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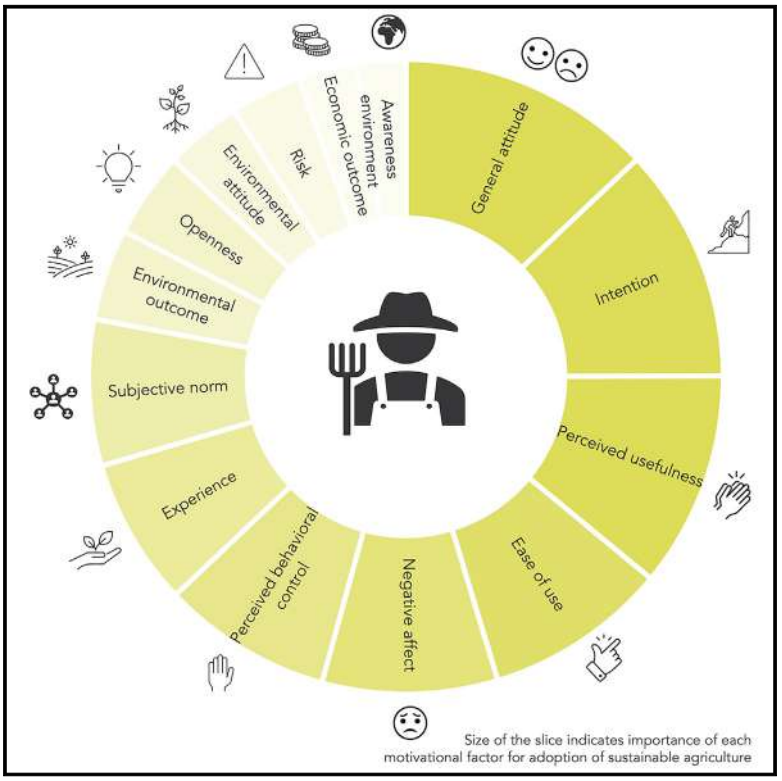
Meta-analyses reveal the importance of socio-psychological factors for farmers' adoption of sustainable agricultural practices

Graphical abstract



Highlights

- Quantitative overview of EU farmers' motivations to apply sustainable agriculture
- Attitude, intention, and perceived usefulness are most important for adoption
- Farmers' economic outcomes and environmental awareness least important
- EU's Common Agricultural Policy should target a mix of socio-psychological factors

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In brief

Transitioning agricultural systems requires understanding farmers' motivations for implementing sustainable agriculture. By using meta-analysis models, we quantified the importance of motivational factors for adoption of sustainable agriculture in Europe. Results indicate that the current focus of the European Union's Common Agricultural Policy (CAP) on economic incentives alone will likely lead to limited sustainability improvements. Instead targeting a mix of farmers' socio-psychological factors is essential.

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Meta-analyses reveal the importance of socio-psychological factors for farmers' adoption of sustainable agricultural practices

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SCIENCE FOR SOCIETY Global agricultural systems are currently failing to both ensure food security and contribute to environmental sustainability. Agricultural practices play a crucial role in achieving sustainability targets, yet we lack generalizable knowledge on why farmers apply sustainable practices. Understanding farmers' motivations for adoption is crucial for transformations of agricultural systems. Here, we present a quantitative assessment of all available articles on farmers' motivational factors for implementing sustainable agricultural practices across Europe. Our results indicate that attitude, intention, and perceived usefulness were most important for practice adoption, while economic outcomes and environmental awareness were of less importance. This underlines that economic incentives alone might lead to limited sustainability improvements. Instead, policies that target a mix of socio-psychological factors may be more effective in transitioning toward sustainable agricultural systems.

SUMMARY

Agricultural systems support societies in various ways but also cause substantial sustainability challenges. Sustainable agricultural practices are key to achieving sustainability targets, yet we lack generalizable knowledge on why farmers apply such practices. Here, we quantified the relationship between farmers' adoption of sustainable agricultural practices and their underlying motivational factors. Based on a systematic review, we meta-analyzed 14 motivational factors from 225 studies reporting 522 effect sizes, representing 327,778 farmers from 23 European countries. We found (1) substantially stronger positive effects for general attitude, intention and perceived usefulness compared with economic outcomes and environmental awareness, (2) dissonance between intention and actual behavior, and (3) geographic, thematic, and effort-effect bias in literature. Stimulating the adoption of sustainable agricultural practices hence requires reconsidering the currently strong emphasis on economic factors in favor of a wider set of motivational factors, especially by addressing socio-psychological factors via transparency, communication, and training.

INTRODUCTION

Agriculture is continuing to change our natural ecosystems and degrade the environment at unprecedented rates.[1–3] As one of the key drivers of global environmental change, agriculture is responsible for a substantial share of global carbon emissions,[4] leads to massive losses of biodiversity,[5,6] and degrades land, soil, and freshwater systems.[1,7] Current agricultural production is likely to fall short of sufficiently addressing future food insecurity, and with a growing world population and increasing meat and dairy consumption, pressures will rise further, threatening resilience of socio-ecological systems.[8,9] Global agricultural systems hence need to undergo a substantial transformation to move toward more sustainable states.[10,11]

Sustainable agricultural practices offer a solution, as their uptake can protect the environment and biodiversity and enhance food security.[12–16] On a local scale, farmers can implement sustainable farming practices such as adapted cropping, conservation tillage,

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integrated pest management, irrigation systems, reduction of fertilizers, and data-based farming, which benefit the environment and increase or maintain productivity.[17–19] Thus, understanding why and how farmers decide to implement sustainable agricultural practices is essential to design policies supporting the adoption of these practices, to reduce further impacts on the environment, and hence for the transformation toward sustainable agriculture.[20,21] Although industry groups and policymakers are aware that farmers need support to implement sustainable agricultural practices, coherent long-term strategies have yet to be developed to support sustainable agriculture at scale.[22]

Reasons why farmers adopt sustainable practices are manifold and often context-specific.[23] Yet, several practical factors affecting farmers' adoption of sustainable agriculture, where factors are observable and can be directly measured, are well documented in the scientific literature: farmer characteristics (e.g., age and education), physical conditions (e.g., farm size and farm type), financial capital (e.g., income and labor), and natural conditions (e.g., location and soil quality). In contrast, motivational factors, defined as cognitive and affective factors underlying behavior,[24] are studied less. Apart from a few studies that demonstrated the influence of farmers' socio-psychological factors such as attitudes and social norms on decision-making,[25–27] the majority of studies neglect farmers' motivational factors to explain adoption of sustainable agricultural practices.[28]

Current reviews and meta-analyses investigating motivational factors and farmers' adoption behavior use vote-count methods,[23,28–31] qualitatively summarize motivations[26,32–34] and incentive types,[13] or focus only on environmental attitudes,[35] technologies[36] and the methodological application of the Theory of Planned Behavior.[27] Vote counting is problematic in meta-analyses, as it leads to statistically biased and often misleading results, which can lead to wrong conclusions regarding the overall outcome across studies.[37] Qualitative summaries often lack objectivity and standardized approaches to summarize research findings and do not provide estimates of effect sizes and their uncertainty, which affects the comparability across studies and the reliable identification of patterns and relationships. Focusing solely on incentives (often aimed at economic benefits) may neglect that other factors can influence adoption. This also holds true for studies focusing on sub-categories of farmer motivations or practice types. Moreover, the relationship between study effort and effect size of motivational factors behind practice adoption is unclear, with potential discrepancies indicating inefficient allocation of effort and capital. Overall, these individual shortcomings lead to an incomplete understanding of the broad suite of motivational factors influencing the adoption behavior of sustainable practices, impeding effective and targeted policy making. Thus, a rigorous quantitative synthesis of farmers' motivations to adopt sustainable agricultural practices is currently lacking.

