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Farmers' adoption of environmental soil management practices across four European regions: willingness to accept analysis

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Abstract

This study investigates farmers' willingness to accept (WTA) compensation for adopting soil-friendly management practices across four European countries (Finland, Estonia, Belgium, and Germany). The objective is to understand how socio-demographic factors shape compensation expectations and to provide guidance for designing effective incentive schemes. Using a triple-hurdle model, we estimate farmers' decisions in three stages: intention to adopt, willingness to adopt if compensated, and the compensation amount required. Results show that compensation schemes should account for heterogeneity in farmers' expectations. Gender, age, and educational level influence WTA differently across countries: For example, younger farmers in Finland demand higher compensation, whereas in Estonia, Belgium, and Germany, they expect lower compensation. Higher education is generally associated with lower WTA in Estonia, Belgium, and Germany, suggesting that more educated farmers may require smaller financial incentives. Overall, approximately half of the farmers who would not adopt soil management practices without support would do so if adequately compensated, highlighting the importance of well-designed financial incentives to promote sustainable farming.

Keywords: Soil management, Sustainable farming practices, Willingness to accept (WTA), Triple-hurdle model

Introduction

Soil is a fundamental natural resource that sustains life on Earth through its role in ecosystems, agriculture, and water regulation. It forms the basis for food production, supports biodiversity, and plays a key role in nutrient cycling and carbon sequestration. Healthy soil is essential for profitable, productive, and environmentally sustainable agricultural systems (Pretty and Bharucha 2014). Healthy soils are also essential for water management as they improve water infiltration, reduce runoff, and decrease the need for irrigation (Lal et al., 2020). Key practices such as crop rotation, cover cropping, and reduced tillage improve soil structure, nutrient retention, and microbial diversity, which in turn support ecosystem resilience and agricultural yield (FAO 2023). Conservation agriculture practices such as reduced tillage practices and organic amendments not only help retain soil moisture but also foster better microbial health, aiding carbon storage (Lal, 2018; Amundson et al., 2022). However, implementation of these practices for soil health is heavily reliant on farmers' interest and willingness to adopt them.

Previous literature exploring farmers' willingness to improve soil quality highlights a multifaceted interplay of economic, social, and environmental factors. Studies indicate that farmers' willingness often depends on their awareness of the long-term benefits of soil health, including increased crop yields, reduced input costs, and enhanced sustainability (Dessart et al. 2019). Socioeconomic factors, such as education levels, farm size, and access to subsidies or incentives, also significantly influence decisions (D'souza et al. 1993). Additionally, external pressures including regulatory policies and market demands for sustainably produced goods play critical roles (Schröder et al. 2018). However, the existing policies have not effectively addressed the issue; therefore, a more coordinated effort across policy sectors is needed to make soil health a priority (Winkler et al. 2025). Behavioral theories suggest that farmers' attitudes, subjective norms, and perceived behavioral control are pivotal in shaping their adoption of soil-improving practices (Prokopy et al. 2008).

Sustainable soil management, like other agricultural measures, can be enhanced though policies that provide economic support to cover the costs of these practices. The knowledge gaps addressed in this article stem from the need to better understand the regional and demographic variability in farmers' willingness to adopt soil-friendly practices, particularly regarding compensation expectations. While previous research has explored general trends in the adoption of sustainable practices, limited attention has been given to how socioeconomic factors—such as age, gender, education, landholdings, and full-time farming status—interact with farmers' compensation demands in a comparative, cross-national context. Additionally, the nuanced roles of trust in government subsidies and attitudinal factors, such as perceptions of soil quality and the benefits of sustainable practices, remain underexplored.

This study aims to analyze the impact of various factors on farmers' willingness to adopt soil-friendly practices in Europe. Our contribution is threefold. First, we examine differences in farmers' willingness to accept compensation for adopting soil-friendly practices across four European countries. Second, we categorize farmers' willingness to accept compensation for adopting new soil practices—based on their stated intentions for the next season or the next five years—into adoption status, distinguishing those who would adopt with or without compensation from those who would not adopt. Third, we incorporate attitudinal factors that shape decision-making, such as perceived community influence, perceived benefits from implementation of soil practice, perceived importance of government policies and subsidies, and farmers' knowledge requirements. By combining a triple-hurdle modeling framework with cross-country analysis and detailed attitudinal variables, this study provides novel insights into how compensation schemes can be tailored to heterogeneous farmer preferences, bridging the gap between general adoption studies and actionable, policy-relevant recommendations.

Literature review

Farmers' intention to apply soil-friendly practices can be viewed as a decision-making process involving both economic rationality and behavioral considerations. Adoption of such practices represents a choice between traditional and new technologies, shaped by farmers' expectations of profitability and recognition of environmental externalities. As rational economic agents, farmers' choice of new technology is a decision made by comparing the costs and benefits of the old and new technology to maximize profit (Yu et al. 2017; Konstantinos et al. 2025). When famers can perceive the harm that traditional farming models may cause to harvest quality, they are inclined to adopt soil-friendly practices driven by economic rationality (Menozzi et al. 2015). Economic motivation remains a key determinant, and practices such as no-till farming are often perceived as beneficial for reducing operational costs (e.g., labor and fuel) while enhancing long-term soil productivity (Kawa 2021). Empirical evidence shows that financial incentives, such as subsidies or compensation schemes, significantly increase farmers' adoption of sustainable practices, especially when new technologies involve high risks or costs (Liu et al., 2021).

Beyond profitability, a growing body of research emphasizes that farmers' willingness to adopt or their willingness to accept (WTA) compensation for environmentally friendly practices depends on a complex interplay of socio-demographic, farm, environmental, and institutional factors (Ahiale et al. 2019; Liu et al. 2023). These factors shape not only adoption behavior but also preferences for policy design and compensation levels. Methodologically, prior studies have applied diverse analytical approaches such as discrete choice experiments (DCEs) (Wang et al. 2019a; Liu et al. 2023), contingent valuation methods (CVMs) (e.g., Ahiale et al. 2019), and survey-based behavioral models (e.g., Wang et al. 2019b) each with distinct assumptions about decision-making and information framing. For instance, DCEs capture trade-offs between policy attributes under hypothetical scenarios (Mariel and Arata, 2022; Liu et al. 2023), while CVMs directly elicit monetary values for environmental changes (Kaleji et al. 2025). Behavioral models, on the other hand, often integrate psychological and social variables to explain adoption heterogeneity (Bagheri and Teymouri 2022). Such methodological variations partly explain discrepancies in estimated adoption probabilities, WTA values, and policy implications across studies. Highlighting these differences is crucial for situating new findings within the broader empirical context.

Block et al. (2024) used a discrete choice experiment with 150 German farmers to assess participation in humus (soil carbon) programs. Results from a mixed logit model show that both payment size and program design strongly affect participation. The estimated WTA indicates that introducing a minimum increase in humus threshold would require raising the premium by roughly €320–€440/ha per 0.1% humus gain, effectively more than doubling the baseline premium of €240/ha per 0.1%, to maintain participation. Thiermann et al. (2025) explore how Dutch farmers perceive different financial and non-financial incentives to adopt soil health practices and carbon farming measures. Using a Q methodology experiment, the study shows that no single incentive mechanism fits all farmers. A diverse mix of incentives, including value chain payments, improved public schemes, and well-designed carbon markets, is needed to motivate broader adoption of soil health practices.

Environmental awareness and recognition of ecosystem services further shape adoption behavior. For example, farmers who understand the benefits of improved soil health, such as increased productivity and resilience to climate change, are more likely to adopt conservation practices (Dessart et al. 2019). In contrast, those lacking such awareness may remain hesitant, emphasizing the need for targeted outreach and education efforts. Furthermore, the adoption of soil-friendly practices is often region-specific, shaped by local environmental challenges, regulatory pressures, and market demands for sustainably produced goods (Prokopy et al. 2008).

Existing agri-environmental programs, such as Natura 2000 (Kokkoris et al. 2023) and national agri-environmental schemes (AES) (European Commission, Agriculture and rural development, 2025), provide financial incentives and regulatory frameworks that promote the adoption of sustainable practices. Studies suggest that participation in these programs increases adoption rates by offsetting economic costs and signaling social recognition for environmentally friendly practices. But cross-country comparisons are limited, and region-specific programs like Natura 2000 and AES are often underrepresented. Methodological differences such as choice of discrete choice experiments (e.g., Ribeiro et al. 2017), contingent valuation (e.g., Ahiale et al. 2019), or survey-based models can lead to inconsistencies in estimated effects. The method of compensating participants in surveys can influence their responses. For example, session-based payments can lead to greater risk-taking behavior compared to decision-based payments, which can affect the estimated outcomes (Ferrey and Mishra 2014).

