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Better safe than sorry? European farmers' perceptions on agroecological practices: a theory of planned behaviour case study

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Adoption rates of agroecological farming practices remain low amongst European farmers and vary from country to country, despite European or national policies aimed at achieving 'sustainable agriculture'. Our study, based on the Theory of Planned Behaviour and conducted in eight European countries in 2023 with 268 farmers surveyed, examines behavioural drivers of adoption of agroecological practices in terms of attitudes, perceived behavioural control, social norms, perceived risk, and the role of formal and informal information sources. The main findings reveal three key points: 1) Farmers were more likely to adopt agroecological practices if they had a positive attitude towards them and felt confident in their ability to implement them whilst social pressure had only a limited impact on adoption. 2) Perceived risks associated with agroecological practices significantly reduced farmers' willingness to adopt. 3) Formal sources of information had a significant positive effect on the perceived risks, whereas informal information sources did not. However, the latter had a significant positive effect on social pressures, suggesting that they influence farmers' perceptions of what is socially expected by their communities. These findings imply that to accelerate the adoption of agroecological practices, policy and advisory services should focus on mitigating farmers' risk perceptions through formal, evidence-based information, thereby fostering positive attitudes and a stronger sense of control.

KEYWORDS

agroecological farming practices, farmer behaviour, practice adoption, risk perception, sustainable agriculture, TPB

1 Introduction

Conventional systems of food production mostly rely on the necessary use of synthetic chemical inputs (e.g., fertilizers and pesticides) for optimal yield of monocultures, as well as on the use of heavy machinery. These farming practices cause environmental damage including water and soil pollution, declining biodiversity, decreased soil fertility, and various health problems among both farmers and consumers (Clark et al., 2019; Tuomisto et al., 2017; Mzoughi, 2011). In response, policymakers and institutions, including the European Union (EU), have developed agri-environment schemes - such as payments for environmentally beneficial practices implemented under rural development programmes (e.g. agri-environment-climate measures) -, aiming to promote the adoption of more environmentally-sustainable farming practices, such as reduced tillage, crop diversification, or the use of cover crops (Barreiro-Hurlé et al., 2010); and more recently eco-schemes, introduced under the CAP 2023–2027 as payments linked to voluntary practices such as permanent grassland maintenance, carbon farming, or biodiversity-enhancing measures (Bazzan et al., 2023; Sidhoum et al., 2023). These strategies have led to the implementation of what we refer to as Agroecological Farming Practices (AFP). Agroecological Farming Practices are defined as a set of farming practices designed to provide agricultural ecosystem services. They aim to mitigate the negative environmental impacts associated with conventional or intensive agriculture and improve the ecological quality of agroecosystem (Delaroche, 2020; Blazy et al., 2011). Examples of these practices include intercropping, cover crops, reduced or zero/no tillage, addition of organic matter to the soil, use of biocontrol or biopesticides, but also practices that support biodiversity such as establishing hedgerows or planting flower strips (Wezel et al., 2014). These practices are well-known for enhancing biodiversity and soil organic matter, and for providing ecological services including nitrogen fixation, soil preservation, weed and pest control, pollination and water purification (Skaalsveen and Clarke, 2021; Albrecht et al., 2020; Woodcock et al., 2025).

However, despite the importance of AFP within different agri-environment schemes in EU and UK, where they are well integrated into the EU's Common Agricultural Policy, and UK's Sustainable Farming Incentives, these practices still present a low adoption rate among farmers (Rizzo et al., 2023; Thompson et al., 2023), with 50% of eco-schemes targeting less than 4% of EU agricultural land (Münch et al., 2023). This discrepancy between substantial policy support and limited implementation represents a critical challenge for European agriculture. While considerable financial resources—amounting to approximately 25% of total direct payments under the EU's 2023–2027 Common Agricultural Policy—and policy instruments have been dedicated to promoting agroecological transitions, the actual transformation of farming systems has progressed much slower than anticipated (European Court of Auditors, 2024).

The adoption of AFP has received increasing attention from scholars in recent years (Han and Grudens-Schuck, 2022). A growing body of empirical literature has examined farmers' adoption of agroecological practices across different contexts and decision settings (reviewed by Serebrennikov et al., 2020), including participation in agri-environmental schemes (DeFrancesco et al., 2018), engagement in organic farming (Toma and Mathijs, 2007), and the uptake of environmentally oriented management practices more broadly (Mishra et al., 2018). More recent studies focusing on the European context highlight that these adoption decisions are often characterised by a high degree of cognitive, technical, and social complexity, as they involve cumulative, practice-specific choices embedded in regulatory, informational, and social environments (Thompson et al., 2023; Ujj et al., 2025). Taken together, this literature suggests that farmers' adoption of AFPs cannot be reduced to single economic or technical drivers, but rather reflects multifaceted decision-making processes shaped by perceptions, norms, and risk considerations.

In the scientific literature, there are several approaches to understand the processes affecting adoption outcomes. One way is to study economic and financial drivers, such as prices and costs (van der Ploeg et al., 2019; Chouinard et al., 2008). In fact, farmers' decisions to adopt sustainable farming practices are often stated as being primarily driven by economic factors (Foguesatto et al., 2020; Trujillo-Barrera et al., 2016; Zhang et al., 2015). However, such decisions are complex, and farmers frequently show behaviours that go beyond profit maximization (Wilson and Hart, 2000). Numerous studies have shown that psychological factors also influence farmers' decision-making (Dessart et al., 2019; Liu et al., 2018; Martinovska Stojcheska et al., 2016). For instance, social pressure and risk attitudes have frequently been studied as determinants of farmers' adoption of sustainable practices (Best, 2010; Kisaka-Lwayo, 2008; McCarthy et al., 2007; Rommel et al., 2023). A better understanding of the socio-psychological factors and processes influencing farmers' decisions to adopt practices would enable the identification of levers that policymakers and extension services could use to support them changing towards such practices. From a farm management point of view, these potential levers are based on the beliefs of farmers, particularly with regard to attitude and social pressure, but also their knowledge and access to information (Klebl et al., 2023; Daxini et al., 2019). Numerous studies have also found a positive association with environmental attitudes (Koesling et al., 2008; Läpple and Van Rensburg, 2011). Moreover, perceived benefits generated by the adoption of the sustainable practice may be critical in farmers' intentions (De Cock, 2005; Kabii and Horwitz, 2006; Piñeiro et al., 2020). Therefore, gaining a comprehensive understanding of farmers' decisions about the implementation of their agricultural practices may require considering additional personal motivations, as proposed by psychological theories.