It is, however, possible to analyze motivational factors in relation to human behavioral change, as shown in a recent global meta-analysis of human adaptation behavior of climate change.[24] In such analyses, it is important to distinguish between the intent to implement changes and the actual behavior (for instance done by Lu et al.[29]), because perceptions of outcomes can both influence behavior and be influenced by behavior,[38] and discrepancies between intended and actual behavior (i.e., the intention-behavior gap[39]) can affect the assessment of the impacts related to adoption. Complementing existing analysis, we focus on *adoption behavior* (intention and actual adoption), applied to the agricultural system, with a geographic focus on Europe. Europe represents an interesting region to study adoption behavior, as its agricultural system is experiencing a multitude of challenges calling for a fundamental sustainability transition.[40] The region has a long agricultural history resulting in a variety of landscapes and farming systems, and years of intensification and land abandonment have caused various environmental and socio-economic challenges.[41–43] The European Union's (EU) CAP aims to address these challenges, although at present payments are unequally distributed and the CAP is failing its environmental objectives.[44–46] Despite various schemes that support farmers to implement agri-environmental measures, farmers' uptake of sustainable practices is low. Several studies argue that the current rationale for agri-environmental policy adoption is dominantly economic and a deeper, more nuanced, understanding of farmer decision-making is required for better policy design.[26,27,34,47] This is also reflected by the dominance of economic outcomes as incentives or constraints for adopting sustainable practices in both policy (CAP) and literature, thereby largely omitting the environmental psychology literature. Knowledge of European farmers' motivational factors thus benefits effectiveness of policy programmes such as the CAP (reform), as well as the EU's Green Deal, Farm to Fork Strategy, and the Biodiversity Strategy, additionally giving an example for other world regions and informing on policy uptake of, for instance, climate change adaptation measures.

Here we assess the relationship between motivational factors and farmers' adoption behavior of sustainable agricultural practices in Europe. To do so, we gathered all literature evidence on farmer adoption behavior available for the period 1998 to 2020, and assessed the relationship between farmers' adoption behavior and 14 motivational factors (Table 1) by using three-level meta-analysis models. Therefore, we relied on standard theoretical approaches for farmer adoption behavior (e.g., Theory of Planned Behavior) that correspond to broader environmental psychology. Furthermore, we investigated whether certain moderators (e.g., effect of actual behavior and intended behavior) exerted influence on the strength of the relationships. Last, we compared research effort to the effect sizes of individual motivational factors to identify under- and over-researched domains. Specifically, we aimed to (1) identify the most researched sustainable agricultural practices for farmers' motivational studies in Europe, (2) determine the most influential motivational factors for farmers' adoption behavior, (3) examine the impact of moderators such as type of behavior and type of practice on the strength of their relationships, and (4) evaluate the alignment between research effort and the importance of farmers' motivational factors for the adoption of sustainable agriculture. We found stronger positive effects for general attitude, intention, and perceived usefulness compared with economic outcomes and environmental awareness, a dissonance between intention and actual behavior, and a geographic, thematic, and effort-effect bias in literature. Stimulating the adoption of sustainable agricultural practices hence requires reconsidering the currently strong emphasis on economic factors in favor of a wider set of motivational factors, especially by addressing socio-psychological factors via transparency, communication, and training.

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Table 1. Farmers' motivational factors for adoption of sustainable agricultural practices

Motivational factor	Description
General attitude	Attitude toward adoption behavior: positive or negative evaluation about adoption of sustainable agricultural practice
Intention	Intention to adopt sustainable agricultural practice
Subjective norm	Perception of whether others are engaging in adoption of sustainable agriculture, and whether adoption behavior will be approved or disapproved by others
Perceived behavioral control	Perception of ability to adopt sustainable agricultural practice
Perceived usefulness	Perception of usefulness and benefits of adoption of sustainable agricultural practice
Ease of use	Perception of ease or difficulty of adoption of sustainable agricultural practice
Environmental attitude	Attitude toward environment: positive or negative evaluation about the (degrading) environment, agricultural system, climate change
Awareness environment	Awareness and knowledge about the human impact on (degrading) environment, agricultural system, climate change
Environmental outcome	Perception about environmental outcome: expected positive or negative environmental consequence of adoption of sustainable agricultural practice
Negative affect	Concern, worry or fear toward (degrading) environment, agricultural system, climate change
Economic outcome	Perception about economic outcome: expected positive or negative economic consequence of adoption of sustainable agricultural practice
Openness	Open or innovative attitude or personality
Risk	Perceived risks of adoption of sustainable agricultural practice, also includes attitude toward risk
Experience	Experience with sustainable agricultural practice and adoption behavior

Motivational factors are defined based on included studies, descriptions aligned to descriptions in the literature and behavioral frameworks (see also van Valkengoed et al.[48]; Table S1 for more detail on definitions and operationalization of factors).

RESULTS

Systematic search results

The systematic search resulted in a total of 13,747 unique articles of which we included 148 publications (see experimental procedures for exclusion criteria and Figure S1 for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [PRISMA] diagram). The publications included 225 studies with a total of 327,778 farmers from 23 European countries. A study was characterized based on geographic location (country, province, town the study was conducted in), type of behavior (intention or adoption), type of practice, and farmer group (i.e., one publication can contain multiple studies see Table S2). A total of 522 individual observations of motivational factors (effect sizes) were obtained from the studies for further use in the meta-analyses. Motivational factors were first identified by a bottom-up approach (based on earlier reviews of farmer decision-making and human adaptation behavior, e.g., Dessart et al.[26] and van Valkengoed & Steg[24]), and subsequently categorized following behavioral frameworks, models and theoretical definitions (see Steg and Vlek[49] and section "systematic search and inclusion/exclusion criteria" for details).