Additionally, social norms and peer influence play a pivotal role. Farmers who observe neighbors or community members successfully implementing soil-friendly practices are more likely to adopt similar measures, a phenomenon well documented in agricultural innovation diffusion research (Rogers 2003). This highlights the importance of fostering collaborative learning and creating demonstration projects to encourage broader adoption.

Existing research largely focuses on external incentives rather than farmers' intrinsic valuation of soil biodiversity and its long-term benefits for productivity and resilience. The links between socioeconomic characteristics, behavioral attitudes, and knowledge in shaping WTA remain underexplored. Addressing this gap is crucial for designing policies that promote active farmer investment in soil biodiversity rather than reliance on compensation alone.

Materials and methods

The paper examines the data collected with an Internet survey from farmers in four different European countries: Finland, Estonia, Germany, Belgium, in the EU Horizon2020-funded project SoildiverAgro. The overall aim of the survey was to collect information on farmers' perceptions of soil conditions, their interest in investing in soil management, their opinions on new soil management practices, and the factors that impact their choices. In this study, we use the abbreviation ESMP (environmental soil management practice) to indicate these regional soil management practices.

Survey design

To understand the drivers of adoption of environmental soil management practices (ESMP), the survey included both common practices across regions and context-specific practices tailored to each country. Region-specific practices were chosen for their clarity and relevance to farmers' local conditions. These practices had to be suitable for large-scale implementation and not too novel, ensuring that they were already familiar to some adopters. The selected region-specific management practices and their descriptions are given in Table 11 (Appendix). The analysis applied the theory of planned behavior (TPB)[1] to assess how farmers' attitudes, perceived norms, and control beliefs influenced their behavioral intentions regarding these practices.

Semi-structured interviews[2] were used to help identify commonly held beliefs, key outcomes, referents, and control factors for each practice among farmers. Based on these insights, a survey questionnaire was designed to capture farmers' beliefs on the likelihood of outcome to take place and the perceived importance of outcomes, the influence of social referents, and control factors affecting adoption of the ESMP.

The survey questionnaire began by collecting background information on the farmer and farm characteristics. It then moved on to questions related to soil management, including how farmers assess soil quality on their farms, the indicators they use, and their perceptions and experiences with different soil management practices. The second part of the survey, providing the dependent variable for this analysis, focused on region-specific management practices, asking whether farmers currently apply these practices and their intentions to adopt them in the future. For those not interested in adopting a specific practice, additional questions explored whether they might reconsider whether compensation was provided, along with their compensation requests. In this section, the components of TPB were measured for region-specific management practices. In addition, behavioral, normative, and control beliefs as well as their importance were measured (Table 12, Appendix).

Data collection

The survey was conducted online (using Webropol online survey platform) across the selected regions, targeting a sample size large enough for statistical modeling ($N > 300$ per region) and focusing on areas where the selected practices were viable. The survey was translated into the local language of each target region.

The aim was to have enough data for statistical modeling from each of the four regions. The approaches were different because the opportunities to reach the farmers varied between regions. E-mail invitations were preferred for inviting farmers to respond to the survey, but also other methods for contacting respondents had to be used in some of the regions as contact information for farmers was not available. In these cases, survey links were distributed through farmers' organizations, newsletters, and agricultural press.

In Belgium, the Agency for Agriculture and Fisheries, part of the Government of Flanders, has extensive identification data on all Flemish farmers. Contact details were requested from the Agency for Agriculture and Fisheries in Flanders, in accordance with the protocol for providing personal data to Flanders Research Institute for Agriculture by the agency. In Germany, panel data company Product + Markt was used for data collection. The sample for the Estonian survey was formed on the basis of the list of agricultural producers, who applied for CAP single area payment in 2022. In Finland, e-mail

[1] The theory of planned behavior is used in this study as a guiding framework to structure the inclusion of key attitudinal variables influencing farmers' adoption decisions, rather than as a formal latent variable model.

[2] Focus group interviews were conducted with 11 farmers in Belgium and with 7 farmers in each of Estonia, Finland, and Germany between February and May 2022. For more detail, see Appendix.

addresses were drawn from the register of the Finnish Food Authority. The survey questionnaire was pilot tested with a small group of farmers from Belgium, Estonia, and Finland. Based on the feedback received during this testing phase, minor adjustments were made to the questionnaire, resulting in a slight reduction in the length of the survey. The response rate was 6.7% in Belgium, 4.23% in Estonia, and 18.5% in Finland. The final data were collected from March to October 2023. The timing of data collection varied by region to avoid the busiest farming seasons, aiming for minimal disruption to the farmers' schedules.

Because recruitment relied on voluntary participation, we acknowledge the possibility of self-selection bias, for instance if farmers with stronger interest in environmental sustainability were more likely to respond. To mitigate this, we accounted for selection bias directly in our modeling strategy: The triple-hurdle framework incorporates the inverse Mills ratio (IMR) correction at each relevant stage (see Section Triple-hurdle model for details).

Intention measure

Survey measures providing dependent variables for this study include intention-based questions, contingent behavior, which assesses responses to hypothetical scenarios, and contingent valuation, which estimates WTA compensation for intention to apply ESMP. To study WTA there are several methods to measure farmers' interest to implement ESMP with different compensation schemes including contingent valuation (CV) method (e.g., Ahiale et al. 2019) and choice experiment method (e. g., Lee and Youn, 2023; Maas et al. 2023). Here we applied contingent valuation in payment card form. While CV is subject to hypothetical bias, our modeling framework (triple-hurdle model with inverse Mills ratio correction) helps mitigate potential bias by separating the adoption decision from the compensation amount, allowing more robust estimation of WTA for policy-relevant ESMP adoption.

To measure intention in the survey, we used the two statements with three-point scale ("No," "Maybe," or "Yes"):

> *I intent to apply ESMP on at least one parcel next season and I have the intention to apply ESMP on at least one parcel in the next five years.*

After the intention question, we focused on farmers' compensation request i. e. willingness to implement ESMP with certain amount of compensation. For those not interested ("No" responses in the question of intention) in adopting a specific practice, additional questions were posed. They explored whether they might reconsider ESMP whether compensation was provided, along with their compensation requests. The questions were:

You were not that interested to apply the ESMP either next season or within the next five years. Would you be interested to apply them, if your farm would get compensation that aims to cover the possible economic cost caused by their use?

- Yes
- No

If yes.

What would be the lowest possie compensation per year per hectare that you would be willing to apply ESMP? Note that if claims are too high, they are unrealistic[3] *for policy development.*

We constructed variable Y (adoption status) as defined in formula (1):

$$Y = \begin{cases} 1, & \textit{unwilling to adopt, even if compensated} \\ 2, & \textit{willing to adopt ESMP with compensation} \\ 3, & \textit{willing to adopt ESMP without compensation} \end{cases} \tag{1}$$

Triple-hurdle model

To model farmers' decision-making from economic point of view the hurdle models are used. The most common is the double hurdle model as proposed by Cragg (1971) and Heckman (1979). The triple-hurdle model, applied here, expands on the double hurdle model by including a third decision-making stage (Burke et al. 2015; Familusi et al. 2023). The triple-hurdle model was selected to capture the sequential decision-making process of farmers regarding adoption of environmentally sustainable management practices (ESMP). Specifically, it separates the decision to consider adoption, the decision to adopt conditional on compensation, and the amount of compensation required. Compared to contingent valuation (CV) or discrete choice experiments, which typically measure WTA or preferences in a single stage, the triple-hurdle approach allows for modeling heterogeneity in both adoption probabilities and compensation expectations while correcting for potential selection bias (Burke et al. 2015).

Since the respondents rank their intention to adopt the ESMP on an ordered scale, the outcome is categorical but ordered that makes the ordered logit regression appropriate. Therefore, starting with all sample observation, the first stage uses ordered logistic regression to define whether an individual intended to apply ESMP.

We considered proportional odds model, also called the constrained cumulative logit model that compares the probability of an equal or smaller response with the probability of large response:

$$g_j(X) = \log\left[\frac{\Pr\left(Y \le j|X\right)}{\Pr\left(Y > j|X\right)}\right] = \alpha_j - \beta' X, \tag{2}$$

where $\beta = \left(\beta_1, \ldots \beta_p\right)'$ is a vector of p regression coefficients; $j = 1, ..c - 1$.

The log odds do not depend on the response level, and the regression coefficients $\beta_1, \ldots \beta_p$ are constant across the logits. The negative sign of $\beta' x$ is included to allow for the usual interpretation that a positive value of β_k means that as x_k increases, the probability of higher values of Y also increases.