This study adopts the Theory of Planned Behaviour (TPB) (Ajzen, 1991) as a theoretical framework, widely adopted to model individuals' behaviour (Ajzen, 2020). According to TPB, an individual's intention to perform a certain behaviour is the most direct predictor of that behaviour. Intention, in turn, is explained by three factors: attitudes, perceived behavioural control, and subjective norms. Attitudes are defined as the degree to which a person has a favourable (or unfavourable) assessment of the behaviour in question. Perceived behavioural control refers to the subjective assessment of

how easy (or difficult) the individual perceives it to perform the behaviour/practice. Subjective norms are the perceived social pressure to perform (or not perform) the behaviour, reflecting the influence of peers, family, or community. The adoption of AFP is a rarely a one–off binary choice, it typically unfolds through cumulative, context–specific and learning–intensive decisions under technical and market uncertainty. In this regard, the TPB is particularly suited to capture intention formation in such decision contexts, as it explicitly integrates cognitive evaluations, perceived feasibility, and social embeddedness of behaviour, all of which are critical in agronomic transitions that unfold progressively rather than instantaneously (Läpple and Van Rensburg, 2011; Dessart et al., 2019). While previous studies have applied the TPB to agricultural contexts (e.g., Batbay and Kahramanoğlu, 2024; Maleksaeidi and Keshavarz, 2019; Timpanaro et al., 2023), we aimed to extend the framework by incorporating risk perception and different sources of information: formal, organized sources versus community-driven or media-based sources, as key explanatory variables. This positioning complements diffusion and transition perspectives, where networks, niches and systemic lock-ins are central, by specifying the *within-actor* cognitive mechanisms that translate perceived advantages and social signals into intentions; this dual perspective is well-suited to agroecological change, where coupled technical and social innovations require both system-level coordination and farmer-level deliberation (Cascone et al., 2025; Duru et al., 2015; Meynard et al., 2017).

We conducted a cross-country comparison across eight European nations to explore how these factors shape farmers' intentions to adopt AFP. We employed a Partial Least Squares Structural Equation Modelling (PLS-SEM) approach to identify the key drivers influencing decisions on the adoption of AFP. PLS-SEM was selected due to its suitability for exploratory research, as well as its ability to handle complex interaction among latent constructs measured by multiple indicators. In doing so, we aimed to provide policymakers and advisory services with insights into socio-psychological factors for the adoption of AFP, that can influence the design of more effective interventions to promote sustainable agriculture.

In this study, we applied an extended TPB framework to investigate the determinants of farmers' intentions to adopt AFP. The TPB posits that behavioural intentions are shaped by three key factors: attitudes, perceived behavioural control, and social norms (Ajzen, 1991). Attitudes (AT), representing personal evaluations of AFP, significantly influence farmers' willingness to adopt new farming approaches (Koesling et al., 2008; Läpple and Van Rensburg, 2011). Perceived behavioural control (PBC) (farmers' subjective assessment of their ability to implement practices) plays a crucial role in sustainable practice adoption (De Cock, 2005; Kabii and Horwitz, 2006). Social norms (SN), manifested as perceived pressure from peers, family, and community, substantially impact farmers' decision-making processes (Mozzato et al., 2018; Prokopy et al., 2008). Hence, in contexts where adoption of AFP is considered, AT captures anticipated agronomic and environmental benefits versus trade-offs; PBC reflects know-how, equipment, labour and advisory support; and SN mirrors peer visibility, community expectations and supply-chain demands—dimensions repeatedly emphasised in European transition research (Duru et al., 2015; Meynard et al., 2017).

Based on these three TPB components - AT, PCB, and SN - this study investigates the following hypotheses:

H1: Attitudes (AT) have a positive and significant effect on farmers' intention to adopt agroecological farming practices.

H2: Perceived behavioural control (PCB) has a positive and significant effect on farmers' intention to adopt agroecological farming practices.

H3: Social norms (SN) have a positive and significant effect on farmers' intention to adopt agroecological farming practices.

Besides including AT, PBC and SN as main antecedents of farmers' intentions, this study extends the TPB framework to identify the role of other factors to explain intentions. The first factor is the risk perceived by farmers of adopting an AFP. Risk aversion is known to play a central role in farmer decision-making (Erekalo et al., 2025; Menapace et al., 2013; Rommel et al., 2023). In this study we focused on the perceived risk of adopting AFP as potential barrier. Perceived risk operates as a cross-cutting cognitive filter within TPB, shaping how farmers evaluate outcomes, feasibility, and social expectations. Higher perceived risk tends to reduce favourable attitudes by amplifying anticipated losses and uncertainty (Dessart et al., 2019; Menapace et al., 2013), constrain perceived behavioural control by undermining confidence in resources and capability to manage potential failures (Knapp et al., 2021), and weaken social norms by discouraging peer endorsement and legitimisation of innovative practices under shared uncertainty (Mozzato et al., 2018). Hence, the rationale is that the perceived risk (RISK) of adopting the practice influences all the three TPB dimensions. Therefore, we postulated three additional hypotheses:

H4: Perceived risk *(RISK) has a negative and significant effect on Attitudes (AT).*

H5: Perceived risk *(RISK) has a negative and significant effect on Perceived Behavioural Control (PBC).*

H6: Perceived risk *(RISK) has a negative and significant effect on Social Norms (SN).*

The second extension to the TPB model concerns the information and knowledge provisioning services used by farmers as an external influencing factor. Indeed, information and knowledge provision have demonstrated influence on farmers' strategies and are often addressed as critical factors in their decision-making (Bavorová et al., 2020; Knickel et al., 2009; McBride and Daberkow, 2003). However, different sources of information play distinct roles in shaping farmers' behaviour (McBride and Daberkow, 2003). On the one hand, formal and organized sources of information (IF), such as public advisory services or training programmes, are expected to provide structured, expert-driven insights that primarily enhance perceived behavioural control by building technical competence and reducing uncertainty, while also mitigating perceived risk through structured guidance (Asenso-Okyere et al., 2010; Wossen et al., 2017). In contrast, community-driven or media-based sources

of information (IC), such as peer exchanges, operate through social learning, reinforcing subjective norms and legitimising practices within peer networks, while simultaneously reframing risk perceptions through shared experiences (Asprooth et al., 2023; Skaalsveen et al., 2020). Hence, here we investigated the effects that both types of information have on social norms and on the perceived risk. Specifically, the hypothesis tested are:

H7: Formal information (IF) has a negative and significant effect on Perceived risk (RISK).

H8: Formal information (IF) has a positive and significant effect on Social Norms (SN).

H9: Community information (IC) has a negative and significant effect on Perceived risk (RISK).

H10: Community information (IC) has a positive and significant effect on Social Norms (SN).

The structural model and hypothesized relationships among constructs are illustrated in Figure 1.