Characteristics of studies on farmer motivations

Motivational factors for adoption of sustainable agricultural practices were predominantly studied in Western and Southern Europe, with Germany, United Kingdom, Netherlands, and Italy each covering more than 10% of studies (Figure 1A). In contrast, Portugal, Norway, and Central and Eastern European countries are each studied less than five times. In particular, countries in Southeastern Europe are rarely studied (no studies, except Greece). Agri-environmental measures (i.e., practices related to CAP agri-environmental and climate measures) are dominantly studied, followed by adapted technologies, and adapted cropping practices (Figure 1B). Technologies are mainly studied in Northwestern Europe. Ecosystem practices are studied throughout Europe, although predominantly in Western and Southern European countries.

Effect sizes motivational factors

All meta-analyses found a significant effect of motivational factors on adoption behavior (Figure 2 and Table S3). Our models showed that general attitude, intention, perceived usefulness, ease of use, negative affect, and perceived behavioral control are the strongest predictors of farmers' adoption of sustainable agricultural practices (summary effect size $r > 0.30$; Figure 2). We found moderate effects for experience and subjective norm ($r = 0.20–0.30$), while environmental outcome, openness, environmental attitude, risk, economic outcome, and environmental awareness had weak relationships with adoption behavior ($r < 0.20$). Perceived usefulness, ease of use, negative affect, and perceived behavioral control show substantial variability, whereas all other motivational factors showed smaller dispersion. Experience, subjective norm, environmental awareness, and economic outcome showed less variability.

Our moderator analysis showed that correlations differed depending on the type of behavior: intended and actual behavior (Figure 3 and Table S4). For eight motivational factors, actual behavior shows a smaller effect size than intention. In contrast, negative affect, experience, environmental outcome, environmental attitude, and risk show higher and significant effects for actual behavior compared with intention. For almost all factors, intended behavior had a higher effect, however not statistically significantly different from the reference category (Table S4). Only one model (negative affect) showed a significant difference between both intention and actual behavior. This indicates a potential overestimation of effects of motivational factors on the actual adoption of sustainable practices. Our second moderator analysis showed that correlations were rarely statistically significantly different depending on the type of sustainable practice, likely because of too few studies in the respective subgroups (Table S5).

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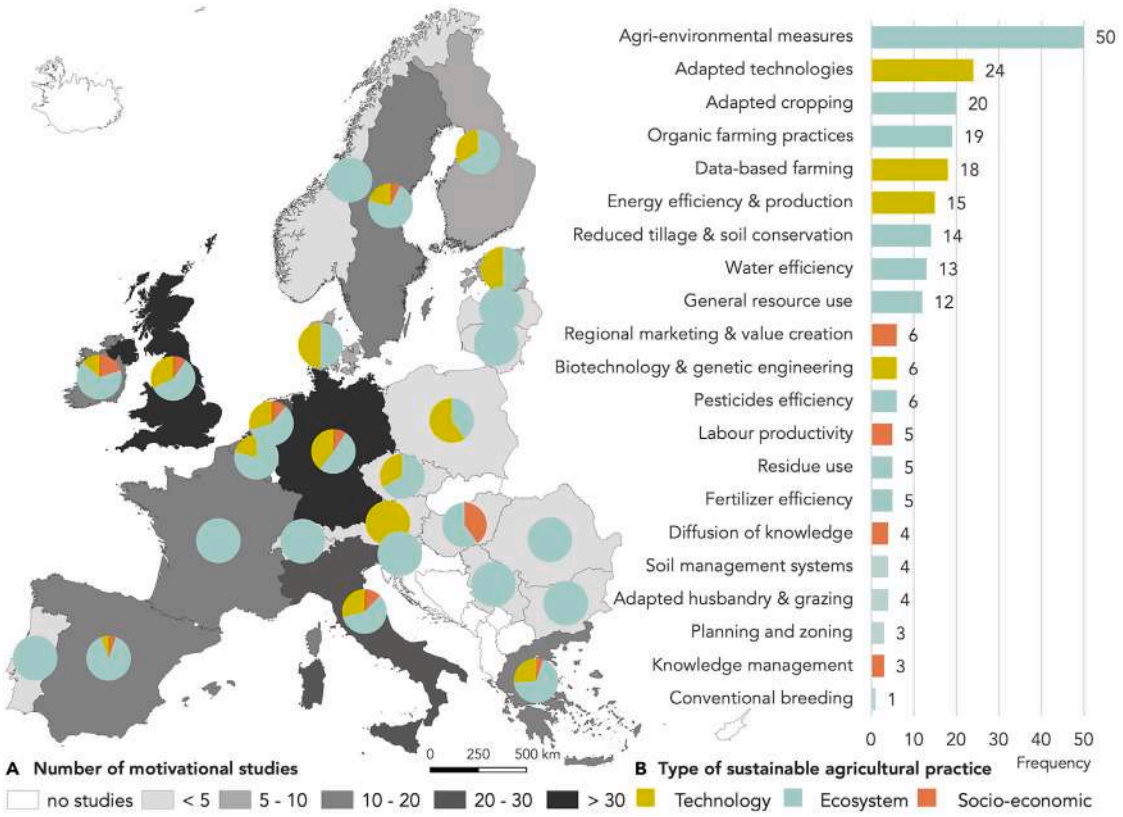

Figure 1. Overview of geographic and thematic characteristics of motivational studies for adopting sustainable agricultural practices in Europe

(A) Circle diagrams represent types of practices studied per country (technology, ecosystem, and socioeconomic). Map shows total number of studies per country. (B) Bar graphs shows types and frequency of sustainable agricultural practices in Europe. We used the conceptual framework of sustainable intensification by Weltin et al.[19] to group our studies into types of practices.

Study effort and importance

We found that the motivational factors, awareness environment and economic outcome, had high overall study efforts compared with their relatively low effect size (Figure 4). Decomposed by the type of sustainable practice, economic outcomes and perceived usefulness are factors that are extensively studied in relation to technologies, each with more than 10% of all observations (Table S6). Experience and subjective norm had the highest study effort (>60 observations) for all types of sustainable practices, with moderate importance (effect size: 0.20–0.30). In contrast, less researched motivational factors such as negative affect, general attitude, ease of use, and intention (15–40 observations) are understudied compared with their respective importance (effect size: 0.30–0.50). Moreover, these factors are underrepresented for all types of sustainable practices (<10% of total observations).

DISCUSSION

Sustainable agriculture plays a crucial role in achieving sustainability targets and transitioning global agricultural systems, yet we lack generalizable knowledge on why farmers apply these practices. In this study, we identified motivational factors influencing farmers' adoption behavior, which, based on our meta-analyses, resulted in three key findings. First, we found a strong imbalance in the published articles regarding geographic focus (mostly on Western and Southern Europe) and thematic focus (mostly on agri-environmental measures). Second, all motivational factors had a significant effect on the adoption of sustainable agricultural practices; however, we found substantial differences in strength of the effect between motivations, with, for example, general attitude, intention, and perceived usefulness having stronger positive effects compared with perceived economic outcomes and environmental awareness. In addition, we detected a mismatch between research effort in relation to factor effects (most effort on factors with intermediate effects). Third, we found different effects between type of behavior and motivational factors. Actual behavior showed lower effect sizes as compared with intended behavior, implying that the effect of motivational factors on adoption might be overestimated by studies focusing on behavioral intention.