The conditional probability of each response level given x is derived from Eq. (2) by using the equality $\Pr\left(Y > j|X\right) = 1 - \Pr\left(Y \le j|X\right)$ to obtain

[3] By "realistic," we mean size of compensation that lies within the observed ranges of existing national and regional compensation schemes.

$$\Pr\left(Y \leq j|X\right) = \frac{e^{g_i(X)}}{1 + e^{g_i(X)}}$$

The second stage evaluates the intention to adopt ESMP under the condition that compensation is provided. Thus, the second-stage variable (would you applied if compensated) is only observed; then, Y from the first stage takes the value 1:

$$D = \begin{cases} 1, & \text{if } Y > 0 \text{ and } Y = 1 \\ 0, & \text{otherwise} \end{cases}$$

The binary decision is modeled by a probit model to analyze the factors influencing this adoption decision:

$$P(D = 1|X) = \Phi(\gamma X), \tag{3}$$

where Φ is the cumulative normal distribution.

The third stage involves the regression model to obtain farmers' WTA and its determinants. The dependent variable for WTA compensation model is the compensation amount that farmers would accept if compensated. The third-stage variable (desired minimum compensation per year per hectare) is only observed; then, D from the second stage takes the value 1:

$$WTA^* = \alpha X + \in, \ \in \sim N\left(0, \sigma^2\right), \tag{4}$$

where WTA^* is unobserved variable, but observed WTA is defined by formula (5):

$$WTA = \begin{cases} 40, & \text{if } WTA^* < 40, \\ WTA^*, & \text{if } 40 \leq WTA^* \leq 800, \\ 800, & \text{if } WTA^* > 800 \end{cases} \tag{5}$$

The third-stage regression was estimated as truncated Poisson regression. The truncated Poisson distribution is used when zero counts are not observed in the dataset. It adjusts the standard Poisson distribution to account for the absence of zero counts, which affects the mean and variance calculations (Ngamkham and Panta 2023).

The decisions made at each stage may be conditional on the outcomes of the previous stage, and there is a risk that unobserved factors affecting one stage could bias estimated in the next stage. We used the standard method to correct for selection bias by calculating and including the inverse Mills ratio (IMR). This accounts for the correlation between the errors in the selection process and those in the outcome equation. (Ma et al. 2012). In this context, the null hypothesis that the IMR is not statistically significantly different from zero is tested. The IMR is first predicted from the initial equation and subsequently included in the second equation. If the IMR is found to be statistically insignificant in the second-stage model, it is excluded, and the model is re-estimated without the IMR variable. This indicates that the error terms are uncorrelated, allowing us to fail to reject the null hypothesis, and confirming that the model coefficients remain unbiased and efficient. Conversely, if the IMR is statistically significant (i.e., the null hypothesis is rejected), it suggests a correlation between the error terms. In such cases, robust standard errors are employed to address the statistically significant IMR coefficients, and the IMR is retained in the model to ensure accurate estimation of the parameters (Familusi et al. 2023).

The expected value of WTA has been calculated by formula (6)

$$E(WTA) = \frac{\lambda}{1 - exp(-\lambda)}, \tag{6}$$

where λ is the Poisson mean estimated in Eq. (4). This adjustment accounts for the truncated nature of the distribution, ensuring that the expected compensation values accurately reflect the observed data while correcting for the absence of zero responses.

Robustness checks and sensitivity analysis

As a robustness check for average compensation levels by country, we estimated compensation amounts using a Bayesian approach implemented with the "brms" package in R, which facilitates the specification of a wide range of Bayesian single-level and multilevel models (Bürkner 2017, 2018). We specified the same triple-hurdle structure, consisting of three linked decision stages: (i) an ordered logit model for adoption intention, (ii) a binary logit model for the adoption decision, and (iii) a lognormal regression for the compensation amount, truncated at zero. All three equations include the same set of standardized covariates and share an individual-level random intercept, while residual correlations across equations are fixed to zero. The Bayesian framework combines these likelihood assumptions with weakly informative priors on regression coefficients ($\sim N(0, 1)$) and intercepts (*Student t* with 3 degrees of freedom, mean 0, scale 2.5) to regularize estimation in small samples (Gelman et al. 2008). Individual-level random intercepts account for unobserved heterogeneity, and residuals across stages are assumed conditionally independent.

Bayesian estimation was conducted using Hamiltonian Monte Carlo with four chains and 2,000 iterations per chain, implemented via the "rstan" backend, with an adaptive target acceptance rate of 0.95 (Chaudhuri et al. 2017). These priors provide regularization without being overly restrictive, thereby improving stability and convergence in small samples (McElreath 2020). Models were estimated separately by country using identical specifications.

Unlike the sequential estimation used in the triple-hurdle model, the Bayesian framework allows the three stages to be estimated jointly within a unified model, distributing uncertainty across decision stages while incorporating prior information to stabilize inference in the presence of small samples (Depaoli et al. 2016). Posterior distributions were summarized using medians and 95% credible intervals.

To assess the potential impact of missing data—specifically variables capturing the perceived importance of government policies and subsidies, and farmers' knowledge requirements—on model estimates for Belgium, we conducted a sensitivity analysis. These variables were not collected in Belgium because, based on preliminary interviews conducted prior to the survey, farmers in this country did not identify government policies and subsidies, or knowledge requirements as relevant barriers or drivers. Therefore, these questions were deemed unnecessary for further analysis in Belgium. Nevertheless, we simulated three hypothetical scenarios using quantiles of these variables from other countries: low (25th percentile), medium (50th percentile), and high (75th percentile).

Results

Differences in ESMP uptake across regions

To assess farmers' current and potential adoption of soil management practices, 13 practices were presented in the survey. Farmers were asked to indicate whether they currently use each practice or intend to use it in the future (Fig. 2, Appendix). Among the 13 practices assessed, the most popular were incorporating crop residue (79%) and implementing long rotation periods in cultivation (74%). Additionally, over 70% of farmers expressed interest in less frequent plowing and reducing tillage depth. Agroforestry was the least favored practice. Typically, 40% to 70% of farmers were currently applying the practice, while fewer than 10% of farmers were not currently applying it but intended to do so in the future.

Analyzing each region separately revealed distinct preferences. In Belgium, cover crops (that are mandatory) and incorporating crop residue were particularly applied by farmers. Belgian farmers also showed high interest in catch crops and long rotation periods. Estonian farmers prioritized the incorporation of crop residue, with additional interest in longer rotation periods. In Finland, reduced tillage depth and less frequent plowing were the top choices, alongside an interest in long rotation periods. German farmers showed significant interest in incorporating crop residue, with nearly all farmers either already applying or intending to adopt this practice. Additionally, they expressed interest in intercropping, catch crops, and several other practices, with over 50% of farmers indicating their intent to adopt nine practices in total. We also measured farmers' perceptions of the possible impacts of different practices (Fig. 3, Appendix). Especially covering field with organic matter, intercropping and cover crops were seen as practices that contribute to good soil quality. In Belgium, also long rotation periods in cultivation incorporation of crop residue in soil were seen useful. In Estonia, farmers had very positive perceptions of cover and catch crops and precision fertilization. Finland's evaluations were in line with the average of all countries but were somewhat less optimistic, similar to Germany.

Variables measures

Table 1 presents an explanation of variable Y constructed above:

Figure 1 displays variable Y results regarding various ESMP in different regions in the percentage of respondents. The regions with the highest interest in participating in the given agricultural practices were Finland and Belgium, indicating a strong inclination toward ESMP without compensation, whereas Estonia and Germany had a nearly equal distribution among respondents with more than half showing definite interest in ESMP (Fig. 1).