2 Materials and methods

2.1 Online survey with farmers

An online survey was co-designed with input from 76 farmers responsible for their farm investments across Europe. The questionnaire was provided and distributed in eight European countries in their respective languages (Austria, Bulgaria, England, Finland, France, Germany, Italy, and Sweden). It was made available to farmers, farm advisors and farm networks through a website link using the online SurveyXact survey system. Data collection was carried out during 2022 to 2023 by the academic partners of the EcoStack project (https://ecostack-h2020.eu/)[1]. In total, 268 farmers from eight European countries participated in the study. Farmers were made aware of the survey primarily through advisory services, via producer organizations, farmers unions, and at farmers field events (educational events held on-farm). The number of respondents varied between countries. Hence, the sample is not designed to support statistically representative cross-country comparisons and country-level analyses should be intended as exploratory and indicative. Data gathering was conducted in accordance with ethical standards and the Helsinki Protocol's guiding principles. Informed consent was obtained from all respondents. The study was approved by Aarhus University Research Ethics Committee (approval number: 2020-104).

As part of the survey, farmers were asked about their use and awareness of a variety of AFP. In this study, we included under this umbrella terminology the following eleven practices: (1) flowering strips, (2) grass field margins, (3) maintenance/establishment of hedges, (4) crop cultivar mixtures, (5) intercropping, (6) under-sowing of legumes/companion plants, (7) trap cropping, (8) organic mulching, (9) no tillage/direct seeding, (10) biopesticides, and (11) use of beneficial microorganisms (e.g. plant growth promoting rhizobacteria).

2.2 Variables and scales

Before answering the questions on the TPB constructs, farmers were first asked to select from the list of the eleven AFP (see Section 2.1) the one they considered most appropriate or important for their farm. The subsequent questions forming the TPB model were explicitly directed toward the practice selected by each farmer. This procedure was adopted to avoid potential incompatibility between the practice and farm characteristics - such as structural constraints or the scope of the practice - thereby reducing the risk of confounding the measurement of farmers' intention to adopt agroecological practices more broadly. The distribution of the farmers' selected AFP can be found in the Supplementary Materials.

2.2.1 TPB scales

Intentions to adopt agroecological practices were measured by asking respondents to indicate their agreement with a statement about their intention to adopt the AFP selected previously, within the next five years, using a seven-point scale ranging from one (totally disagree) to seven (totally agree). An example is "*I intend to adopt flowering strips on the farm in the next five years*". Attitude toward sustainable practice was evaluated using five items on a seven-point semantic differential scale (Osgood, 1964). Perceived Behavioural Control and Social norms were measured with two four-item seven-point scales (see Supplementary Material for the complete questions list).

2.2.2 Perceived risk of adopting agroecological farming practices

To measure the farmer's perceived risk of adopting AFP, we used a six-item adaptation of the seven-item scale originally used by Sharifuddin et al. (2016) to study organic farming adoption by farmers. The scale is designed to measure farmers' perceived risks and negative perceptions associated with adopting AFP. Specifically, the items cover: financial risk, practical difficulties, general risk, market/marketing risk, effectiveness concerns, and safety concerns. An item example is "*Using agroecological farming practices may cause my income to decline*" (see Supplementary Material for the complete questions list). While the relative importance of these risk dimensions may vary across agricultural contexts, the scale is intended to capture a general, multidimensional perception of risk rather than to isolate the effect of individual risk components. In the European context, some dimensions, such as income-related risks, may be more salient for farmers considering AFP adoption, whereas others, such as marketing risks, may play a comparatively smaller role. Nevertheless, combining these items into a single latent construct allows for an integrated assessment of perceived risk as a whole, which is consistent with the focus of this study and with prior applications of the scale.

1 EcoStack is a European Union's Horizon 2020 research and innovation programme with the overall objective to develop and support ecologically, economically and socially sustainable crop protection via enhancement of ecosystem services provision and protection of functional biodiversity.

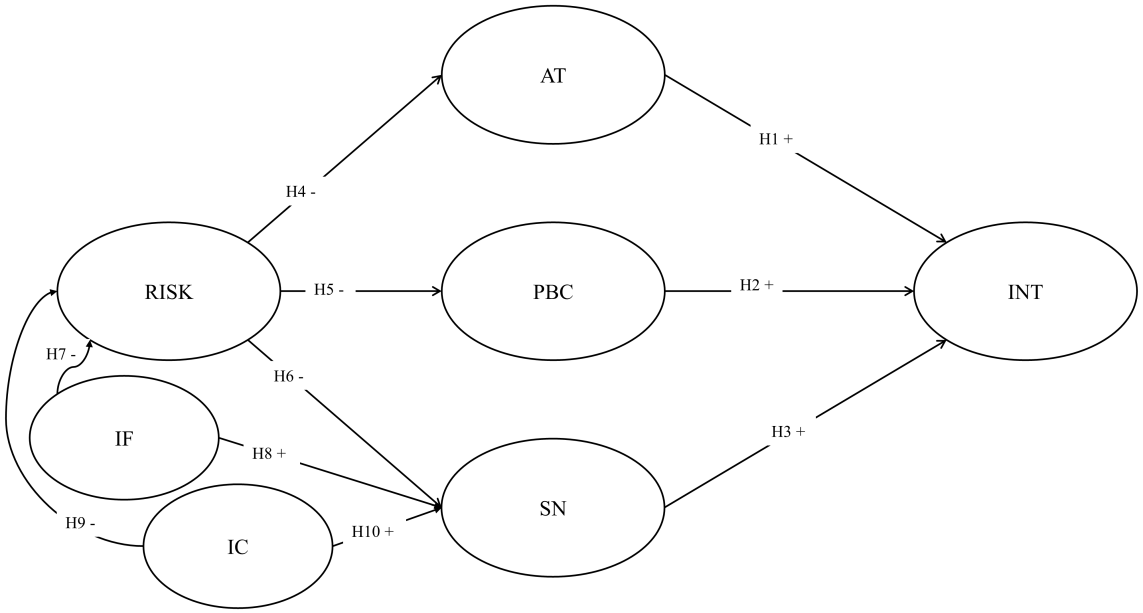

FIGURE 1
Structural model displaying the relationships between the intention to adopt agroecological farming practices (AFP) and its antecedents. Arrows represent hypothesized paths between latent variables. The expected direction of each relationship is indicated by a "+" or "−" sign, along with the corresponding hypothesis number. INT, Intention to adopt AFP; AT, Attitudes toward adoption of AFP; PBC, Perceived Behavioural Control over adoption of AFP; SN, Social Norms related to AFP; RISK, Perceived risk related to AFP; IF, Formal and Organized sources of information; IC, Community-based or Media-based sources of information.

2.2.3 Formal and organized sources of information and community-driven or media-based sources of information

To account for the influence that sources of information and knowledge have on farmers' decision-making, responses were collected on six potential sources of information. These sources were selected based on the previous work of Pascucci and de-Magistris (2011), which explored the relationship between different information sources (among other factors) and the Agricultural Knowledge and Innovation System. Each source of information was presented to the respondents who were asked to indicate how influential these sources would be in their adoption of AFP. The sources of information are: 1) Public extension service, 2) Private extension service, 3) Public agencies or authorities, 4) Local network, 5) Specialist farming newspapers and periodicals, and 6) Social media. The sources of information are grouped into two dimensions: Formal and Organized Sources of Information (IF) (source 1 to 3) and Community-driven or Media-based Sources of Information (CF) (source 4 to 6). See Supplementary Material for the complete questions list.