Imbalance of geographic and thematic focus

The studies included in our sample showed a geographic focus on Western and Southern Europe. This imbalance has also been observed in studies on landscape change drivers[43,50] and land use decision-making,[51] in which mainly Eastern and Central European countries are underrepresented. Previous narrative reviews on farmer decision-making also identify the dominance of Western European case studies,[32,34,52] potentially explained

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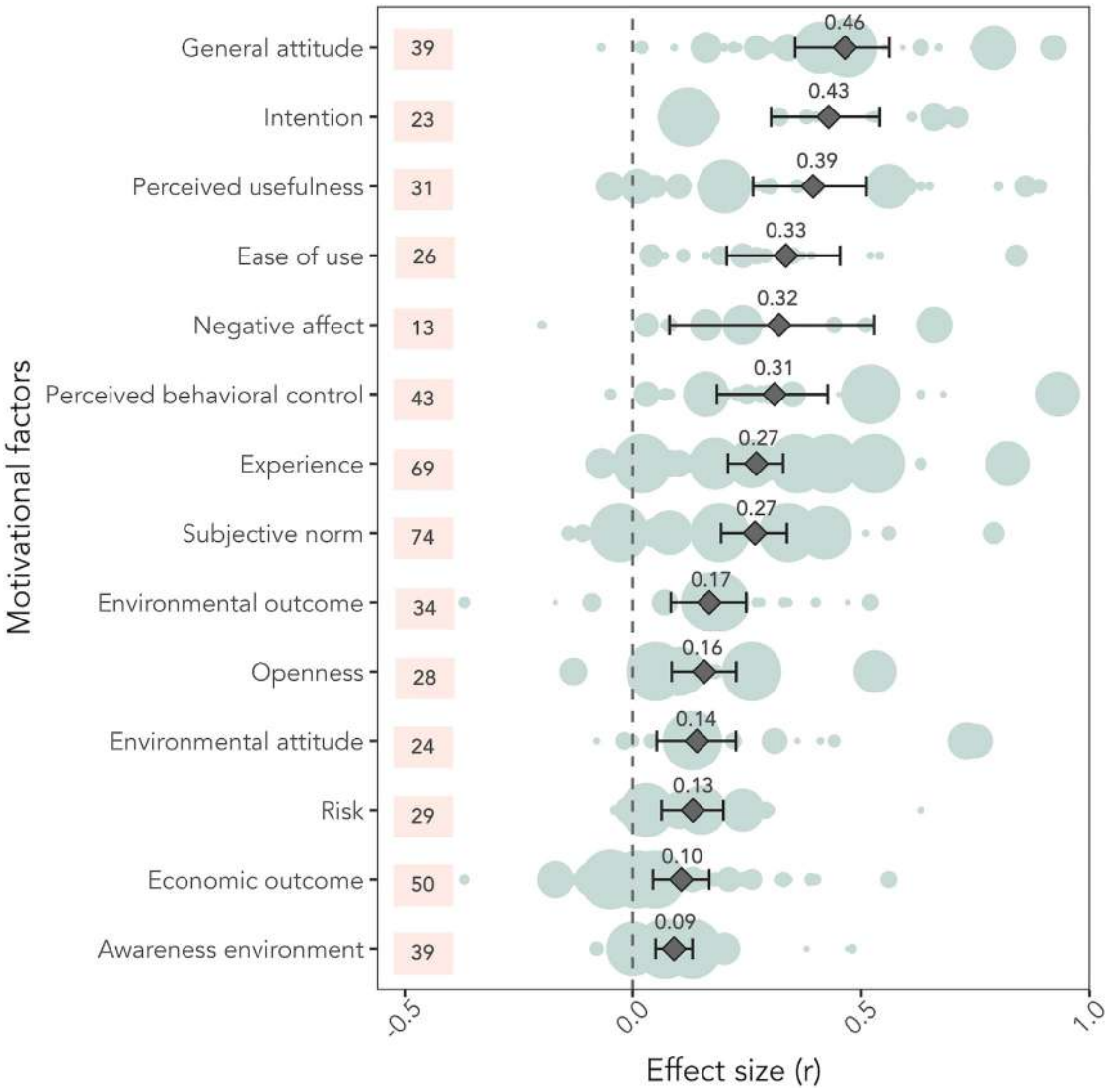

Figure 2. Mean summary effect sizes for 14 motivational factors of adoption behavior of sustainable agricultural practices

Effect sizes are expressed as Pearson *r*, error bars represent 95% confidence intervals (CIs). Pink boxes show individual observations per factor (studies can contribute multiple times per meta-analysis). Blue circles show studies and their size represents the number of farmers per study. See also Table S3.

by the late accession of the Eastern European member states to the EU.[33] CAP agri-environmental measures are dominant in our sample (also detected by Bartkowski and Bartke[33]), which could be an explanation. This geographic focus makes it difficult to generalize the results beyond Western and Southern Europe. The importance of voluntary schemes to the implementation of agri-environmental measures in the European CAP might explain the strong thematic focus on agri-environmental measures (25% of studies). Another reason for a geographic imbalance could be our selection of publications in the English language, which misses publications in languages other than English (e.g., local case studies published in the countries' official language).

Importance of motivational factors

We found a positive significant effect of all motivational factors on adoption behavior. Our ranking of factors according to their importance in explaining farmers' adoption behavior is largely in line with the literature. Although heavily understudied, we find the strongest relationships with constructs of socio-psychological models, which confirms the significance of behavioral frameworks.[53–55] Our results compare favorably to a global meta-analysis on motivations for climate change adaptation behavior[24] and a scoping review that emphasizes the role of perceived benefits for the farm.[13] For example, Belgian farmers who had a positive attitude toward reducing pesticide use[56] and German farmers who perceived grazing practices as useful and easy[57] showed higher adoption behavior. In Serbia, farmers' positive attitudes determined the adoption of integrated pest management.[58] Moreover, subjective norms were influential as people with close relationship to farmers approving of agroforestry increased adoption of that practice for Swiss farmers,[59] while in the Netherlands mitigation measures were implemented