Table 2 presents the distribution of WTA compensation bids for the lowest possible compensation per year per hectare that farmers would be willing to apply ESMP. The compensation bids used in the payment card were chosen to span a policy-relevant range informed by (i) pilot feedback and (ii) observed compensation rates in existing agri-environmental and Natura 2000 schemes in the study countries. For example,

Table 1 Explanation of dependent variable constructed. *Source* Authors' elaboration

	I have the intention to apply ESMP on at least one parcel next season	*I have the intention to apply ESMP on at least one parcel next five years*	Would you apply ESMP, if compensated?	Adoption status (*Y*)	Interpretation
Responses	2 (maybe) or 3 (yes)	Any	NA	3	Would adopt without compensation
Responses	Any	2 (maybe) or 3 (yes)	NA	3	Would adopt without compensation
Responses	1 (no)	1 (no)	1 (yes)	2	Would adopt if compensated
Responses	1 (no)	1 (no)	2 (no)	1	Would not adopt even if compensated

NA—not asked

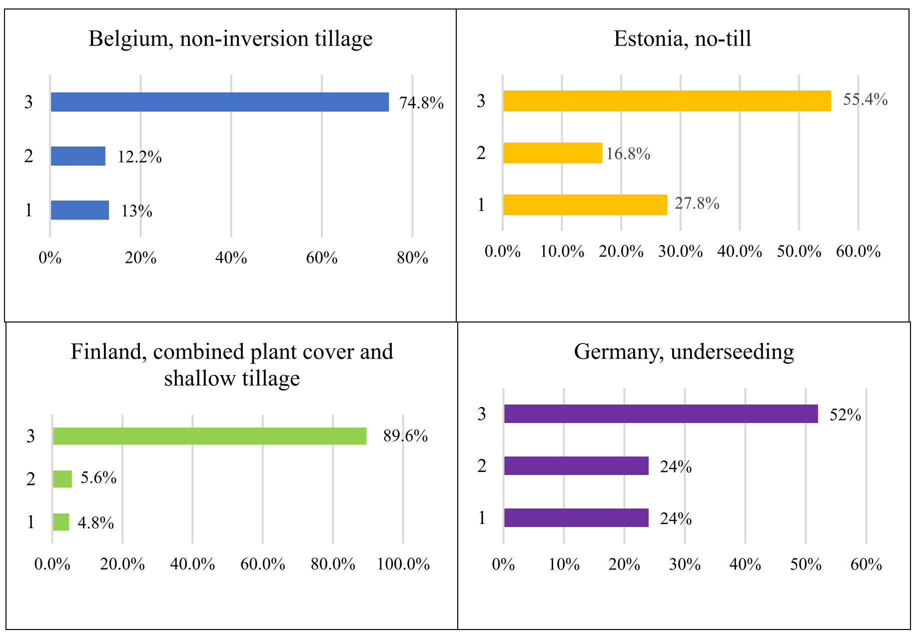

Fig. 1 Farmer's adoption decision to apply the ESMP (%) *Source* Authors' elaboration

Estonia's Natura 2000 subsidy for agricultural land is reported at approximately €27/ha/year, with higher rates for some forest conservation zones (up to €60—€134/ha/year depending on protection level) (Natura 2000 funding roadmap 2014–2020). Finland's CAP strategic documents and historic agri-environmental programs show typical support in ranges around €90–110/ha for common measures (European Commission, 2025). In Belgium, conversion and eco-scheme premiums around €150/ha (and higher rates for high-intensity conservation measures) have been documented (European Commission, 2025). National CAP and agri-environment guidance in Germany likewise indicate region- and measure-specific payments that typically fall within the tens to low hundreds of euros per hectare (EU Common Agricultural Policy 2014–2020). Very low bids (€1, €10, €20) were deliberately included in the payment card to avoid imposing an artificial lower bound on WTA.

Table 2 Willingness to Accept (WTA) Compensation Bids. *Source* Authors' elaboration

WTA €/ha/year	Finland		Estonia		Belgium		Germany	
	No. of responses	%	No. of responses	%	No. of responses	%	No. of responses	%
40	2	10%	2	4%	1	6%	2	4%
60	0	0%	1	2%	0	0%	1	2%
80	1	5%	2	4%	1	6%	4	8%
100	5	25%	12	26%	6	38%	19	40%
150	2	10%	5	11%	3	19%	7	15%
200	1	5%	8	17%	3	19%	8	17%
300	5	25%	7	15%	0	0%	4	8%
400	1	5%	1	2%	1	6%	2	4%
600	1	5%	2	4%	1	6%	1	2%
800	1	5%	1	2%	0	0%	0	0%
> 800	1	5%	5	11%	0	0%	0	0%

The compensation bids 1€, 10€ and 20€ also were offered to the respondents, but no one selected these bids

Table 3 Summary statistics of dependent variables in econometric model for intention to apply the ESMP. *Source* Authors' calculations

Dependent variable	Unit (description)	Country	Observations	Mean / frequency
Adoption status	1—Unwilling to adopt even if compensated 2—Willing to adopt if compensated 3—Willing to adopt without compensation	Finland	357	1-— 0.048 2—0.056 3—0.896
		Estonia	273	1-— 0.28 2—0.17 3—0.55
		Belgium	131	1-— 0.13 2—0.12 3—0.75
		Germany	200	1—0.24 2—0.24 3—0.52
Intention to apply if compensated	0—No, 1—Yes	Finland	37	No—0.46 Yes—0.54
		Estonia	122	No—0.62 Yes—0.38
		Belgium	33	No—0.52 Yes—0.48
		Germany	96	No—0.18 Yes—0.82
Compensation amount	Euro per hectare per year	Finland	20	263
		Estonia	46	290
		Belgium	16	173
		Germany	48	159

Observations for adoption status and intention correspond to farmers who answered the respective questions. Compensation amount refers to average WTA among those willing to adopt if compensated

The intentions to apply the ESMP were modeled with an econometric approach using a triple-hurdle model to focus on the intention to apply ESMP and the compensation demands of farmers. The results of farmers' decisions (Table 3): 1) whether the farmers

Table 4 Frequency distribution of the independent variables used. *Source* Authors' calculations

Variables	Categories	Finland	Estonia	Belgium	Germany
Gender	"1"—male	90%	82%	91%	92%
	"0" – other	10%	18%	9%	8%
Age	continuous mean	55.3	52.77	52.72	48.94
Education	"1" high education	35%	48%	47%	51%
	"0" other	65%	52%	53%	49%
Land	Continuous (ha) mean	77.67	351.13	45.36	290.13
Farmer ownership	"1" full-time farmer	75%	61%	73%	91%
	"0" other	25%	39%	27%	9%
N		357	273	131	200

intend to apply soil-friendly practices, 2) whether they intend to apply soil-friendly practices if compensation is provided, and 3) farmers' compensation demands to implement the practices (WTA).

We used different types of variables as explanatory variables: firstly, socio-demographic and farm characteristics (Table 4), and secondly, variables related to attitudes and beliefs (Table 5).

The attitudinal and belief-related variables captured farmers' perceptions of the benefits of practices for them and their farms. The variables were:

- Perceived soil quality (*perception of the average soil quality of farm*)
- The perceived benefit that adoption of soil practice improves soil structure (*How likely the regional practice helps to achieve the following results on your farm?*)
- The community influence (*Do you feel that the following people or entities expect you to use regional soil-friendly practice?)*
- Government subsidization policy (*How do the following factors affect your decision to use regional soil-friendly practice?*)
- Knowledge (*How would the following factors affect your decision to use regional soil-friendly practice?*).

Table 5 summarizes key belief measures included in the econometric models.

Tables 6, 7, and 8 report the results from the triple-hurdle model focusing on intention to apply the ESMP and the compensation demands of farmers. The farmers' decisions in stages were 1) whether the farmers intend to apply ESMP (adoption status); 2) whether they intent to apply ESMP if compensation is to be provided; and 3) farmers' compensation demands (WTA) to implement the ESMP. To format the tables' results in this section, we used the package "stargazer" (Hlavac 2022) in R.

Ordered logistic regression analysis results

Table 6 presents the ordinal regression model results (first hurdle) for the intention to apply the ESMP. Age has a negative influence on the outcome in Estonia, meaning that younger farmers are more likely to adopt ESMP. Land size is showed a positive and statistically significant association with the intention to apply ESMP in Finland and Belgium, indicating that larger land areas are associated with a higher likelihood of adoption. The coefficients for "perceived benefits from implementation ESMP" and "community influence" were positive and statistically significant across all countries analyzed. This means that the perceived benefits of implementing ESMP (such as improving soil quality or soil structure) and the community influence (such as people whose opinion is important for respondents), are increased the likelihood of adopting friendly practices. Specifically, for each unit increase in "perceived benefits," the log odds of moving to a higher category ("Yes" or "Maybe") increases for Finland, Estonia, Belgium, and Germany by 0.88, 0.67, 0.86, and 1.11, respectively. Analogously, for each unit increase in "community influence," the log odds of moving to a higher category ("Yes" or "Maybe") increases for Finland, Estonia, Belgium, and Germany by 0.51, 0.58, 0.56, and 0.56, respectively (Table 6).

Farmer's knowledge requirements about ESMP are increased the probability of applying ESMP without compensation in Finland. Threshold effects (1|2 and 2|3) are positive and indicate that as the predictor variable increases, the likelihood of being in a higher category (e.g., 2 (adopting with compensation) or 3 (adopting without compensation)) is increased.