2.3 The partial least square - structural equation model

To analyse the data of the structural model, a PLS-SEM (Partial Least Squares Structural Equation Model) analysis was carried out. PLS-SEM is a powerful variance-based approach, firstly developed by Wold (1975). It is suited for complex models with multiple constructs, small-to-medium sample sizes, and non-normally distributed data (Hair et al., 2022). PLS-SEM allows for the simultaneous computation of both the measurement model and the structural model. The first computes the relationships between each observed item and latent constructs (assessing the reliability and validity of the latent constructs), and the latter tests the hypothesized relationships among variables.

The measurement model was constructed to represent the relationships between the latent constructs and their respective indicators (observed variables). The estimation of the measurement model produces factor loadings, which indicate the strength of the relationship between each observed item and its assigned construct. To ensure the quality of the model, convergent validity was assessed using the Average Variance Extracted (AVE), as recommended by Hair et al. (2019). Internal consistency reliability was evaluated using Cronbach's. Additionally, potential problematic collinearity among the items was monitored using the Variance Inflation Factor (VIF) for the formative constructs.

This approach is appropriate for the present study, as it enables the inclusion of formative and reflective constructs, such as those employed in the analysis.

3 Results

3.1 The sample

In total, 268 farmers responded fully to the questionnaire (Table 1). The number of responses varied greatly between

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TABLE 1 Sociodemographic characteristics of the sample (N = 268).

Sample characteristic	Frequency	%
Gender		
Woman	55	20.6
Man	209	78.0
Other/Prefer not to say	4	1.5
Age		
20 - 35	68	25.4
36 - 50	84	31.3
51 - 65	91	34.0
65+	25	9.3
Education		
Secondary education	58	21.6
Tertiary education - Short course	54	20.2
Bachelor	59	22.0
Master	85	31.7
Doctoral	12	4.5
Annual net income		
Less than 15,000 EUR	75	27.0
Between 15,000 EUR and 45,000 EUR	96	35.8
Between 45,000 EUR and 105,000 EUR	59	22.0
Above 105,000 EUR	38	14.2
Country of origin		
Austria	2	0.8
Bulgaria	5	1.9
England	9	3.4
Finland	93	34.7
France	32	11.9
Germany	78	29.1
Italy	42	15.7
Sweden	7	2.6
Years of farming experience		
Less than 10	109	40.7
More than 10, less than 20	60	22.4
More than 20, less than 30	52	19.4
More than 30	47	17.5

countries, with Germany and Finland having a relatively high number of responses (78 and 93, respectively), France and Italy with a medium number of responses (32 and 42, respectively) and a group with fewer responses (Austria, Bulgaria, England and Sweden with less than ten respondents each). A higher number of men than women responded to the survey in almost all countries. However, this reflects the typical situation on European farms (Fanelli, 2022). The average age of respondents was 46. The average number of years of farm experience was 18 years, with respondents having longest farming experience in England and least in Bulgaria. Most respondents had received some form of tertiary education with the largest group of interviewees having a master's degree.

Most farms were family farms or single enterprises specialized in arable crops or mixed crop and livestock systems. Almost half of the farms have 100 ha or more of farmland. About one third of farms are certified for organic agriculture or have a geographical indication label (e.g., EU's Protected Designation of Origin and Protected Geographical Indication). The specialization and characteristics of the farms are listed in Table 2.

3.2 The theory of planned behaviour antecedents

The farmers' responses to TPB's main antecedents are summarized in Table 3. They include statements on the three main TPB constructs (attitudes, perceived behavioural control, and social norms). The adoption intention is generally high, with a mean score of 6.3 out of 7 points. As for the items on AT, PBC and SN, respondents stated to be predominantly slightly agreeing or agreeing, with mean values between 4.6 and 6.4.

TABLE 2 Farm characterisation of the farmers participating in the survey.

Farm characteristic	Frequency	%
Legal status		
Family farm/single enterprise	227	84.7
Group holding	30	11.2
Other	11	4.1
Production system		
Arable crops	98	36.6
Horticulture	17	6.3
Permanent crops	23	8.6
Mixed cropping	17	6.3
Mixed crops-livestock	99	36.9
Other	14	5.2
Certification or label		
Organic agriculture	72	26.9
Geographical indication	32	11.9
Farm area		
< 11 ha	29	10.8
11–50 ha	69	25.8
50–100 ha	52	19.4
> 100 ha	118	44.0

TABLE 3 Theory of planned behaviour measures summary statistics regarding agroecological farming practices.

Label	Item	Mean	St. dev.	Min-max
INT	Adoption intention toward AFP			
INT1	I intend to use the sustainable farming practice on the farm in the next five years	6.3	1.3	1-7
AT	Attitudes			
AT1	Applying it on my farm over the next five years is? Important	6.3	1.0	2-7
AT2	Useful	6.4	1.0	2-7
AT3	Pleasant	5.8	1.4	1-7
AT4	Positive	6.2	1.2	1-7
AT5	Applying the sustainable farming practice on my farm over the next five years would make me happy	5.8	1.3	2-7
PBC	Perceived behavioural control			
PBC1	It would be possible for me to continue using it on my farm over the next five years.	6.2	1.2	1-7
PBC2	If I wanted, I could continue to use it on my farm over the next five years.	6.2	1.2	1-7
PBC3	It is up to me whether or not I continue to use it on my farm over the next five years.	5.9	1.6	1-7
PBC4	How much control do you believe you have over continuing to use the sustainable farming practice on your farm over the next five years?	5.7	1.5	1-7
SN	Subjective norms			
SN1	Most people who are important to me think that I should continue to use it on the farm over the next five years.	5.1	1.5	1-7
SN2	The people in my life whose opinion I value think that I should continue to use it on the farm over the next five years.	5.2	1.5	1-7
SN3	Many farmers like me think that I should continue to use it on the farm over the next five years.	4.6	1.6	1-7
SN4	Society thinks that I should continue to use it on the farm over the next five years.	4.9	1.6	1-7

With 1 = Strongly disagree, 4 = Neither disagree nor agree, 7 = Strongly agree. Respondents were asked to determine one practice most relevant to their farm from a choice of eleven practices.

The results of the perceived risk toward the selected AFP scale (RISK) are presented in Table 4. Farmers' responses to the six statements indicate that risk perception levels vary across individuals and across the different aspects covered by the scale. Higher scores indicate greater perceived risk toward the AFP. Results indicate that farmers are more concerned by the possible loss of income due to the application of AFP and the difficulties in implementing the practices, which are rated with an average of 4.3 and 4.5 out of 7 points respectively. Conversely, farmers showed less concern about the marketing outcomes of sustainable practices and the possibility that these practices are still at an experimental stage, with average scores of 2.4 and 2.9.