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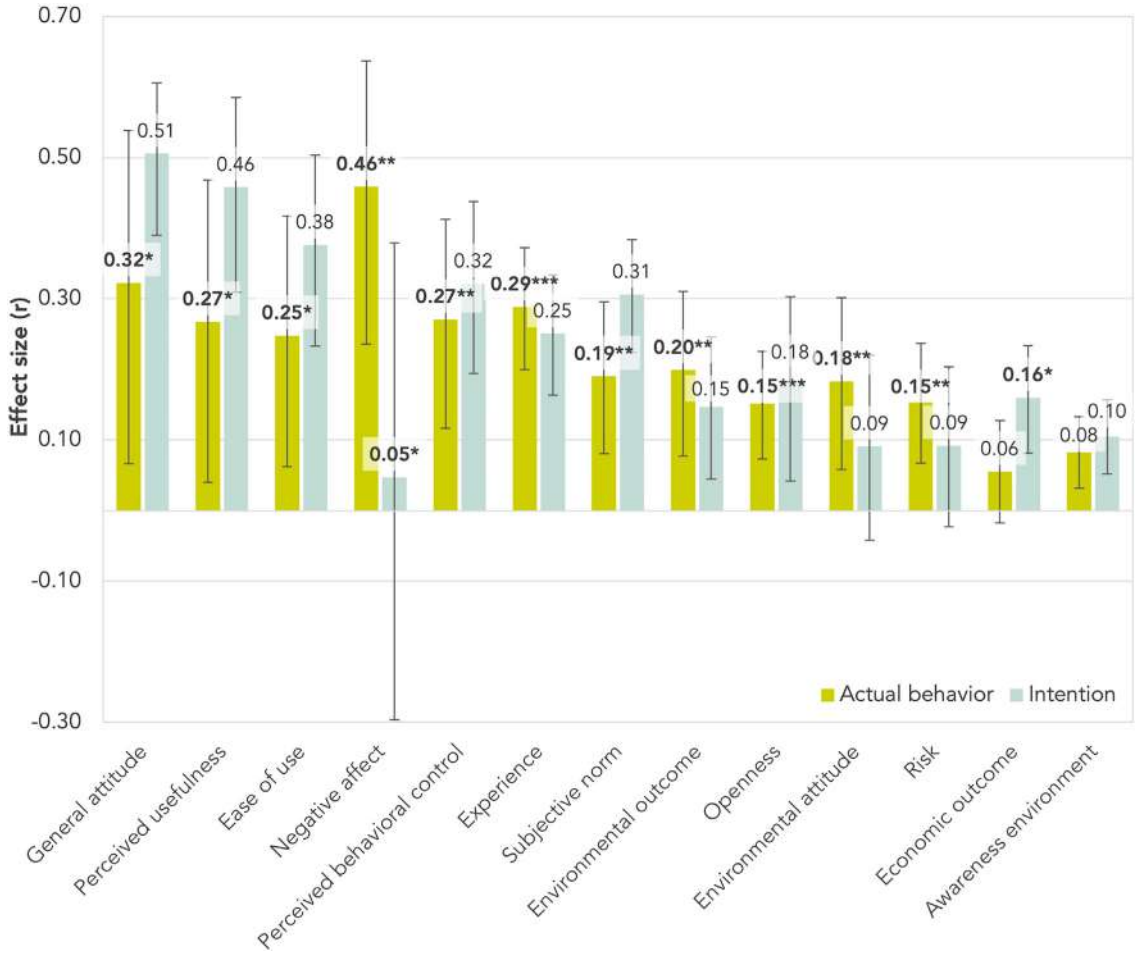

Figure 3. Moderator analysis for type of behavior per motivational factor

Yellow bar = actual behavior. Blue bar = intention. Effect size in Pearson *r*. Error bars depict 95% confidence intervals (CIs). Bold values highlight the statistical significant effect of the factors, while asterisks indicate the level of significance (*p < 0.05, **p < 0.01, ***p < 0.001). See also Table S4.

more when farmers detected the use by other farmers.[60] As expected, farmers' attitudes toward sustainable agricultural practices and the perceived social norms were important predictors of their adoption.

We do, however, detect that essential psychological constructs explaining pro-environmental behavior (e.g., value-belief-norm theory [Stern et al.[61]]) are hardly studied: negative affect (negative emotions toward environmental problems), ascription of responsibility (feeling of responsibility for environmental consequences), personal norms (moral obligation), and self-focused emotions (emotions people feel in response to environmental behavior).[48] Our moderator analysis confirms the importance of factors that capture emotional involvement,[62] as negative affect had a high correlation with the actual adoption of sustainable practices (Figure 3). For instance, in Romania[63] and the United Kingdom,[64] farmers who are concerned and worried about the environment were more likely to change toward organic farming.

The smallest effects were found for environmental knowledge and economic motivational factors, which leads to two key implications. First, despite a scientific focus on farmer knowledge and awareness (40 observations in our analysis), we found that in practice environmental knowledge was a weak predictor for the adoption of sustainable agricultural practices. This result aligns with other reviews of pro-environmental behavior[62] and adaptation.[24] Despite this weak effect, environmental consciousness and pro-environmental behavior are generally prominent factors mentioned in discussion around farmers' adoption of sustainable agriculture.[30,35] In fact, in the broader literature ignorance is seen as a key barrier to human climate change mitigation.[65] It is important to note that 80% of our studies measured motivational factors, such as environmental knowledge, in isolation or as direct predictors (a phenomenon also detected by Sok et al.[27]), and hence relations between motivational factors are unknown. Environmental awareness could in fact be related to general attitudes or other mediating factors such as environmental outcome and environmental attitudes.[62] Meta-analysis estimating effect sizes across studies using the same variable either in a direct or indirect way is imperfect, but there are few alternatives to this approach. Structural equation models offer potential to explicitly model the dependencies between factors,[66] yet this was not possible for our analysis due to inapt input

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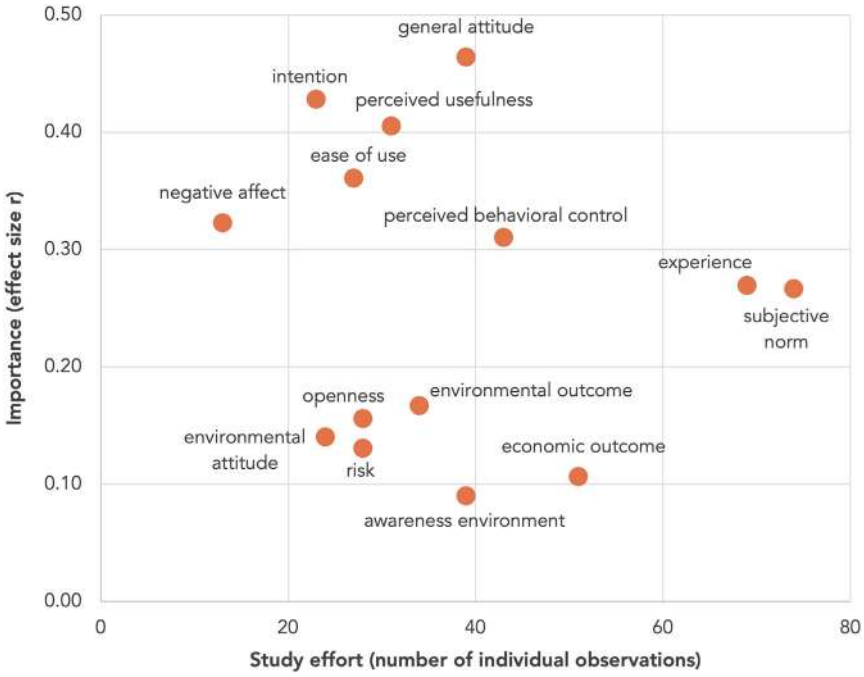