Binomial probit model results

The results from the binomial probit models (Table 7) for Finland, Estonia, Belgium, and Germany examine the factors influencing decision of whether a respondent is willing to accept (WTA) compensation or not (yes/no) for implementing ESMP. Positive coefficients indicate a higher likelihood of agreeing to WTA for ESMP implementation, while negative coefficients suggest a lower likelihood. More educated farmers in Germany are more likely to accept compensation for ESMP adoption. Farmers with large landholdings in Estonia may be slightly less willing to accept compensation for ESMP adoption. Being a full-time farmer has a statistically significant negative effect in Estonia, meaning part-time farmers in Estonia are more likely to accept compensation. Farmers who recognize benefits from ESMP implementation are statistically significant more likely to accept compensation in Estonia and Germany. Perceived community influence had a positive association with likelihood to accept compensation in Finland and Germany. Perceived importance of government policy and subsidies is negatively associated with likelihood of WTA in Estonia. The need for knowledge is positively associated with WTA in Finland and Estonia, suggesting that farmers who feel they need more information are more likely to accept compensation.

Truncated Poisson model results

Table 8 presents the factors influencing the decision of farmers to obtain compensation for the implementation of ESMP (third hurdle). The columns show the coefficient estimates for predicting the WTA value conditional on applying ESMP.

Being male is associated with a higher expected compensation in Finland and Germany, while in Estonia, it is linked to a lower compensation demand. Older farmers are less likely to demand higher compensation in Finland, while in Belgium and Germany, older farmers are more likely to demand higher compensation. Higher education is associated with lower compensation expectations in Estonia, Belgium, and Germany. The size of the farm, specifically the amount of arable land, increases compensation demand in Finland, Estonia, and Belgium, but decreases in Germany.

In Finland, Estonia, and Belgium, identifying as a full-time farmer is linked to higher compensation expectations, whereas in Germany, full-time farmers expect lower compensation. Farmers who perceive soil quality as high on their farms are more likely to request higher compensation in Finland and Germany. However, in Estonia and Belgium, those who perceive soil quality as high tend to demand less compensation.

Farmers who are motivated by the perceived benefits of ESMP adoption tend to expect higher compensation in Belgium. However, in the other countries, perceived benefits of ESMP adoption do not significantly influence compensation expectations. Farmers who feel influenced by others' opinions are more likely to seek compensation in Estonia, Belgium, and Germany, but less in Finland.

The perceived importance of government policy and subsidies in Finland and Germany is negatively associated with the compensation amount required for adopting ESMP. This suggests that farmers who view policies and subsidies as important decision-making factors are less likely to demand higher compensation. Lastly, in Finland, farmers who perceive a greater need for knowledge regarding regional practices are more likely to expect lower compensation, whereas in Estonia, these farmers are likely to demand more compensation.

The expected values of WTA for adoption of ESMP

Calculated expected WTA (€/per ha/year) are shown in Table 9. Respondents were willing to adopt the management practice if compensated with 263 € in Finland; 290 € in Estonia; 173 € in Belgium; and 159 € in Germany for the implementation of ESMP. These

Table 5 Measures of beliefs for each region. *Source* Authors' elaboration

Variable	Indicator / Description	Country	Scale (1–5)
Perceived soil quality	How do you estimate the average soil quality on your farm?	All	1—very bad … 5—very good
Perceived community influence	Do people or institutions you value expect you to use ESMP?	All	1—strongly disagree … 5—strongly agree
Perceived benefits from ESMP	How likely is ESMP to achieve these results on your farm?	Finland	Improves soil structure
		Estonia	Would improve soil quality and conditions
		Germany	Improve soil quality
		Belgium	Fertile topsoil layer
Importance of government policy and subsidies	How do government policies and subsidies influence your ESMP decisions?	Finland	Dependence on politics and subsidies
		Estonia	Current policies and subsidies
		Germany	Policy and subsidies
Farmer's knowledge requirements	How do knowledge requirements influence your ESMP decisions?	Finland	Need for knowledge
		Estonia	Availability of knowledge tested in practice
		Germany	Need for know-how

For Belgium, data for the last two questions were unavailable because they were not identified as barrier and drivers during interview preceding the survey. The results from these interviews indicated that these questions were unnecessary for further analysis in this country

Table 6 Ordered logistic regression analysis results for the intention to apply the ESMP. *Source* Authors' calculations

Explanatory variables	Finland	Estonia	Belgium	Germany
Male	0.45 (−0.67, 1.58)	−0.14 (−0.83, 0.55)	−0.66 (−2.59, 1.26)	−0.55 (−1.70, 0.60)
Age	0.02 (−0.02, 0.06)	−0.03*** (−0.05, -0.01)	−0.01 (−0.05, 0.03)	−0.004 (−0.03, 0.02)
Education	−0.09 (−0.92, 0.74)	−0.13 (−0.67, 0.40)	0.06 (−0.90, 1.03)	0.10 (−0.54, 0.75)
Land	0.01** (0.001, 0.02)	0.0001 (−0.0004, 0.001)	0.02* (−0.001, 0.04)	0.0002 (−0.001, 0.001)
Full-time farmer	0.53 (−0.39, 1.46)	−0.14 (−0.71, 0.44)	0.29 (−0.76, 1.33)	−0.74 (−1.67, 0.18)
Perceived soil quality	−0.27 (-0.85, 0.32)	−0.05 (-0.45, 0.36)	0.21 (−0.57, 1.00)	−0.24 (−0.66, 0.18)
Perceived benefits from implementation of ESMP	0.88*** (0.45, 1.31)	0.67*** (0.41, 0.94)	0.86*** (0.40, 1.32)	1.11*** (0.64, 1.57)
Perceived community influence	0.51** (0.11, 0.90)	0.58*** (0.29, 0.88)	0.56** (0.07, 1.04)	0.56*** (0.24, 0.88)
Perceived importance of government policies and subsidies	−0.02 (−0.33, 0.29)	−0.10 (−0.39, 0.20)		−0.14 (−0.39, 0.11)
Farmers' knowledge requirements	0.57** (0.04, 1.11)	0.10 (−0.20, 0.41)		0.17 (−0.22, 0.56)
1|2	4.103**	0.753	3.035	2.571
2|3	5.074**	1.755	4.076	3.927**
Akaike Inf. Crit	265.56	469.22	179.53	376.08
N	357	273	131	200

$p < 0.001$***, $p < 0.01$**, $p < 0.05$*; 95% confidence intervals are reported in parentheses; for Belgium, data for the last two questions are unavailable because they were not identified as barrier and drivers during interview preceding the survey. The results from these interviews indicated that these questions were unnecessary for further analysis in this country

values are realistic and not different from the mean compensation amount in the raw data (Table 2). The predicted mean from the truncated Poisson regression is matched the observed mean, which is expected due to the maximum likelihood estimation (MLE) property. This alignment suggests that the models are well specified and appropriately captures the distribution of the truncated count data (Ngamkham and Panta 2023).

Robustness check and sensitivity analysis results

The Bayesian model mirrors the triple-hurdle structure used, but is employed here solely to assess the stability of country-level compensation magnitudes rather than to provide formal parameter-level inference. For each country, posterior predictive distributions of compensation amounts were generated and summarized by posterior medians and 95% credible intervals. These posterior medians closely correspond to the point estimates obtained from the triple-hurdle model with inverse Mills ratio correction, with differences remaining small relative to the overall scale of compensation and preserving the same cross-country ranking. Specifically, the posterior medians from the Bayesian model were 291€ in Finland, 319€ in Estonia, 178€ in Belgium and 165€ in Germany (Table 10). This concordance indicates that the estimated average compensation levels are not driven by the choice of estimation framework, supporting the robustness of the reported results.

