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Farmers' adoption of ecological practices: A systematic literature map

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Abstract

Understanding the factors associated with adoption of ecological farming practices is a well-established topic of interest to agricultural economists. As the transition to more sustainable agriculture has become a policy priority for the European Union, broad and balanced reviews of this literature are important. We develop a systematic map of quantitative observational studies which describes the ecological practice(s) adopted, the frequency of inclusion and significance of a range of independent variables, and how the dependent variable is measured. We also conduct a quality assessment. We find that while socio-demographic variables and farm structural variables are frequently included, they were insignificant more often than they were significant. For behavioural factors we find stronger evidence for the importance of cognitive or attitudinal variables compared to dispositional attitudinal variables. We also find a growing interest in social factors which will be valuable for researchers to explore further and reflect on the policy implications of our findings.

KEYWORDS

adoption, agriculture, behaviour, ecological, practices

JEL CLASSIFICATION

L20, M20, O13, Q12, Q29, Q57

1 | INTRODUCTION

The transition to more sustainable agriculture has become a policy priority for the European Union (EU). The Farm to Fork strategy sets the ambition for a food system that has a neutral or positive environmental impact, can mitigate and adapt to climate change, reverse the loss of biodiversity, and ensure our ability to produce sufficient, safe, and nutritious food (European Commission, 2020). Furthermore, the Common Agricultural Policy (CAP) plans to support climate change mitigation and adaptation efficient management of natural resources, halting and reversing biodiversity loss, enhancing ecosystem services and preserving habitats and landscapes (European Commission, 2021). The adoption of more sustainable agricultural practices by farmers in the EU is essential to the realisation of these ambitions, as is an understanding of what factors encourage farmers to adopt these practices.

Understanding the factors associated with adoption of ecological practices, which are understood as having environmental, economic and social benefits, is a well-established topic of interest to agricultural economists, resulting in a broad literature on the subject. However, recent reviews of this literature have three important limitations. First, many reviews are restricted topically in that they consider the adoption of a narrow range of practices such as precision technologies (Pierpaoli et al., 2013), nutrient and soil management practices (Blackstock et al., 2010), organic production (Lamine & Bellon, 2009) or focusing on a contractual type of adoption such as agri-environment schemes in the EU (Lastra-Bravo et al., 2015). Second, the type of factors are restricted; for example, except for the work of Dessart et al. (2019), few reviews actually include behavioural variables while others pay limited attention to farm and farmers' characteristics (Burton, 2014; Lastra-Bravo et al., 2015; Riley, 2011). Third, there are many narrative reviews, some focusing only on significant results (Dessart et al., 2019) and only a few following a review protocol or conducting a meta-analysis (Baumgart-Getz et al., 2012; Lastra-Bravo et al., 2015; Borges et al., 2019). Overall, this means it is difficult to get a clear assessment of the evidence as to which factors are found to be consistently important drivers of ecological practice adoption, or which are important for some practices but not others.

Topical restriction to a single or limited range of practice types is useful and can be justified by reference to the Theory of Planned Behaviour (TPB) (Ajzen, 1991) or Diffusion of Innovation Theory (Rogers, 1995). The TPB highlights the importance of a clearly defined target behaviour, performed in a specific context over a defined period. When these principles are not applied, application of the theory is inappropriate (Sok et al., 2021). Diffusion of Innovation Theory similarly emphasises that the decision to adopt is influenced by the relative advantage, compatibility, complexity, tribality and observability of the practice in question. While for empirical studies, restricting practices included in the dependent variable is important, it is nevertheless useful in reviews to compare across practice types to understand if attitudes, or complexity, are indeed always important.

In covering the heterogeneous literature on ecological practice adoption, narrative reviews have proved useful. Recently they have highlighted the influence of specific types of factors such as behavioural factors (Dessart et al., 2019) or the limitations of rational actor models (Carlisle, 2016). However, in describing only studies with significant results (Dessart et al., 2019) or not using a systematic approach (Carlisle, 2016) narrative studies do not provide a strong evidence base on which to develop policy or plan further research. On the other hand, the vote count approach—used by Knowler and Bradshaw (2007) and Prokopy (2008) and more recently Borges et al. (2019) in a study on innovation—is a more effective method for understanding and covering the broad range of evidence in the literature of interest as both significant and non-significant results are included. It is also a useful way to identify which factors are most frequently included in studies and which are most frequently found to be associated with practice adoption.