Figure 4. Comparison between the importance of motivational factors for farmers' adoption behavior of sustainable practices in relation to study effort

data. Therefore, it is essential to include the interconnectedness with other motivational factors in future primary studies assessing farmers' adoption behavior, and not solely focus on factors (such as environmental awareness) in isolation.

Second, economic outcomes is one of the most frequently mentioned incentives or constraints for the implementation of sustainable agriculture in both policy (CAP) and literature.[13,21,33,34] Farmer adoption literature is dominated by economic theory,[21,34] where farmers are seen as rational agents following utility maximization model.[67] As an illustration, a recent review[13] counted the number of studies that measure short-term economic benefits and, based on that analysis, concluded that short-term economic benefits were important. If our review employed the same vote counting method, we would have arrived at the same conclusion (as it is studied a lot). However, our empirical evidence showed that the effect size for economic benefits was relatively low, in particular for actual adoption (Figure 3), and was therefore less important for farmers' adoption behavior. Another explanation for the difference is that Piñeiro et al.[13] addressed incentive-based programs (i.e., interventions), for which they find that market and non-market incentives had a higher adoption rate compared with those providing ecological services, especially for those incentives targeting environmental outcomes and profitability. In contrast, our study addresses farmers' perceived economic outcomes as motivation to adopt a sustainable practice. This difference is noteworthy, as it suggests that incentives (that clearly outline economic benefits) have the capacity to influence farmers' decision-making, while the anticipation of such effects has a considerably lower impact.

Yet, this finding does not imply that economic perceptions are not of importance. Factors such as perceived usefulness and ease of use (self-efficacy) are closely related to economic perceptions, as is perceived behavioral control.[68] Moreover, attitudes are shaped by behavioral beliefs, of which economic beliefs can be an important part. For example, Italian farmers who perceived the implementation of precision farming as useful did that because of perceptions of economic suitability.[69] Irish farmers were more likely to adopt grassland management practices when they perceived lower resource constraints in terms of costs and labor.[70] One explanation for the low effect size of perceived economic outcomes could be that practices related to this factor are rarely economical under current market conditions. Hence, farmers who adopt such practices likely do not face economic constraints. If market conditions were to change so that sustainable farming would result in (higher) economic benefits, the effect of this factor would potentially increase. In the end we observe that, while acknowledging the complexity of economic motivations, only looking at economic factors is limiting our perspective on farmers' adoption of sustainable agriculture.[62,71]

The meta-analyses detected large heterogeneity between studies (Table S3), implying that contextual factors play a role in the relationship between motivational factors and adoption behavior. The variety in contexts and differences between countries, land use legacies, and for instance access to resources such as information and agri-environmental payments, affect the ability of farmers to implement sustainable agricultural practices; however, the data did not allow us to test for this directly.

Intention-behavior gap

About half of the studies in our meta-analyses measure farmers' intentions instead of actual behavior. Intention is often defined as the most important predictor of behavior.[53,54,72] Confirmingly, we found a relatively strong relationship between intention and adoption behavior ($r = 0.41$). However, intention does not necessarily lead to the implementation of sustainable agricultural practices. In fact, psychological literature suggests that intention leads to action for only about half of the individuals, the so-called intention-behavior gap.[73] Our moderation analysis supports this, as we found a difference in the overall effect size if the outcome is measured as actual behavior or intended behavior, implying that the effects of motivational factors on the actual adoption of sustainable agricultural practices might be overestimated (Figure 3). In the context of adoption of sustainable agricultural practices, this has been linked to the problem of (limited) action space that farmers have, a concept related to perceived behavioral control in TPB (Theory of Planned Behavior).[68] Literature proposes many constructs and interventions for reducing the intention-behavior gap: e.g., aligning intentions with moral norms,[74] if-then planning and monitoring progress,[73] or

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perceived self-efficacy and action-control.[39,75] This again emphasizes the importance of studying various motivational factors for farmers' adoption of sustainable agriculture to reduce the intention-behavior gap: knowledge about farmers' attitudes, their perceptions of (positive) outcomes, and beliefs of the farmers' own capabilities to maintain sustainable agriculture. Moreover, awareness of this gap is important for decision- and policy-making processes because currently most studies focus on intention or willingness (see for instance Piñeiro et al.[13]; van Valkengoed and Steg[24]). Conducting longitudinal studies that assess both intention and actual behavior would have great potential to further quantify the intention-behavior gap and to provide more detailed information about farmer motivations.[31]

Methodological considerations

The quality of any meta-analysis results is limited to the data it is based on.[76] Behavioral frameworks like the Theory of Planned Behavior tend to be inconsistently applied,[31,77] for instance not following exact guidelines to measure socio-psychological constructs such as attitudes,[25,27] which can lead to biased results.[78] Specifically, one cause for potential overlap is that many studies entered in our analyses do not clearly operationalize motivational factors, or provide a theoretical backing for their choices, which is especially problematic when researchers' definitions are determined post hoc. A potential solution could have been to report on further disaggregated factors. However, as a large share of studies only report statistics over broader factor categories, this is not feasible. The problem of inconsistent categorization in meta-analyses is well-known,[78] yet not easy to solve. Nevertheless, the motivational factors that might be most sensitive to such overlap all score high on importance as compared with many of the other factors concerned (e.g., ease of use and perceived behavioral control have similar effect sizes, so do attitude and perceived usefulness, see Figure 4). Hence, the main insights remain valid even with this potential overlap.

Moreover, despite heterogeneity in the included studies and individual issues of the studies, for instance due to sampling and interviewer bias,[79] we believe that our quantitative synthesis offers useful insights.[80] The results are based on a large number of observations, followed behavioral frameworks and the constructs defined by authors, applied three-level meta-analysis models, conducted robustness checks, checked for outliers, and tested for publication bias. Publication bias might influence our results, as small studies with insignificant lower effect sizes are often not published.[81] In the end, we detected publication bias (small-study effect) only for economic outcome and experience, implying a neglectable lower summary effect size than our results currently show.