Table 7 Binomial probit model results: Determinants of respondents' WTA. *Source* Authors' calculations

Explanatory variables	Finland	Estonia	Belgium	Germany
Male	−1.08 (−3.19, 1.03)	−0.02 (−0.75, 0.70)	−0.42 (−2.59, 1.75)	0.12 (−1.04, 1.28)
Age	0.03 (−0.04, 0.09)	−0.003 (−0.03, 0.02)	0.005 (−0.04, 0.05)	−0.01 (−0.03, 0.02)
Education	0.75 (−0.47, 1.98)	0.07 (−0.47, 0.61)	−0.29 (−1.54, 0.96)	0.54* (−0.08, 1.17)
Land	−0.01 (−0.02, 0.003)	−0.001* (-0.001, 0.0000)	0.01 (−0.02, 0.04)	0.0003 (−0.0004, 0.001)
Full-time farmer	0.18 (−1.14, 1.50)	−0.59* (−1.20, 0.01)	0.59 (−0.78, 1.96)	0.21 (−0.59, 1.01)
Perceived soil quality	−0.42 (−1.26, 0.43)	−0.14 (−0.54, 0.25)	−0.60 (−1.43, 0.23)	0.03 (−0.35, 0.41)
Perceived benefits from implementation of ESMP	0.38 (−0.26, 1.02)	0.46*** (0.18, 0.73)	0.19 (−0.29, 0.66)	0.52** (0.07, 0.97)
Perceived community influence	0.77** (0.13, 1.42)	0.22 (−0.08, 0.51)	0.0004 (−0.48, 0.48)	0.37** (0.03, 0.71)
Perceived importance of government policies and subsidies	0.22 (-0.37, 0.82)	−0.65*** (−1.01, −0.30)		−0.005 (−0.25, 0.24)
Farmers' knowledge requirements	0.84* (−0.04, 1.72)	0.36* (-0.001, 0.71)		-0.15 (-0.52, 0.23)
IMR	ns	ns	ns	ns
Constant	−4.54 (−10.29, 1.21)	−0.51 (−2.53, 1.52)	1.19 (−4.63, 7.00)	−2.36 (−5.22, 0.51)
Observations	37	122	33	96
Log Likelihood	-16.62	-60.32	-20.09	-58.48
Akaike Inf. Crit	55.24	142.64	58.17	138.96

ns means statistically nonsignificant; $p<0.001$***, $p<0.01$**, $p<0.05$*; 95% confidence intervals are reported in parentheses; for Belgium, data for the last two questions are unavailable because they were not identified as barrier and drivers during interview preceding the survey. The results from these interviews indicated that these questions were unnecessary for further analysis in this country

The Bayesian credible intervals were wider, particularly in Finland and Belgium, reflecting the smaller number of observations in the final stage. Overall, the central tendency of the estimates was stable across methods, supporting the reliability of the reported compensation levels.

Table 13 3A (Appendix) reports the results of the truncated Poisson regression for Belgian farmers, including the sensitivity analyses. Since Belgium lacks direct measures for perceived importance of government policies and subsidies, and farmers' knowledge requirements, the coefficients for these variables differ across scenarios, reflecting how these factors could influence compensation amounts. Importantly, the other covariates and the IMR correction remain largely consistent across scenario models, indicating that the third-stage estimates are robust to the missing attitudinal data.

Discussion

Our results reveal heterogeneity in the expected compensation to adopt ESMP amount across age, gender, and farmers' education, which influences their willingness to accept the ESMP. These findings partially align with Guo et al. (2022), who found a statistically significant positive association between age, education, and the adoption of conservation tillage technology among farmers in Jilin Province, China. Farmers with larger arable

Table 8 Truncated Poisson model results: Determinants of respondents' WTA. *Source* Authors' calculations

Explanatory variables	Finland	Estonia	Belgium	Germany
Male	1.954*** (1.727, 2.181)	−0.049* (−0.094, −0.005)	−0.193 (−0.722, 0.337)	0.428*** (0.277, 0.580)
Age	−0.024*** (−0.032, −0.017)	−0.001 (−0.003, 0.000)	0.041*** (0.032, 0.050)	0.016*** (0.012, 0.020)
Education	0.074 (−0.054, 0.202)	−0.588*** (−0.628, −0.549)	−1.243*** (−1.543, −0.943)	−0.951*** (−1.130, −0.773)
Land	0.021*** (0.019, 0.023)	0.000*** (0.000, 0.000)	0.087*** (0.073, 0.102)	−0.001*** (−0.001, 0.000)
Full-time farmer	0.217*** (0.100, 0.333)	0.416*** (0.371, 0.460)	3.169*** (2.596, 3.741)	−0.772*** (−0.884, -0.661)
Perceived soil quality	0.163*** (0.072, 0.254)	−0.460*** (−0.489, −0.430)	−3.003*** (−3.580, −2.427)	0.161*** (0.127, 0.195)
Perceived benefits from implementation of ESMP	−0.628*** (−0.688, −0.569)	−0.127*** (−0.146, −0.109)	1.256*** (1.057, 1.456)	−1.103*** (−1.282, −0.925)
Perceived community influence	−1.533*** (−1.637, −1.429)	0.083*** (0.064, 0.102)	0.395*** (0.349, 0.441)	−0.726*** (−0.854, −0.599)
Perceived importance of government policies and subsidies	−0.673*** (−0.717, −0.629)	−0.021 (−0.042, 0.001)		−0.077*** (−0.095, −0.058)
Farmers' knowledge requirements	−0.473*** (−0.597, −0.350)	0.085*** (0.058, 0.112)		0.048 (−0.005, 0.102)
IMR	−3.021*** (−3.283, −2.760)	0.401*** (0.375, 0.428)	9.622*** (7.947, 11.296)	−3.570*** (−4.161, −2.979)
Constant	14.312*** (13.388, 15.236)	6.698*** (6.561, 6.835)	−2.572*** (-3.372, -1.771)	12.362*** (11.041, 13.683)
Observations	20	46	16	48
Akaike Inf. Crit	1010.2	7677.6	731.5	2182.1

$p<0.001$***, $p<0.01$**, $p<0.05$*; 95% confidence intervals are reported in parentheses; for Belgium, data for the last two questions are unavailable because they were not identified as barrier and drivers during interview preceding the survey. The results from these interviews indicated that these questions were unnecessary for further analysis in this country

land areas request higher compensation in Finland, Estonia, and Belgium, whereas in Germany, they expect lower compensation amounts. Our results regarding arable land area align with those of Dai et al. (2024), who found that compensation demands vary significantly based on land size. Larger farms often require higher compensation due to the greater scale of implementation and potential opportunity costs (Aznar-Sánchez et al. 2020). Full-time farmers exhibit varying compensation expectations across countries. This pattern suggests that full-time farmers may be more reliant on agricultural income, making them more sensitive to compensation schemes that ensure financial stability (Liu et al. 2021).

Prior research (Mezzatesta et al. 2013; Piñeiro et al. 2020; Canales et al. 2024) suggests that if farmers recognize broader ecological benefits from their practices, they may adopt them even with minimal financial incentives. Our results align with this for Finland, Estonia, and Germany, where farmers who perceive greater benefits tend to request lower compensation amount. However, in Belgium the farmers who recognize benefits still demand higher compensation amount. Social interactions play a crucial role in farmers' decision-making processes, including the adoption of sustainable practices and participation in compensation programs. Farmers' decisions are significantly influenced by their peers, especially in the adoption of new technologies and practices

Table 9 Expected values of WTA for adopt of ESMP. *Source* Authors' calculations

Country	Finland	Estonia	Belgium	Germany
WTA in euros	263	290	173	159

Table 10 Posterior medians from the Bayesian model. *Source* Authors' calculations

Country	Mean	Median	Bayesian credible intervals
Finland	424.46	291.38	[237.54; 1307.18]
Estonia	334.72	318.78	[253.08; 503.40]
Belgium	223.08	177.75	[152.46; 528.99]
Germany	167.62	165.27	[141.60; 205.88]

(Niu et al. 2022). This peer influence can extend to compensation expectations, as farmers may align their demands with those of their peers to maintain social cohesion and perceived fairness (Niu et al. 2022).

Our results regarding the perceived importance of government policy and subsidies are not consistent with Guo et al. (2022), who found that government subsidies statistically significantly influence farmers' willingness to adopt conservation tillage in China. Farmers often rely on subsidies and government policies to support their agricultural activities, which can reduce their demands for higher compensation when adopting new practices (El Bakali et al. 2023). Finally, farmers who perceive a high need for knowledge regarding regional practices are less inclined to demand high compensation in Finland, but not in Estonia. This suggests that access to knowledge and education May reduce financial barriers to ESMP adoption, highlighting the potential role of knowledge transfer initiatives in promoting sustainable practices. Knowledge-sharing initiatives are a cornerstone of AES and Natura 2000 (Kokkoris et al. 2023), and our results confirm that well-designed advisory systems can reduce financial barriers to adopting soil-friendly practices. While our study focuses on the willingness to accept compensation for soil-friendly practices, the results contribute to a broader understanding of how farmers respond to environmental policy incentives.

Conclusion

This study examined farmers' willingness to accept (WTA) compensation for adopting regional soil-friendly practices across four European countries, with a focus on compensation levels and the socio-demographic, economic, and attitudinal factors that influence these decisions. The results provide important insights for policymakers seeking to design effective and equitable incentive mechanisms to promote sustainable farming practices.

The findings reveal notable variations in compensation expectations across countries, ranging from 159€ in Germany to 263€ in Finland that is natural because the management practices studied differed. Beyond the practices themselves, the differences may indicate also the influence of regional economic conditions, farming practices, and cultural attitudes on farmers' compensation demands. The estimated compensation values align closely with raw data averages, underscoring the robustness of the analysis.