Summary statistics on the source of the individual information influences are presented in Table 5. The influence of formal and organized sources of information ranged from 3.7 for *Public agencies or authorities* to 4.1 for *Private extension service*. Community-driven or media-based information sources had a higher influence ranging from 4.2 for *Social media* to 4.9 for

TABLE 4 Perceived risk toward selected AFP (RISK).

Label	Item	Mean	St. dev.	Min-max
RISK1	Using environmentally friendly farming practices may cause my income to decline	4.2	1.8	1-7
RISK2	There are difficulties to use environmentally friendly farming practices	4.5	1.8	1-7
RISK3	It is risky to use environmentally friendly farming practices	3.6	1.9	1-7
RISK4	I do not think it is a good idea to use environmentally friendly farming practices because of concerns marketing my farms produce	2.4	1.5	1-7
RISK5	Using environmentally friendly farming practices will not satisfy my requirements to control pests	3.5	1.9	1-7
RISK6	I do not think it is safe to use environmentally friendly farming practices because they are just at an experimental stage.	2.9	1.7	1-7

Scale ranged from 1 = Strongly disagree (=low perceived risk) to 7 = Strongly agree (high perceived risk).

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TABLE 5 Influence of the source of information and knowledge on farmers' adoption of AFP.

Label	Source of information	Mean	St. dev.	Min-max
IF	Influence of formal and organized sources of information			
INF1	Public extension service	3.9	1.6	1-7
INF2	Private extension service	4.1	1.5	1-7
INF3	Public agencies or authorities	3.7	1.6	1-7
IC	Influence of community-driven or media-based sources of information			
INF4	Local network	4.9	1.6	1-7
INF5	Specialist farming newspapers and periodicals	4.8	1.3	1-7
INF6	Social media	4.2	1.8	1-7

Scale of 1–7 where (1 = Not at all influential, 4 = Neither uninfluential nor influential, 7 = Extremely influential).

Local Network. The farmers' stated higher influence of Community-driven or media-based information sources on their AFP adoption process is descriptive and may reflect unobserved heterogeneity.

3.3 Measurement model estimates

Table 6 presents the results of the PLS-SEM measurement model. The estimates indicate the magnitude of the relationships (i.e., factor loadings) between observed items and latent constructs.

Indicator reliability was assured by excluding items with low factor loadings, falling below the 0.708 threshold, suggested by Hair et al. (2010). All constructs surpass the average variance extracted (AVE) recommended threshold of 0.5, in accordance with Hair et al. (2019), with AVE values ranging from 0.6 to 0.8. This highlights the convergence of the measurement items toward their respective constructs. Formative constructs, IF and IC, show loadings higher than 0.5 and all the items should be retained (Hair et al., 2022). The Variance Inflation Factor (VIF) is also computed for the formative constructs and indicates an acceptable level of collinearity among items. Discriminant validity is thoroughly evaluated using the Heterotrait-Monotrait Ratio of Correlations (HTMT) (Henseler et al., 2015), along with the recently introduced HTMT2 method by Roemer et al. (2021). To avoid sign problems in the computation HTMT and HTMT2, the absolute value of the correlation among items is used, as suggested by Ringle et al. (2023). Both the resulting HTMT+ and HTMT2+ (Table 7) confirm the discriminant validity of the measurement model.

3.4 Effect of attitudes, perceived behavioural control and social norms, risk perception, and information sources

H1 to H3: TPB relationships

The results of the TPB estimates from the model calculations (Figure 2) reveal that both attitudes (AT > INT, $\beta = 0.38$, $p < 0.01$) and perceived behavioural control (PBC > INT, $\beta = 0.30$, $p < 0.01$) had significant and positive effects on farmers' intentions to adopt AFP (INT), confirming H1 and H2 (see Table 8 for a Summary of hypothesis testing). This suggests that farmers with a more positive attitude towards adopting agroecological practices and a stronger sense of control over their ability to implement these practices are more likely to adopt them. However, in disagreement with H3, the influence of social norms was low; slightly negative and not statistically significant

TABLE 6 PLS-SEM measurement model. Factor loadings, internal consistency reliability, and Convergent validity.

Item\Construct	IF	IC	RISK	INT	AT	PBC	SN
INF1	0.58						
INF2	0.67						
INF3	0.90						
INF4		0.83					
INF5		0.64					
INF6		0.67					
RISK1			0.73				
RISK3			0.76				
RISK5			0.80				
RISK6			0.80				
INT1				1.00			
AT1					0.86		
AT2					0.84		
AT3					0.78		
AT4					0.83		
AT5					0.75		
PBC1						0.92	
PBC2						0.94	
PBC3						0.71	
SN1							0.94

(Continued)

TABLE 6 Continued

Item\Construct	IF	IC	RISK	INT	AT	PBC	SN
SN2							0.95
SN3							0.84
Cronbach's α			0.78	1.00	0.87	0.82	0.90
AVE			0.60	1.00	0.66	0.74	0.83

AT, Attitudes toward adoption of the sustainable farming practices; IC, Influence of Community-based or Media-based Sources of Information; IF, Influence of Formal and Organized Information Sources; INT, Intention to adopt sustainable farming practices; PBC, Perceived Behavioural Control over adoption of sustainable farming practices; RISK, Perceived risk related to the selected sustainable farming practice.
Items are arranged by construct and named after it. Low factor loadings (< 0.708) items were excluded.

TABLE 7 Reflective construct discriminant validity. HTMT+ and HTMT2+.

HTMT2+\ HTMT+	RISK	AT	PBC	SN
RISK	\	0.37	0.30	0.15
AT	0.36	\	0.54	0.52
PBC	0.28	0.53	\	0.45
SN	0.09	0.51	0.44	\

AT, Attitudes toward adoption of the sustainable farming practices; IC, Influence of Community-based or Media-based Sources of Information; IF, Influence of Formal and Organized Information Sources; INT, Intention to adopt sustainable farming practices; PBC, Perceived Behavioural Control over adoption of sustainable farming practices; RISK, Perceived risk related to the selected sustainable farming practice.

(SN > INT, β = -0.07, p = 0.27), indicating that perceived social pressure from peers or the community did not have a substantial influence on farmers' decision-making in this context.

H4 to H6: Effects of perceived risk

Supporting hypotheses H4, H5, H6, the results indicate that perceived risk had a negative and significant effect on all three TPB components (RISK > AT, β = -0.30, p < 0.01; RISK > PBC, β = -0.24, p < 0.01; RISK > SN, β = -0.17, p < 0.01). Given that the coefficients are standardized, these effects can be directly compared. The influence of perceived risk was strongest in relation to the attitudes, suggesting that higher perceived risks significantly reduce farmers' predisposition toward adoption. The effect of RISK on PBC was also negative, but of moderate magnitude, indicating that higher perceived risk reduces farmers' confidence in their ability to successfully apply AFP. Lastly, the effect on SN was negative and significant, but lower in magnitude compared to the other two TPB constructs. These findings emphasize the critical role that risk perceptions play in influencing farmers' decision-making.