The choice of meta-analysis methods and the way we applied them arguably influences results as well. We acknowledge that the coding process and the definition of motivational factors, although fully based on seminal literature and good practice documents, is inherently subjective. A different coding scheme executed by a different coding person(s) would likely result in a different grouping of studies, which can arguably affect results. Further, our definition of the search string and the restriction on publications in English language bears the risk of omitting relevant studies. We also highlight that the results of our moderator analysis regarding the type of practice must be interpreted with caution as several subgroups contained only a small number of studies. Studies of farmers' behavior often happen in a niche that is separate from the general study of pro-environmental behavior among members of the general public. Still, their decision-making has strong similarities with other societal groups, as farmers are influenced by, for example, social norms as well. Farmers tend to implement practices when adoption is easy and useful, and if they perceive control over their behavior, which aligns well with results of reviews about human pro-environmental behavior.[65,66] We are confident that our findings regarding farmers' behavior are generally comparable to insights from environmental psychology. However, while the studies we used in our analysis employ theoretical concepts of farmers' behavior based on general environmental psychology, they often overlook, or pay less attention to, other concepts that can explain pro-environmental behavior, such as values, beliefs, personal norms, and emotions.[48,49]

Policy implications

Increasing farmers' adoption of sustainable agricultural practices requires focusing on motivations that actually influence farmer behavior: emotional and socio-psychological factors. Attitude was the strongest predictor of practice uptake in our analysis. However, we caution that this result has to be interpreted with care, as studies assessing attitude tend to apply theories (i.e., Theory of Planned Behavior and Value-Belief-Norm Theory) inconsistently and operationalize constructs in different ways (see Delaroche[25] and Sok et al.[27]). Also, attitudes are the result of multiple behavioral beliefs, which can partly overlap. On a practical level, these factors could be addressed through education, training, or exchange with other farmers.[33] Social networks such as farmer organizations, but also neighbors or other people important to farmers, can influence perceived social norms. Moreover, attitudes can be influenced through different information provision interventions, such as information about the consequences of environmental change or about the benefits or costs of certain behaviors.[48] For example, farmers may perceive their production system less positively after they learn about the environmental degradation it causes, and, because of their changing attitude, might adopt sustainable practices in response. Public and private extension services, as well as information and technical assistance, provide opportunities to enhance the rate of adoption as they influence understanding of the practice and hence ease of use, perceived usefulness,[13] and perceived behavioral control (e.g., through self-efficacy). Another option is participatory policy design or other forms of farmer involvement such as collaborations between stakeholders, as this might increase sense of ownership and stewardship,[44] thereby farmers' feelings of responsibility for the environment, enabling adoption of sustainable agriculture. However, despite being more influential on farmers' adoption behavior, emotional and socio-psychological factors remain difficult to address, especially for farmers with an established mindset and work style.[82] Yet, there might be a window of opportunity with generational change in farm ownership, as intergenerational knowledge transfer can spur the development of sustainability and because young farmers are more likely to implement sustainable practices.[35,83,84]

Our results have clear policy relevance, as they can inform the upcoming reform of the EU CAP in 2027, as well as related

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strategies (such as Farm2Fork), and suggest reconsidering the currently strong emphasis on economic factors to influence farmers' decision-making. Instead, policies could focus on transparency, farmer engagement, education, training, and communication to stimulate the adoption of sustainable agricultural practices on farms in Europe. We must note that the bias in the geographic spread of studies impedes the application of our findings to the entirety of Europe. This is especially true for farmer realities in Eastern Europe that are not well represented in the existing body of literature and hence potentially in policy making, which calls for increased research efforts in currently understudied regions. However, as farming systems in Western Europe are among the most intensively used systems in Europe[85] with strong environmental externalities, the focus on this region in the body of literature is understandable and addresses a region with strong needs for transforming its farming systems. Although European agriculture has a specific historic development and particular social and biophysical characteristics, our results can be indicative for farmers' adoption of sustainable practices in other world regions characterized by industrial and consolidated agricultural systems[86] that face similar sustainability challenges. For example, both conservation intention and action (i.e., actual behavior) could be explained by attitudinal factors in the United States, while the current or previous application of conservation practices only influenced actions, not intentions.[29]

We show, in line with existing research, that farmer adoption behavior in Europe is more nuanced than the current predominant focus on economic rationale,[71] and broader perspectives beyond economic aspects are needed.[26,87] A recent study found that European national policymakers and advisors solely focused on rational economic considerations, leading to an imposition of productivist policies on farmers,[34] despite evidence that farmer behavior is influenced by a more diverse set of factors.[26] Based on this, policy making in general, and CAP in particular, seems to address motivational factors insufficiently. Although attitudes, values, and norms are more difficult to address than economic outcomes, it is more likely that addressing these factors would be more effective, as evidenced by our results. Van Valkengoed et al.[48] provide an overview of behavioral determinants linked to interventions, which is useful in targeting motivational factors to fit in local policy and cultural context. Policies should focus less on economic outcomes and environmental knowledge, by expanding their focus from pure payments-based schemes[44] to also consider and target socio-psychological factors for which strong, significant effects on farmers' adoption behavior can be found in the literature. Efficiently and effectively targeting motivational factors that positively affect farmers' adoption behavior of sustainable practices will hence contribute to achieving a sustainability transformation in Europe's agricultural system.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Further information and requests for resources and reagents should be directed to and will be fulfilled by the lead contact, Rebecca Swart (rebecca.swart@vu.nl).

Materials availability

This study did not generate new unique materials.

Data and code availability

Meta-analysis coding sheets, input data, and r code generated during this study have been deposited at DataverseNL under https://doi.org/10.34894/RUOI2S and are publicly available as of the date of publication. Any additional information required to reanalyze the data in this paper is available from the lead contact upon request.

Meta-analysis

To address our research questions, we used meta-analysis, a statistical synthesis of results from a series of studies that are collected in a systematic way.[37] We follow systematic review guidelines and PRISMA standards.[88]

Systematic search and inclusion/exclusion criteria

We searched the current body of literature (July 2020) for studies that described farmers' adoption behavior of sustainable agricultural practices (Figure S1 for PRISMA literature search). Search terms were selected using a systematic method based on existing reviews on farmers' adoption behavior of sustainable agricultural practices.[21,26,31,33] We defined *adoption behavior* as any actual behavior or intention to adopt sustainable agricultural practices, e.g., the uptake of technologies or participation in agri-environmental programs. For example, "adoption," "decision," and "implementation" were used as keywords (Figure S2 for full search string). We based the search terms for *sustainable agricultural practices* on a recent review by Weltin et al.[19] and included all farm-level practices such as precision farming, agroforestry, legumes, reduced tillage, and soil conservation.