Based on the results, several key conclusions can be drawn:

Firstly, we found the heterogeneity in compensation amount expectations. Farmers' compensation demands vary between countries and influenced by factors such as gender, age, education, and farm size. These findings underscore the need for tailoring compensation schemes carefully for each practice on each region rather than one-size-fits-all approaches, which provide uniform compensation regardless of individual or regional differences. Secondly, gender differences in compensation expectations suggest varying priorities, with men and women valuing soil-friendly practices differently depending on the country. Similarly, younger farmers in Finland are more willing to adopt practices only with higher compensation, while younger farmers in other countries have lower compensation demands, suggesting generational differences in risk perception and valuation. Thirdly, higher education levels generally decreased WTA (willingness to accept) compensation to adopt ESMP in Estonia, Belgium, and Germany, suggesting that more educated farmers may expect lower compensation for implementing ESMP. This may be because they better understand the long-term benefits, such as improved soil health and reduced input costs. Additionally, they are more aware of available subsidies and policy support, reducing their reliance on direct compensation. Furthermore, this suggests that more educated farmers in these countries may feel they have sufficient resources or knowledge to adopt ESMP without requiring significant financial incentives. Fourthly, in almost all countries, farmers with larger arable land areas expected higher compensation for implementing the ESMP. Fifthly, in almost all countries, about 50% of farmers who do not adopt the ESMP would reconsider if they were compensated for doing so.

Policymakers aiming to encourage soil-friendly practices should design compensation schemes that reflect local economic conditions and account for demographic and attitudinal differences. Additionally, integrating educational initiatives could enhance the adoption of sustainable practices while potentially reducing compensation demands. Policymakers could use the WTA benchmarks reported here as reference points when designing agri-environmental payments. To ensure cost-effectiveness and feasibility, compensation amounts should be aligned with the ranges already established in existing AES or Natura 2000 programs.

Limitations of study

Despite the robust modeling approach, our study has several limitations. Certain attitudinal variables were not collected for Belgian farmers, and while sensitivity analyses simulate their potential impact, the true responses may differ. Sample sizes for compensation amounts were small, particularly in Belgium and Finland, which could affected the precision of estimates. Finally, some unobserved behavioral and social factors may influence adoption but were not included in the models.

Future research could expand the geographic scope of this analysis and explore the long-term impacts of compensation mechanisms on the adoption of soil-friendly practices and agricultural sustainability.

Appendix

See Tables 11, 12 and 13. See Figs. 2 and 3

Table 11 Management practices in each region

Country	Management practice	Description
Belgium	Non-inversion tillage	Non-inversion tillage means not using a plow to turn the soil for at least a year
Estonia	Direct seeding (no till)	A tillage method where land is not plowed, minimizing soil disturbance. Seeds are sown directly, which reduces soil erosion and improves soil quality
Finland	Cultivation with plant cover	A practice where the soil is lightly tilled in spring (8–10 cm depth) and covered with plants or plant residues, enhancing soil protection
Germany	Undersowing	Sowing a second crop with or after the main crop, which improves soil quality

Table 12 Measures for TPB, a) general intention to invest in soil quality and b) regional measures

Concept	Scale	Measure
a) *general intention to invest in soil quality*		
Intention	1–13	Number of currently used or intended practices from the list of 13 practices and their perceived impact on soil quality
Attitude	1 not at all necessary—5 very necessary	Investing in good soil quality on my farm is.
Subjective norm	1 completely disagree—5 completely agree	People who are important to me in farming issues think I should invest in having good soil quality on my farm
		People whose opinion I value think I should invest in having good soil quality
Perceived behavioral control	1 completely disagree—5 completely agree	I am confident that I am able to maintain soil in good quality
		I believe I have the ability to improve quality of my soil
		Having soils of good quality on my farm is entirely up to me
		Improving soil quality is beyond my control
Moral obligation	1 completely disagree—5 completely agree	I feel a strong obligation investing in good soil quality on my farm
		I would feel guilty if I didn't focus on the good to the quality of the soil on my farm
		Investing in solutions to environmental problems is in line with my values and beliefs
b) *regional measures, management practice marked as ESMP*		
Intention	1 no 2 maybe 3 yes	I have the intention to apply ESMP on at least one parcel next season
	1 no 2 maybe 3 yes	It is in my plan for the near future to apply ESMP on at least one parcel
Attitude	1 not at all useful – 5 very useful	I think that applying ESMP on my farm is…
Subjective norm	1 completely disagree – 5 completely agree	People who are important to me think I should apply ESMP
		People whose opinion I value think I should apply ESMP
Perceived behavioral control	1 completely disagree – 5 completely agree	To me, ESMP is very difficult to apply
		Whether I apply ESMP or not is totally up to me
		The decision to apply ESMP or not is totally under my own control

Table 12 (continued)

Concept	Scale	Measure
Behavioral beliefs	1 not at all important – 5 extremely important	How important you consider the following topics (regional)?
	1 very unlikely – 5 very likely	How likely ESMP would cause following outcomes (regional) on your farm?
Normative beliefs	1 completely disagree – 5 completely agree	I feel that X (regional) think I should apply ESMP
	1 not at all important – 5 extremely important	How important do you perceive the opinion/advise of the following persons or institutions (regional) while deciding about the use of ESMP?
Control beliefs	1 completely disagree – 5 completely agree	Do you agree or disagree with the following statements? (regional statement of controlling aspects)
	1 strongly hinders adaptation – 5 strongly supports adaptation	How do you perceive the following factors in decision to use ESMP? (regional)

Table 13 Truncated Poisson model results for Belgium: baseline and sensitivity scenarios

Explanatory variables	baseline	scenario 1	scenario 2	scenario 3
(Intercept)	−2.572*** (−3.372, −1.771)	−3.067*** (−3.949, −2.185)	−2.390*** (−3.348, −1.433)	−0.335 (−1.304, 0.634)
Male	−0.193 (−0.722, 0.337)	1.127** (0.434, 1.820)	−1.987*** (−2.727, −1.247)	−0.271 (−0.804, 0.262)
Age	0.041*** (0.032, 0.050)	0.059*** (0.042,0.075)	0.045*** (0.032,0.059)	0.028*** (0.019, 0.038)
Education	−1.243*** (−1.543, −0.943)	−0.074 (−0.440, 0.292)	−1.697*** (−2.024, -1.370)	−2.188*** (−2.600, −1.776)
Land	0.087*** (0.073, 0.101)	0.067*** (0.052,0.082)	0.088*** (0.073,0.102)	0.081*** (0.065,0.096)
Full-time farmer	3.169*** (2.596, 3.741)	2.159*** (1.540,2.778)	4.013*** (3.391,4.635)	3.370*** (2.767,3.973)
Perceived soil quality	−3.003*** (−3.580, −2.427)	−2.138*** (−2.835, −1.441)	−3.849*** (−4.470, −3.228)	−3.208*** (−3.855, −2.561)
Perceived benefits from implementation of ESMP	1.256*** (1.057,1.456)	0.769*** (0.517,1.020)	1.393 *** (1.183,1.604)	1.085 *** (0.865,1.306)
Perceived community influence	0.395*** (0.350, 0.441)	0.891*** (0.812, 0.970)	0.402*** (0.355, 0.449)	0.044 (−0.036, 0.124)
Perceived importance of government policies and subsidies	-	−0.295*** (−0.416, −0.175)	0.225 *** (0.117, 0.331)	−0.402*** (−0.543, −0.262)
Farmers' knowledge requirements	-	−0.744*** (−0.855, −0.633)	0.448*** (0.388, 0.508)	0.565*** (0.460, 0.669)
IMR	9.622*** (7.946,11.299)	8.131*** (6.101,10.160)	12.031*** (10.219,13.843)	9.741*** (7.894,11.587)
Akaike Inf. Crit	731.54	470.59	349.06	619.78

$p < 0.001$***, $p < 0.01$**, $p < 0.05$*; 95% confidence intervals are reported in parentheses; IMR is inverse Mills ratio from stage 2; baseline model includes IMR and all available predictors. Scenarios 1–3 simulate hypothetical variation in knowledge requirements and perceived importance of government policies and subsidies for Belgian farmers, using low (25th percentile), medium (50th percentile), and high (75th percentile) values derived from other countries