This study reviews the literature on the voluntary and non-contractual adoption of ecological practices from 2010 to 2022, taking a systematic approach. A systematic approach is one where empirical evidence is identified that fits the pre-specified inclusion criteria to answer a particular research question (Snyder, 2019). For this review this means identifying the available evidence for the influence of behavioural, social, formal institutional factors as well as farm structural and socio-demographic factors on adoption of ecological practices. It does this using a vote-count approach, identifying how often a particular variable has been included as an independent variable in adoption studies and how often that variable is found to be significant at the 5% level. We expand on Knowler and Bradshaw (2007) and Prokopy (2008), both in terms of time and scope of practices studied, and we expand the range of independent variables studies compared to Borges et al. (2019). This gives us a broad review of the evidence so we can categorise them by both frequency of inclusion and significance. We also consider these results by type of practice and whether single practices, multiple practices (intensity) or the adoption of a new farming system was considered.

2 | METHOD

We describe our method as systematic because we seek to synthesise and compare evidence, have a specific research question to answer, use a systematic search strategy (including search string and predefined inclusion criteria), include only quantitative articles and seek evidence of an effect in order to inform policy and practice (Snyder, 2019). It is not a full systematic review but rather a scoping (Peterson et al., 2017) or systematic mapping (Pullin et al., 2022) exercise. Although we have a research question to answer, it is broad and we are interested in the amount of evidence available on the research topic, not just the evidence for an effect of one or two variables (Peterson et al., 2017). Furthermore, while a critical appraisal of the evidence is incorporated into the results of a full systematic review or meta-analysis when identifying research gaps, it is optional for systematic mapping (James et al., 2016; Pullin et al., 2022). We nevertheless provide a broad critical appraisal of internal and external validity of the evidence, without excluding articles that were originally mapped.

2.1 | Search string

A search string was developed to identify the population, intervention, comparison, and outcome (PICO) based on previous reviews of the farmer behaviour literature and a review of ecological farm types (Rega et al., 2018) conducted as part of the Low-Input Farming and Territories (LIFT) project.[1] The first part of the string defines our population of interest (Table 1). We included terms that would identify studies where either farmers or agriculture were the subject. The second part identifies the intervention, in our case the practices in which we were interested. This section was derived from Rega et al. (2018) and includes the terms for the ecological farming types as well as the individual practices. We also included additional terms such as 'best management practices', 'sustainab*', and 'environment' based on the titles of previous reviews of the farmer behaviour literature. The final list of practices and farming types included in the query (Table 1) was developed iteratively to remove redundant terms. The terms referring to practices or systems were kept broad enough to cover most sub-types of ecological practices. The third part of the string defines the outcomes we were interested in. Here we included terms such as 'transition' as well as terms common in the individual

[1] www.lift-h2020.eu

TABLE 1 Search terms.

Field	Search terms
TITLE =	farm* OR agri* OR agro*
AND TITLE, ABSTRACT, KEYWORDS =	agroecology OR biodiversity OR diversity OR diversification OR ecological OR ecology OR organic OR integrat OR mixed OR low-input OR extensive OR low-intensity OR permaculture OR conservation OR silvopastoral OR agri-environment* OR ecosystem service* OR agroforestry OR intercrop* OR polyculture OR rotation OR integrated pest management OR IPM OR cover crop OR bio-control OR "best management practice" OR BMP OR fixation OR transhumance OR fallow OR mulch OR precision OR set-aside OR sustainab* OR crop residue management OR environment*
AND TITLE =	adopt* OR adapt* OR behavio* OR behavio* change OR decision OR transition* OR intention* OR participation OR attitude* OR perception* OR determinant* OR conversion OR willingness* OR preference
NOT TITLE, ABSTRACT, KEYWORDS =	Argentina OR Bangladesh OR Brazil OR Cambodia OR Chile OR Colombia OR Africa OR Guatemala OR India OR Iran OR Kenya OR Lebanon OR Malawi OR Mexico OR Nepal OR Nigeria OR Pakistan OR Senegal OR South Africa OR Tanzania* OR Thailand OR Uganda OR Vietnam OR Zambia OR Zimbabwe OR Bolivia OR Uzbekistan OR China OR Ethiopia* OR Philippine OR Honduras OR Costa Rica OR Mozambique OR Laos OR Malaysia* OR Ghana OR mammal*

decision-maker literature such as 'attitude'. We limited our geographic scope to developed countries (Europe, the United States, Canada, Australia and New Zealand), where similar institutions and supply chain structures for food and agriculture are in place. We did this by specifying countries to exclude rather than include so we could avoid excluding relevant studies, as the country of origin was not always included in the title, keywords or abstract. We also excluded studies that referred to mammals based on initial reviews of our results as this helped us to exclude many natural science papers returned by our scoping searches that were not relevant to our objectives.