H7 to H10: Effects of information sources

The results only partially confirm the hypothesis regarding the effects of information sources. The analysis shows that formal information sources were positively and significantly associated with perceived risk (IF > RISK, β = 0.20, p < 0.01), rejecting H7, indicating that formal information is important for farmers for their risk judgement. Importantly, as formal information sources were modelled as a formative construct, potential multicollinearity was assessed and found to be negligible (VIF < 1.10). On the other hand, the community or social information sources had a low positive but not significant effect on perceived risk (IC > RISK, β = 0.06, p = 0.36), partially rejecting H9. Informal sources appear to be less influential in shaping farmers' perceptions of risk.

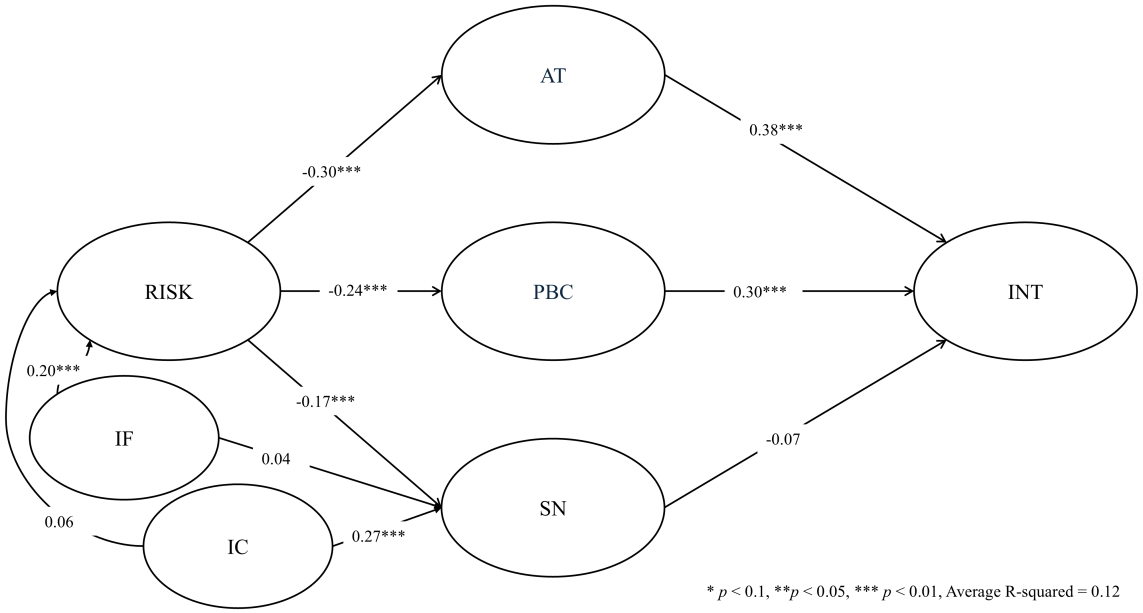

FIGURE 2
Structural model path with coefficients estimates. Arrows indicate the hypothesised relation among constructs, numbers are the estimated coefficients, and stars indicate coefficients' significance. AT, Attitudes toward adoption of AFP; IC, Influence of Community-based or Media-based Sources of Information; IF, Influence of Formal and Organized Information Sources; INT, Intention to adopt AFP; PBC, Perceived Behavioural Control over adoption of AFP; RISK, Perceived risk related to AFP. Asterisks indicate coefficient significance at 0.1 (*), 0.05 (**), and 0.01 (***).

TABLE 8 Summary of hypothesis testing results.

	Hypothesis	Outcome
H1	Attitudes have a positive and significant effect on farmers' intention to adopt agroecological farming practices.	Confirmed
H2	Perceived behavioural control has a positive and significant effect on farmers' intention to adopt agroecological farming practices.	Confirmed
H3	Social norms have a positive and significant effect on farmers' intention to adopt agroecological farming practices.	Rejected
H4	Perceived risk has a negative and significant effect on Attitudes.	Confirmed
H5	Perceived risk has a negative and significant effect on Perceived Behavioral Control.	Confirmed
H6	Perceived risk has a negative and significant effect on Social Norms.	Confirmed
H7	Formal information has a negative and significant effect on Perceived risk.	Rejected
H8	Formal information has a positive and significant effect on Social Norms.	Rejected
H9	Community information has a negative and significant effect on Perceived risk.	Rejected
H10	Community information has a positive and significant effect on Social Norms.	Confirmed

The results indicate that the Formal and Organized Sources of Information have a low positive, but not significant, effect on social norms (IF > SN, $\beta = 0.04$, $p = 0.49$), not fully supporting H8. In contrast, the Community-driven or Media-based Sources of Information had a stronger positive and significant effect on social norms (IC > SN, $\beta = 0.27$, $p < 0.01$), confirming H10. This finding implies that information sources play a more influential role in shaping farmers' perceptions of what is socially expected by their communities.

To explore the results further, we examined the potential differences in the latent variable scores between the groups defined by participants' country of origin and the specific AFP identified as most relevant to their farm. This step, limited by the sample unbalanced distribution across countries and AFP selected, is intended as exploratory and not aimed at fully analysing or explaining the underlying causes of these differences. These scores represent an estimated value for each unobserved construct (e.g., attitudes, perceived risk) based on the participants' responses and the PLS-SEM measurement model's loadings and weights. Essentially, a higher score for a latent variable in a particular group indicates a stronger presence of that construct within that group. The results are shown in Table 9. Differences among variables based on the farmers' country of origin were found to be significant for INT, PBC, and SN. However, the magnitude of these differences is limited. Farmers from Bulgaria scored -1.34 on the intention latent variable, indicating that they are significantly less likely to adopt the practice compared to farmers from Finland, who scored 0.26–the highest score for intention. Similar results were found for PBC, where Bulgaria had a significantly lower score (-1.58) than all other countries. Regarding the social norms latent variable, Italy is the only country with a score that is statistically higher than that of Finland, which recorded the lowest score, although the highest scores were observed in England and Germany. Averaging the latent variables based on the AFP selected by the farmers, statistical differences were found only in attitudes. Adoption intention perceived behavioural control, social norms, and perceived risk did not differ statistically based on the practice selected. No-tillage was the practice most frequently chosen by farmers as the most compatible with their farms (25% of the total sample), and it had the highest attitude score among farmers (AT = 0.4). In contrast, farmers' attitudes toward the adoption of flowering strips (AT = -0.51) and grass field margins (AT = -0.55) exhibited notably lower values, suggesting scepticism or concerns regarding these practices.