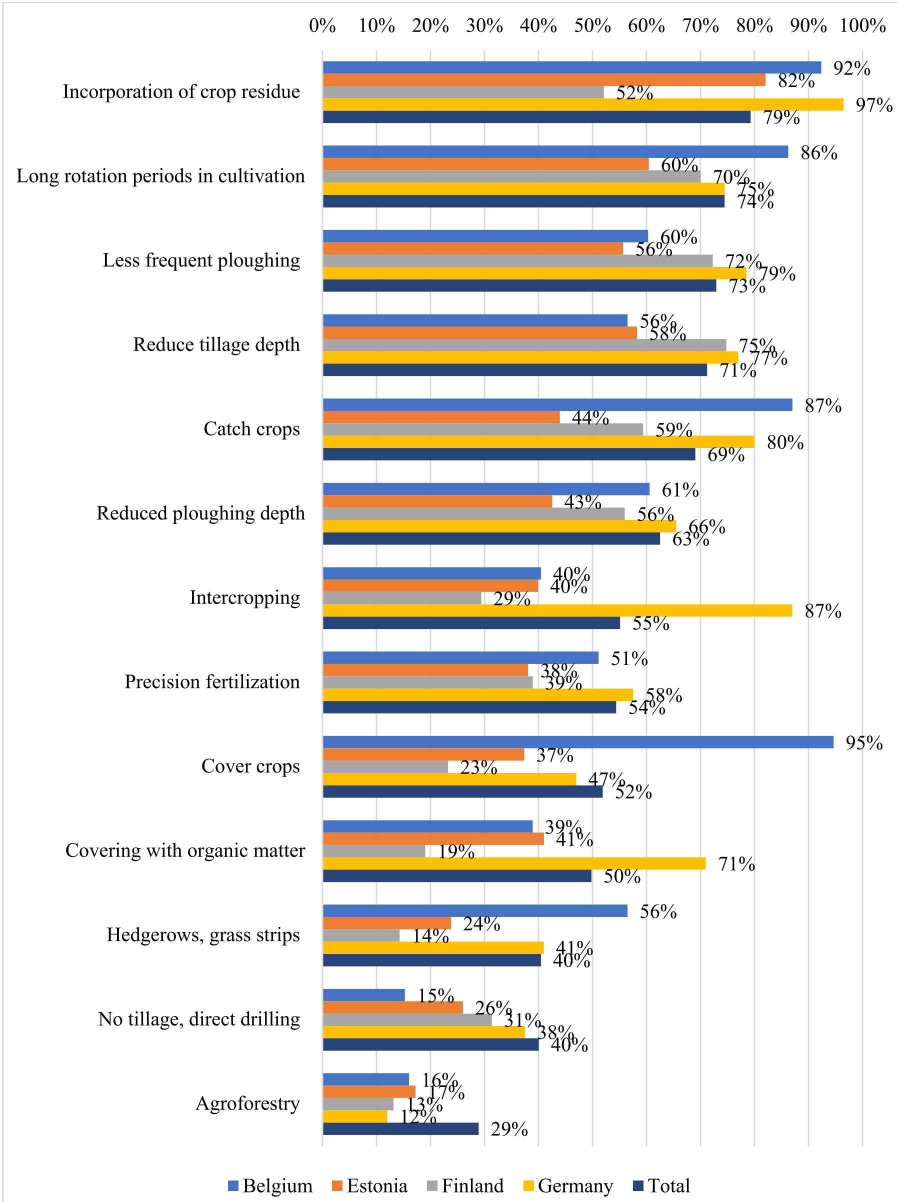

Fig. 2 Share of farmers intending to use different management practices (present appliers and future intenders)

Semi-structured interview guideline

Semi-structured interview guideline

The semi-structured interview guideline was used to guide all focus group interviews. It was designed to identify commonly held beliefs, perceived outcomes, social referents, and control factors related to the adoption of ecosystem service management practices (ESMPs). The guideline was grounded in the theory of planned behavior and designed to

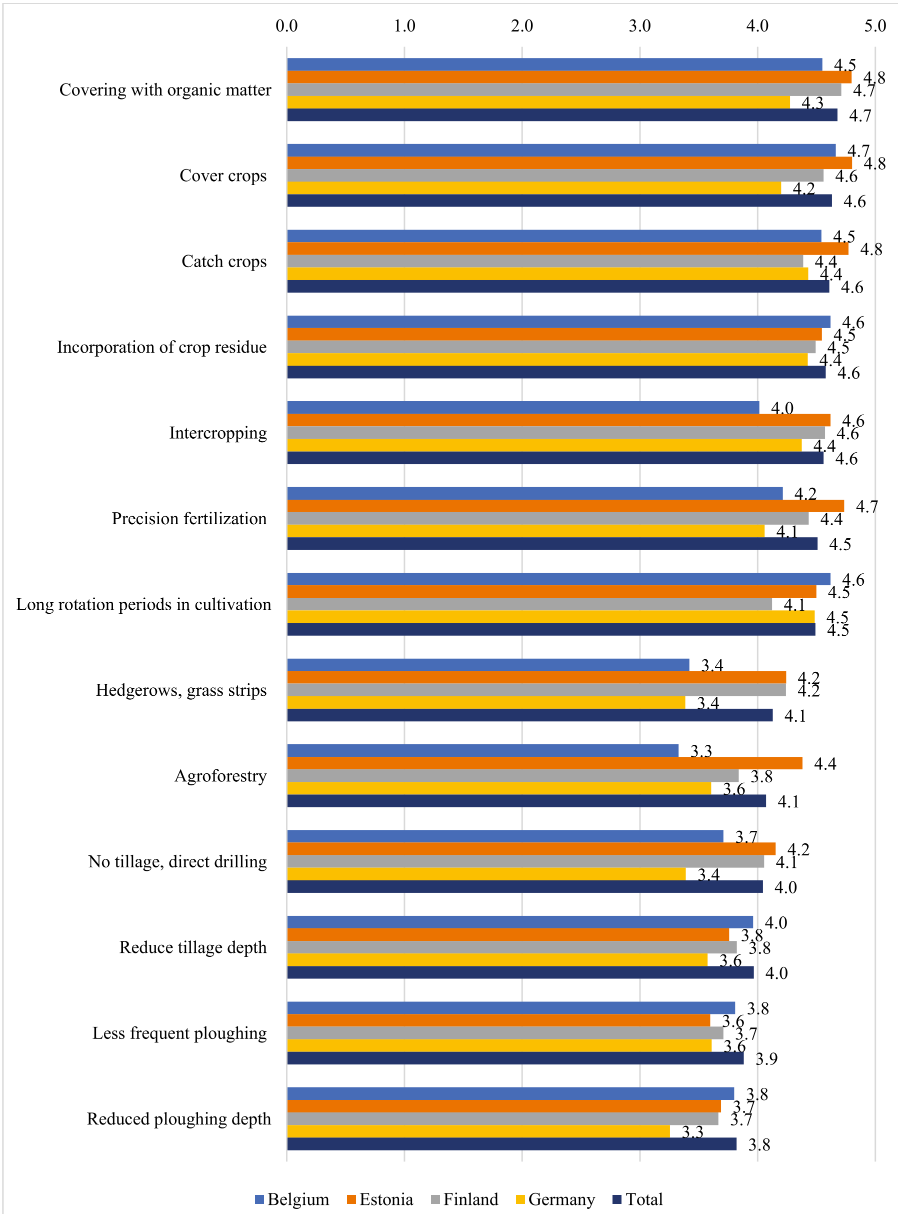

Fig. 3 Farmer's beliefs regarding how management practices contribute to improving or maintaining soil quality (1 strong negative contribution… 3 no contribution… 5 strong positive contribution)

capture farmers' beliefs beyond short-term profitability, including social, cultural, institutional, and practical factors affecting adoption decisions.

Following a two-step methodological approach, the interviews constituted the first step and were used to elicit farmers' salient beliefs regarding specific ecosystem service management practices. The interview questions were structured to identify perceived outcomes of the practices, relevant social referents, and perceived control factors. Emphasis was placed on identifying modal accessible beliefs, those most commonly held within the target population, which subsequently informed the development of a region-specific survey questionnaire in the second step of the study.

The interview guideline consisted of open-ended questions organized into thematic blocks covering: (i) participants' farm characteristics and production systems, (ii) current farming practices and management decisions, (iii) experiences and challenges related to the study topic, (iv) perceptions, motivations, and constraints influencing decision-making, and (v) future expectations and adaptation strategies. Follow-up questions and probes were used where appropriate to clarify responses and encourage discussion among participants.

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Author Contributions
Olha Aleksandrova: Writing—original draft, Visualization, Software, Methodology, Formal analysis. Annika Tienhaara: Writing—review and editing. Omid Zamani: Writing—review and editing, Methodology. Jo Bijttebier: Writing—review and editing. Anne Põder: Writing—review and editing. Eija Pouta: Conceptualization, Writing—review and editing.

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Data availability
The data is available upon request.

Declarations

Ethical approval and consent to participate
Ethical approval was not required for this study as it did not involve human participants, animals, or sensitive data. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for Publication
Not applicable.

Competing interest
The authors declare no competing interest.

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