2.2 | Exclusion criteria

The search query was initially run in the Web of Science and Scopus in February 2019 for peer-reviewed articles, as part of the LIFT project. We re-ran the search query in March 2022 in the Web of Science and Scopus to update our records. We performed a screening of these records based on the title and abstract. The following exclusion criteria were used:

- Wrong country: where these had not been caught by the search string.
- Wrong outcome: the dependent variable of the study was not the adoption of a listed practice or system but rather focused on the intention to engage in a practice, attitude or belief about a practice. For example, those studies that evaluated the efficiency of a practice or its environmental results were excluded unless the study also considered whether those findings affected the adoption of the practice. We use the term 'dependent variable' loosely since we included, at that stage, both qualitative and quantitative studies.
- Wrong population: the population studied was not farmers/growers, for example, the study asked only the opinion of consultants.

- Wrong study design: the study modelled adoption, so results were either simulated or hypothetical,[2] not actual.
- Wrong practice: the study captured compliance with regulation not voluntary uptake.
- Further duplicates or studies where the full text was not available or not available in English.

The same exclusion criteria were applied to the full text review and by reading each paper in more depth we were able to exclude further studies. We also added further exclusion criteria at this stage. These exclusion criteria were:

- Study is a review or theoretical paper.
- Study considers intentions or attitudes or perceptions to adopt, not actual adoption.
- Study focused on adoption of national schemes or programmes as a dependent variable.
- Study is qualitative or descriptive.
- Study was published before 2010.

Review and theoretical studies were retained up until this point as they were used to structure our review, in particular the identification of independent variable categories described below. Studies with national schemes—including agri-environment schemes—as the dependent variable were excluded after the full-text search as many of the independent variables associated with the uptake of these schemes were related to the construction of the scheme (terms of payment, application process etc.). Factors for adoption of these schemes or programmes would have therefore been difficult to compare with the ones of non-contractual adoption of ecological practices. Finally, we decided to restrict the review to those papers that had examined adoption rather than intentions or attitudes to adoption to ensure that the factors we highlight as important have been found to be associated with an actual change in behaviour.

2.3 | Systematic map

The included studies were read a second time to extract information for our systematic map. We extracted information about the construction of the dependent variable and the type of independent variables measured. This process was conducted using an online form for consistency across the researchers. In this way, different articles could be reviewed by the different authors, in a consistent way. The independent variables were classified with reference to existing theoretical and review studies found during the review process. The categories are: personal behavioural; social behavioural; socio-demographic; farm structural; formal institutional.

2.3.1 | Personal behavioural factors

The first category of independent variables we identified were personal behavioural variables derived from several popular behavioural theories. The first two theories are: the TPB (Ajzen, 1991), which asserts that behaviour is determined by behavioural intent, which in turn is determined by three behavioural constructs, namely attitude, subjective norm[3] and

[2]Hypothetical scenarios included experimental studies measuring adoption with stated preferences and could refer to willingness to accept or willingness to pay.

[3] Subjective norm is elaborated below, under social factors.

perceived behavioural control; and the Technology Acceptance Model (TAM) (Davis, 1986), which has similar construction to the TPB but also includes specific attitudes relevant to technology adoption, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). From these two theories we identify two personal behavioural variables: *attitudes towards adoption* (including PU and PEOU), and *perceived behavioural control* (PBC). Both theories emphasise the importance of a close link between determinants and behaviour and for this reason we follow Dessart et al.'s (2019) terminology and call them cognitive behavioural factors.

The second two theories are: the Individual, Social, Material (ISM) model (Darnton & Evans, 2013), which highlights the importance of a person's overall values, beliefs and attitudes (including attitudes to the environment); and Nuthall and Old (2018), whose model of farmer's intuition in decision making highlights the importance of objectives and management style, where the latter concept includes attitudes to risk. Adoption of any new practice incurs some uncertainty about the reliability and performance of that practice (Yu, 2014), and while this uncertainty is captured in the attitudes towards the practice and the benefits it is likely to bring, also relevant is the farmer's disposition, including whether the farmer is a risk taker or is risk averse. Attitudes to risk and management style are considered together in our classification. Following Dessart et al. (2019) we find it useful to refer to these as dispositional behavioural factors, indicating the greater distance between these and the adoption of a particular practice.

2.3.2 | Social behavioural factors

The social factors identified in our models come from the TPB (Ajzen, 1991) and ISM (Darnton & Evans, 2013). From the TPB we take *subjective norms* but extend this to other normative constructs including *descriptive norms*. From the ISM we take the importance of *social institutions*, *networks* and *identity* and identify variables such as participation in farmer networks, identity, use of advisers and membership of organisations.