4 Discussion

4.1 Attitude and perceived risk favouring or constraining adoption of agroecological farming practices by farmers

In our analysis, a positive attitude towards adopting AFP had the most significant positive impact on farmers' intention to adopt such practices. In line with previous studies (Giovanopoulou et al., 2011; Mzoughi, 2011), a strong motivation to implement innovative agricultural practices and a positive attitude towards innovations, be they social, economic, or technical, increases the probability of adopting more environmentally sustainable practices. Farmers who are concerned about environmental threats and are aware of how environmental problems may affect their farming activities are generally more willing to adopt more agroecological practices (Baumgart-Getz et al., 2012; Liu et al., 2018; Mozzato et al., 2018). For example, some farmers are motivated to switch to organic farming when they believe that conventional practices are causing harm (Han and Grudens-Schuck, 2022).

Likewise, higher perceived risk significantly reduced farmers' willingness to adopt. Farmers perceived risk of yield loss and, consequently, loss of income as an important barrier to adoption of agroecological practices. From other experiences with farmers, a gradual process of scaling up and extension could mitigate these risks (Shaffer and Thompson, 2013). However, if the cost of implementing or maintaining a practice is too high, farmers are more likely to reject the practice due to financial risk, especially if no

TABLE 9 PLS-SEM latent variable scores and group differences by participant country of origin and by agroecological farming practice.

	INT	AT	PBC	SN	RISK
Country of origin					
Austria	**0.52 AB**	0.91	**0.8 AB**	**0.9 AB**	0.32
Bulgaria	**-1.34 A**	-0.99	**-1.58 A**	**-0.51 AB**	0.3
England	**0.26 AB**	0.67	**0.42 B**	**0.67 AB**	0
Finland	**0.26 B**	0.02	**0.09 B**	**-0.19 A**	-0.09
France	**-0.13 AB**	-0.12	**0.08 B**	**0.22 AB**	0.1
Germany	**-0.09 AB**	-0.17	**-0.05 B**	**-0.17 AB**	0.19
Italy	**-0.2 AB**	0.34	**-0.09 B**	**0.4 B**	-0.39
Sweden	**-0.25 AB**	-0.24	**-0.18 AB**	**0.32 AB**	0.58
AFP					
No-tillage	0.35	**0.4 B**	0.03	0.05	0.31
Organic mulching	-0.15	**0.28 AB**	-0.2	-0.34	0.16
Variety mixture	-0.09	**0.09 AB**	-0.15	-0.00	-0.01
Biopesticides	0.13	**0.08 AB**	0.15	-0.02	-0.54
Microorganisms	0.04	**0.03 AB**	0.13	0.33	-0.08
Maintenance of hedges	0.13	**0.0 AB**	0.26	-0.08	0.54
Intercropping	0.13	**-0.03 AB**	0.07	0.07	0.18
Under-sowing	0.1	**-0.18 AB**	0.02	0.45	-0.06
Trap cropping	-1.13	**-0.28 AB**	-1.14	-0.34	0.07
Flowering Strips	0.12	**-0.51 A**	0.17	-0.34	-0.1
Grass field margins	-0.19	**-0.55 A**	0.00	0.19	-0.32

AT, Attitudes toward adoption of AFP; IC, Influence of Community-based or Media-based Sources of Information; IF, Influence of Formal and Organized Information Sources; INT, Intention to adopt AFP; PBC, Perceived Behavioural Control over adoption of AFP; RISK, Perceived risk related to AFP. Statistically significant differences are shown in bold. ANOVA $p < 0.05$. Means sharing a letter in the group label are not significantly different at the 5% level. Bonferroni correction was applied to identify significant group differences in the latent variable means.

other incentives are available (Tosakana et al., 2010). It has been observed that farmers who are comfortable making risky decisions regarding their production are more likely to implement agroecological practices. One example of this is the conversion to organic farming among winegrowers in Catalonia, Spain (Kallas et al., 2010).

4.2 Perceived behavioural control and perceived risk

As with attitudes, the same is true for perceived behavioural control and perceived risk towards the AFP. The perception of being in control is significantly positively correlated for the implementation of agroecological practices, but in the case of perceived risk, the willingness to implement is significantly lower. This result could indicate that if farmers have confidence in their ability to introduce and maintain agroecological practices, they are more likely to adopt them. This sense of control can encompass both technical knowledge and access to necessary resources, which together create a foundation for successful implementation. The negative relationship between perceived risk and behavioural control suggests that farmers who perceive higher risks associated with agroecological practices may feel less capable of managing these practices effectively. Perceived risk like delayed spring planting were also seen as disincentives by US farmers to use cover crops (Arbuckle and Roesch-McNally, 2015). Practices such as trap cropping and no-tillage require a lot of prior knowledge and a variety of factors must be taken into account when implementing them (Derpsch, 2008; Holden et al., 2012). Our findings align with previous research showing that farmers' perceived behavioural control plays a crucial role in their decision-making process regarding sustainable practices (Menozzi et al., 2015).

4.3 Social norms' influence

Compared to attitudes and perceived behavioural control, the influence of social expectations was rated as relatively low in our study. This could indicate that farmers are prioritizing their personal beliefs and perceived abilities over external social expectations when adopting more sustainable practices. However,

it should also be considered that social norms may only gain significance once a practice is widely recognized as effective or becomes more visible within the agricultural sector. Since some of the AFPs investigated in this study are not yet widely adopted, the influence of social expectations may still be emerging. Different studies have shown that social pressure can affect the behaviour of individual farmers in adopting environmentally friendly practices. This can be through the farmers' perception of themselves in the society, peer influence, or support of neighbours (Mozzato et al., 2018), community (Prokopy et al., 2008), or other adopters (Pannell et al., 2006). Some studies also suggest that social pressure is an important adoption driver for late adopters rather than early adopters (Welch and Marc-Aurele, 2001). More generally, increase in social pressure among farmers was found to positively influence both adoption rate and long-term commitment (DeFrancesco et al., 2018; Mzoughi, 2011).

