 (0.145)	− 0.410** (0.153)	− 0.217* (0.115)	− 0.217* (0.115)
Age	− 0.039*** (0.010)	− 0.039*** (0.010)	− 0.039*** (0.010)	− 0.039*** (0.010)	− 0.041*** (0.010)	− 0.041*** (0.010)
UniversityDummy	0.440* (0.247)	0.440* (0.247)	0.428* (0.247)	0.428* (0.247)	0.409* (0.242)	0.409* (0.242)
HHIncome	0.160*** (0.060)	− 0.0419 (0.060)	0.161*** (0.060)	− 0.043 (0.057)	0.164*** (0.060)	− 0.027 (0.056)
ContractWorkDummy	− 0.313 (0.253)	0.677** (0.352)	− 0.284 (0.253)	− 0.284 (0.253)	− 0.250 (0.250)	− 0.250 (0.250)
Ley	0.677** (0.352)	0.677** (0.352)	0.813*** (0.306)	0.813*** (0.306)	0.683*** (0.303)	0.683*** (0.303)
LogLand	0.041 (0.041)	0.260 (0.299)	0.044 (0.041)	0.044 (0.041)	0.057 (0.039)	0.057 (0.039)
GrasslandLeySupport	0.260 (0.299)	0.260 (0.299)	NA	NA	NA	NA
ProtectionzoneSupport	NA	NA	− 0.117 (0.306)	− 0.117 (0.306)	NA	NA
Either GrasslandLey or Protection zoneSupport	NA	NA	NA	NA	0.257 (0.293)	0.257 (0.293)
_cons	1.222 (1.004)	0.752 (1.038)	1.2421 (1.003)	0.817 (1.033)	1.820* (0.955)	0.033 (0.957)
Pseudo-R^2	0.293		0.293		0.289	0.289

***, **, and * indicate significant level at 0.01, 0.05, and 0.1, respectively

Table 6 Generalized ordered regression results, excluding covariates on policy support, farmer' and farm's characteristics

Variables	1st stage vs. (2nd and 3rd stages)	(1st and 2nd) stages vs. 3rd stage
	Coef. (SE)	Coef. (SE)
Knowledge	0.535***	1.197****
	− 0.164	− 0.18
EnviBenefit	0.467**	0.467**
	0.208)	− 0.208
FinancialBenefit	0.470**	0.470**
	− 0.201	− 0.201
EnvixFinanceBenefit	− 0.031	− 0.031
	− 0.103	− 0.103
InstrumentalValue	0.549***	0.011
	− 0.173	− 0.172
LandConsevValue	− 0.297*	− 0.297*
	− 0.151	− 0.151
MarketIssue	− 0.276**	− 0.276**
	− 0.14	− 0.14
ApplyEase	0.395***	0.395***
	− 0.133	− 0.132
SeedSeperateCost	0.038	− 0.360**
	− 0.128	− 0.139
_cons	0.14	− 0.874
	− 0.629	− 0.638
Pseudo-R^2	0.236	

*** , **, and * indicate significant level at 0.01, 0.05, and 0.1, respectively

Table 7 Generalized ordered regression results with dummy covariates ApplyEase and SeedSeperationCost

Variables	1st stage vs. (2nd and 3rd stages)	(1st and 2nd) stages vs. 3rd stage
	Coef. (SE)	Coef. (SE)
Knowledge	0.527***	1.190***
	− 0.178	− 0.19
EnviBenefit	0.903***	0.341
	− 0.252	− 0.225
FinancialBenefit	0.633***	0.633***
	− 0.206	− 0.206
EnvixFinanceBenefit	0.013	0.013
	− 0.107	− 0.107
InstrumentalValue	0.640***	0.640***
	− 0.197	− 0.197
LandConsevValue	− 0.397**	− 0.397**
	− 0.154	− 0.154
MarketIssue	− 0.371**	− 0.371**
	− 0.149	− 0.149
ApplyEaseDummy	0.762***	0.762***
	− 0.273	− 0.273
SeedSeperateCostDummy	− 0.585**	− 0.585**
	− 0.242	− 0.242
Age	− − 0.036***	− 0.036***
	− 0.01	− 0.01
UniversityDummy	0.412*	0.412*
	− 0.245	− 0.245
HHIncome	0.168***	− 0.026
	− 0.06	− 0.056
ContractWorkUse	− 0.314	− 0.314
	− 0.253	− 0.253
Ley	0.633*	0.633*
	− 0.353	− 0.353
LogLand	0.054	0.054
	− 0.042	− 0.042
GrasslandLeySupport	0.333	0.333
	− 0.3	− 0.3
ProtectionzoneSupport	− 0.047	− 0.047
	− 0.307	− 0.307
_cons	2.181***	0.379
	− 0.779	− 0.774
Pseudo-R^2	0.29	

*** , **, and * indicate significant level at 0.01, 0.05, and 0.1, respectively

Abbreviations

CAP	Common Agricultural Policy
EFA	Exploratory factor analysis
FAO	Food and Agriculture Organization
FORMAS	The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
KMO	The Kaiser–Meyer–Olkin
N/A	Not applicable
SD	Standard deviation

SE Standard errors
TTM The Transtheoretical Model

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Not applicable.

Authors' contributions
TMH designed the survey questionnaire, managed data collection, analysed the results, and wrote the manuscript. HH, MW, and GM-T aided in the survey design and manuscript preparation. All authors have read and approved the final manuscript.

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Will be provided upon request

Declarations

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Thanh Mai Ha Dr. is a current researcher at the Department of Economics at the Swedish University of Agricultural Sciences. Her research focuses on consumers' perception and decision making in healthy food choice, farmers' adoption of climate change adaptation practices, sustainable farming, and household food security. She is interested in applying psychometric insight in conjunction with economic principles to explain farmers' and consumers' decision making. Most of her research is conducted in either Southeast Asia or Europe, using survey data.

Gordana Manevska-Tasevska Dr. is an associate professor at the Policy Analysis Unit of the Department of Economics at the Swedish University of Agricultural Sciences (SLU), Sweden. Her research field is the performance analysis of primary production in the agricultural sector including economic/ecological/social performance in terms of efficiency, acceptance of agro-ecological approaches, sustainability and resilience analysis, and its interplay with agricultural policy.

Martin Weih is a professor of plant ecology and eco-physiology of agricultural crops at the Swedish University of Agricultural Sciences (SLU) in Uppsala, Sweden. Main research focus of his laboratory is on plant genotype and environment interplay in crop production. Major research activities focus on the improvement of yield and ecological sustainability (e.g. resource use efficiency) of agricultural crops grown for food, feed and biomass.

Helena Hansson is a professor of agricultural and food economics at the Swedish University of Agricultural Sciences. Her work is focused on farmer uptake of sustainable agricultural practices, farm management, farmer decision-making and the economics of certain strategic choices, and production economic analyses related to the efficiency and sustainability of farm production. She works extensively with interdisciplinary approaches where behavioural models are used to explain decision-making or to explain economic behaviour and economic performance, and where knowledge from the natural sciences is instrumental in the analyses.