We conducted an online literature search in the Web of Science database and selected English publications. Calibration and validity of the search string was done by verifying that case studies from a set of review papers also appeared in the search results. We adjusted keywords to include articles referring to, for instance, organic farming and sustainable agriculture, which were missing in our initial search. We applied four criteria to filter search results and construct the database for our analysis. First, we selected all articles that explicitly focused on Europe. Second, we only included articles that reported on sustainable agricultural practices and farmers' adoption behavior. Third, we included only studies that measured at least one motivational factor, which we defined based on the studies on in our meta-analyses, earlier reviews of farmer decision-making and human adaptation behavior,[24,26,35] and behavioral frameworks and models that were applied in the articles: Theory of Planned Behavior (TPB),[53,89] Reasoned Action Approach,[72] Technology Acceptance Model (TAM),[55] Norm Activation Model,[90] and for instance self-efficacy[54] (see Tables 1 and S1 and Steg and Vlek[49]). Fourth, we excluded all articles that did not express the relationship between adoption behavior and motivational factors with a statistical metric suitable for meta-analysis, i.e., mean and standard deviations in two groups, *z*-tests, t tests, Spearman's rho, Kendall's tau, Pearson's r, chi-squared tests, odds ratios, standardized regression coefficients, or unstandardized regression coefficients. Every step involved validation by co-authors, for which we screened 20% of the current number of articles and compared filtered results across assessors. Our internal validation resulted in a 95% similarity between assessors.

Eleven articles that fulfilled all criteria did not provide sufficient detail on the statistics (e.g., missing standard deviations), and we contacted the lead authors of whom only one responded and provided suitable metrics. We coded a final selection of 148 articles that contained a total of 225 studies, representing a sample of 327,778 farmers from 23 European countries. A study was characterized based on geographic location such as country, type of adoption behavior (intention or adoption), type of sustainable agricultural practice, and sample group (e.g., both an article that describes adoption of sustainable agriculture in Belgium and France, and an article measuring both adapted cropping and flower strips, result in two studies that are coded in our analysis). We checked the actual measurements of constructs for our coding, i.e., statements and survey questions for each category (e.g., economic outcome or environmental outcome). Publications that applied TPB or TAM, we checked with less detail, but ensured that researchers measured constructs correctly and followed guidelines. Motivations reported in fewer than five cases were excluded and because of unclear study design or theoretical overlap (e.g., descriptive norms and injunctive norms in subjective norms) some motivations

were merged into one category, resulting in our final list of 14 motivational factors (Table 1). Importantly, all factors related to farmer perceptions, such as environmental outcomes, perceived usefulness, but also economic outcomes, were measured with Likert-scale variables in the original studies. All perception-related factors assess the perception farmers have about future effects of the adopted practice, e.g., on production, profit, or biodiversity. In total, we used 522 effect sizes (i.e., individual observations for a motivational factor for a study case) for the meta-analyses (see Table S2 for included studies and original data).

Effect size calculation and meta-analyses

As there was high heterogeneity between studies, we set up a three-step procedure to make effect sizes comparable. First, if studies reported multiple effect sizes for measuring the same motivational factor (e.g., multiple variables measuring environmental awareness or descriptive norms), we pooled effect sizes by averaging individual effect sizes into one summary effect size.[37,91] Second, we reversed the signs of effect sizes where applicable to report solely on positive effects (following standard methods, see van Valkengoed and Steg[24,37]). For example, if a study reported high perceived difficulty and therefore farmers were less likely to adopt a practice, we reversed this factor. We reversed signs to maintain our way of interpreting effect sizes consistent and to allow the factors to work in the same causal direction. The assumed symmetry could have affected the results; however, reversal of signs was rarely the case (mostly for the "risk" and "ease of use" category, see original data). Third, we converted all effect sizes to Pearson's *r* to allow comparisons between studies[24] (Table S7). Before conducting meta-analyses, we checked for normal distribution of effect sizes, and afterward we ran outlier analyses (Figure S3 and Table S8).

We ran multilevel random-effects meta-analysis models on our final database (see "data and code availability") to account for studies that contributed more than one effect size to the meta-analysis (e.g., subgroups or multiple outcomes).[76] Meta-analysis models used inverse variance weights and restricted maximum likelihood estimation. We ran our models for each motivational factor independently, resulting in 14 meta-analysis models. We calculated two heterogeneity variance parameters for each model: within-cluster heterogeneity (heterogeneity due to differences within studies) and the between-cluster heterogeneity (heterogeneity caused by between-study differences). To compare performance of the models, we checked if nesting of individual effect sizes improved our model by fitting a model in which between-cluster variance was set to zero. Likelihood ratio tests showed that 50% of our meta-analysis models favored a three-level model (Table S3). Nevertheless, from a theoretical perspective the three-level model accounted better for the hierarchical structure of our data (i.e., the design of the included studies), without harming model performance and inference.

Last, we tested moderators (or subgroups) of the overall factor effect to detect systematic differences between studies in a meta-analysis. We analyzed the difference of the type of behavior (intended and actual behavior) and the type of sustainable practice (technology, ecosystem, socioeconomic) for each meta-analysis by using mixed-effect models with random effects on the study level to explain heterogeneity patterns in our data (Tables S4 and S5). Analyses were conducted in R (2022.02.3) using the metafor package (version 3.4–0) and dmetar package (version 0.0.9000).

Robustness checks and publication bias

Between-study heterogeneity was further inspected by running models without outliers and influence analyses to identify studies with high influence on the pooled results and high contribution to overall heterogeneity following.[92] Studies were defined as statistical outliers when their 95% confidence interval was outside the 95% confidence interval of the pooled effects. We found no effect for the summary effect size of eight meta-analyses. However, we identified a neglectable influence for attitude, perceived usefulness, ease of use, negative affect, and perceived behavioral control (lowering between-study heterogeneity, narrowing prediction intervals, and lowering effect sizes) (Table S9). Yet, the overall results compared with the original meta-analyses (including outliers) remained unchanged.

The occurrence of publication bias was assessed using Egger's regression test[93] for every meta-analysis (Table S10). Egger's test identified small-study effects for the experience and economic outcome meta-analysis (the intercept differs significantly from zero see Table S10 and funnel plots Figure S4), whereas the other meta-analyses did not indicate presence of funnel plot asymmetry.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2023.10.028.

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AUTHOR CONTRIBUTIONS

Conceptualization, R.S., C.L., J.D., and P.H.V.; Methodology, R.S. and J.D.; Validation, R.S. and P.H.V.; Formal Analysis; R.S., C.L., and J.D.; Writing – Original Draft, R.S., C.L., and P.H.V.; Writing – Review & Editing: R.S., C.L., J.D., and P.H.V.; Visualization, R.S.; Supervision: C.L. and P.H.V.; Funding Acquisition: P.H.V.

DECLARATION OF INTERESTS

The authors declare no competing interests.

INCLUSION AND DIVERSITY

We support inclusive, diverse, and equitable conduct of research.

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