4.4 Sources of information positively influence perceived risk and social norms

Formal information sources had a significantly positive effect on the perceived risk of adopting agroecological practices in our study. This may suggest that these sources of information, e.g. the greater level of technical detail provided by consultants and institutions, may contribute to a more explicit recognition of challenges, uncertainties, and complexities associated with adopting AFPs. However, our study can of course only give indications of correlations, it cannot establish causal associations. A further element of explanation might be that more concerned farmers make greater use of formal sources. In contrast, informal sources appear to be less influential in shaping farmers' perceptions of risk. Reasonably, this could indicate that farmers rely more on formal, expert-driven sources when evaluating the potential risks involved in adopting sustainable agricultural practices. However, the informal information had a stronger effect than formal information on social norms, suggesting that it was more important in shaping farmers' perceptions of what is socially expected by their communities and that institutional sources did not significantly shape the social pressure perceived by farmers regarding the adoption of agroecological practices. Networking proved to be a key element for adoption of techniques, and the source of information is especially crucial when it comes from other farming stakeholders (Caffaro and Cavallo, 2019). Furthermore, adoption may be favoured by having access to knowledge and training programmes (Boncinelli et al., 2016). Expanding access to extension services and promoting digital platforms, such as mobile apps and websites can play a key role. These channels should focus on communicating the benefits and applicability of sustainable practices through localized and science-based advice, helping farmers to feel capable of adopting new practices, by providing step-by-step guides and decision-support tools, offering hands-on training and follow-up support. A notable digital example is the EU FarmBook (https://eufarmbook.eu/en), which consolidates practical knowledge for farmers and advisors. In parallel, leveraging informal social networks, such as peer farmers, community leaders, and cooperatives, can help shape positive social norms. This can be achieved through initiatives like farmer-led demonstration projects, where early adopters showcase sustainable practices, peer-to-peer learning via farmer field schools, cooperatives, and local workshops and recognition of community champions, who serve as role models for sustainable farming. Encouragingly, the EU has already taken steps in this direction through the establishment of Living Labs (collaborative, co-creative research and innovation ecosystems) and Lighthouses (individual sites that demonstrate best practices). These initiatives are central to the EU Mission "A Soil Deal for Europe" and appear also in the EU agroecology partnership (Agroecology Partnership, 2026) with the establishment of a European network of agroecological living labs, aligning with broader strategies such as the European Green Deal, Farm to Fork Strategy, and the EU Biodiversity Strategy.

4.5 Farmers preferences toward AFP

Although not part of this study's scope, farmers' preferences toward certain practices are worth mentioning. Such preferences depend heavily on agronomic feasibility and economic viability; they do not necessarily reflect different psychological orientations in the first instance. Minimum tillage was the most frequently selected agroecological farming practice, while trap crops were the least. These preferences were partly reflected in farmers' attitudes toward the practices: minimum tillage received the highest scores, whereas trap crops ranked among the lowest along with flowering strips and grass field margins. This may be because minimum tillage has proven cost-saving benefits, and farmers - particularly those applying synthetic chemical herbicides for weeds - may view it as both an economically and agronomically advantageous strategy, in addition to its environmental co-benefits. By contrast, the risks and benefits of habitat diversification measures, including flower strips and trap crops, are less well known, hindering their uptake.

4.6 Limits of the theory of planned behaviour approach

A few authors assert that there is no consensus on the factors that influence the adoption of different practices, as they usually "converge to an insignificant influence and are highly context and case specific" (Knowler and Bradshaw, 2007; Prokopy et al., 2008; Wauters and Mathijs, 2014). As demonstrated in the preceding discussion, a large variety of impact factors have been identified. However, from the analysis of these factors, we have been able to determine the relative importance of each. Nevertheless, the TPB has been criticized for its ability to predict only in the short term. Moreover, some authors have shown that this theory is unable to explain certain behaviours (French et al., 2005) due to a confusion between moral norms and social norms (Armitage and Conner, 2001). Some works have also put forward the idea of adding new variables such as self-identity (Rise et al., 2010; Sparks and Shepherd, 1992), which refers to self-

image, but also of including emotions as important factors responsible for behaviour (Armitage and Conner, 2001).

Several limitations should be considered when interpreting the findings of this study. First, the use of a non-representative sample across the eight European countries, coupled with a relatively small sample size within some national groups, restricts the generalizability of our results to the broader farming populations. The findings should therefore be interpreted as indicative of behavioural patterns rather than as population estimates.

Second, the study encompasses a heterogeneous set of farming practices, which differ in terms of complexity, costs, and compatibility with farming systems. Although respondents were asked to evaluate a practice that they considered suitable for their farm, the heterogeneity across practices may influence adoption intentions and perceived barriers. As a result, comparisons across practices should be regarded as exploratory.

Similarly, cross-country comparisons were conducted in an exploratory manner and were not the primary objective of the study. Differences observed between countries may reflect not only behavioural factors but also country-specific policy frameworks, market conditions, and institutions. A more rigorous assessment of country-specific effects would require larger and more balanced samples and the application of *ad-hoc* methodologies, such as multi-group PLS-SEM, which includes a measurement invariance control of the scales. Potentially, some constructs may be interpreted differently across country sub-samples. Formal tests of measurement invariance across countries were beyond the scope of this study, and future research could address this issue explicitly.

Third, the cross-sectional nature of the data prevents causal inference. Longitudinal or experimental designs would be required to assess causal mechanisms and dynamic adoption processes.

Finally, we acknowledge the presence of other factors influencing farmers' adoption intention beyond those captured in our model. There is a need for further research on other drivers and factors responsible for long-term commitment to new sustainable agricultural practices: for example, it would be beneficial to investigate the potential differences of drivers between crop types and degrees of complexity of proposed innovation related to the combined adoption of different practices at the same time. Other potential drivers must be explored as well, such as the role of farmers' identities, and more generally, all types of subjective norms that are currently understudied because of a lack of appropriate methodologies and qualitative tools (Burton, 2004).

5 Conclusions

A study based on an adapted Theory of Planned Behaviour was performed using an online questionnaire among farmers from eight European countries. The aim was to explore the influence of formal and social information sources on risk perception and social norms related to the intention to adopt different agroecological farming practices. A total of 268 responses were analysed revealing that formal information sources were more important than social sources on influencing risk perception. Conversely, social information sources had a stronger association on perception of social norms. Our findings suggest that strengthening formal information channels —such as agricultural extension services, government advisories, and scientific institutions—could potentially enhance the adoption of agroecological farming practices by supporting farmers' attitudes and reducing perceived risks, which emerged as a critical leverage point. This study gives raise to several directions for future research. First, the explorative nature of the findings, driven by limitations in the sample structure, calls for the confirmatory analyses based on the study hypothesis and results. Finally, further research should investigate the practice-specific drivers and barriers to adoption, as well as the country-level differences in farmers' behaviour toward agroecological practices.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Aarhus University Research Ethics Committee (approval number: 2020-104). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AP: Formal analysis, Methodology, Writing – original draft, Data curation, Writing – review & editing. J-AP: Writing – original draft, Writing – review & editing. JHW: Conceptualization, Writing – original draft, Writing – review & editing. BW: Writing – original draft, Conceptualization, Writing – review & editing. MB: Writing – review & editing, Writing – original draft. HK: Writing – review & editing, Writing – original draft. JW: Writing – original draft, Writing – review & editing. LC: Writing – review & editing, Methodology, Writing – original draft, Conceptualization. SC: Writing – review & editing, Writing – original draft. VN: Writing – review & editing, Writing – original draft. AF: Writing – review & editing. TD: Writing – review & editing, Conceptualization. AW: Writing – review & editing, Writing – original draft.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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