2.3.3 | Socio-demographic factors

Socio-demographic factors do not feature in the theoretical models described; they are nevertheless included in many of the studies in our sample and in studies of ecological practice uptake generally (Burton, 2014). We therefore map the most included variables from our sample: *farmer age*, *gender of main farmer*, *farming experience* and *education*.

2.3.4 | Farm structural factors and compatibility of practice

Material conditions feature in the ISM model (Darnton & Evans, 2013) but not explicitly in psychological behavioural models such as the TPB. Diffusion of Innovation Theory (Rogers, 1995) includes the concept of practice compatibility, arguing that on-farm conditions such as existing practices used, infrastructure and general conditions are important for adoption of individual practices. We therefore include a variable for practice compatibility, which is often included as a variable in adoption models. We map the most often included variables from our sample that might be considered under the farm-structural category: *farm size*, *farm type*, *tenure* and *land type*.

2.3.5 | Formal institutional factors

Formal institutional factors are derived from the ISM model (Darnton & Evans, 2013) which highlights the importance of wider material conditions such as rules and legislation, infrastructure and technologies. This is wider than the concept of compatibility described above, which focuses on the farm level. Rather the variables identified here refer to the wider context within which the farm operates and includes *supply chain relationships*, *input and output prices* and *participation in national schemes and similar.*

2.3.6 | Practices and practice categories

In the systematic map we identify individual practices or technologies adopted, as described in each study. For example, we might list field edge plantings as a single practice. However, to simplify the analysis we also assign the practice to a practice category; in the case of field edge plantings, it is assigned to the practice category landscape features and habitat. Practice categories were chosen to reflect areas of farm activity such as pest management or fertilisation and soil management. Although the list of practices is not definitive of ecological farming techniques, it is comprehensive—being derived from work under the LIFT project on practices highlighted by ecological farming typologies (Rega et al., 2018; Tzouramani et al., 2019). A mapping of practices to practice categories, as well as the definitions of categories, are further detailed in Supplementary Material S1.

2.3.7 | Dependent variable

Studies were also categorised in terms of how their dependent variable was constructed. We considered first the number of practices that were included in the dependent variable—either one for a single practice, between one and five, or greater than five. We also separated out organic adoption studies because the adoption of organic farming entails the adoption of multiple but well-defined practices over time. In this sense the process of organic adoption is different to, say, the adoption of multiple other practices. We also considered whether the dependent variable was categorical, typically measuring a yes/no decision, or measured intensity using a continuous indicator. Studies with multiple practices or technologies were sometimes still bundled together in a categorical indicator, hence why it is useful to map properties of the dependent variable in two ways.

2.4 | Quality assessment

In addition to the mapping process about the content of the paper, we also undertook a quality assessment of the papers in our systematic map. We were particularly interested in their use and application of theory and measurement of independent variables. The criteria selected were based on a template for rapid evidence assessment critical appraisals for quantitative observational studies (Collins et al., 2015). We added additional variables on construct measurement and removed those that we considered unnecessary because we were only assessing peer-reviewed literature (see Table 2). More specifically, regarding criterion #5, we considered attitudinal variables being measured in a reliable way if the study measured the constructs with multiple items rather than with a single item. Reliability of constructs, which refers to the extent a variable, or a set of variables, is consistent in what it is intended to measure, is improved as the number of items increases (Hair et al., 2014). Concerning criterion #6, the sample was

TABLE 2 Quality criteria and scoring.

Area	Criteria number (#)	Criteria	Scoring
General	1	Are the research questions addressed by the study clearly identified?	Yes = 1/ No = 0
	2	Are the hypotheses addressed by the study clearly identified?	Yes = 1/No = 0
	3	Is related existing research acknowledged?	Yes = 1/No = 0
	4	Are related theories acknowledged?	Yes = 1/No = 0
Method	5	Were behavioural/attitudinal variables measured in a reliable way?	No = 0/Some = 1/All = 2
	6	Is the sample population representative of the population of interest and is it relevant in the context of the research question?	Yes = 1/No = 0
	7	Was the selection of explanatory variables based on sound theory?	Yes = 1/No = 0
	8	Were outcome measures reliable? That is, were they validated or subject to QA process?	Yes = 1/No = 0
	9	Were there likely to be confounding factors not controlled for?	Yes = 0/No = 1
Analysis	10	Were the analytical methods appropriate?	Yes = 1/No = 0
	11	Were multiple explanatory variables considered?	Yes = 1/No = 0
	12	Were confidence intervals and/or *p*-values for the effect estimates given or calculable?	Yes = 1/No = 0
	13	Were the estimates of effects size given or calculable?	Yes = 1/No = 0

considered representative of the population of interest if data was collected through random sampling, based on census data or if the author provided convincing statistics that the sample was representative of the target population. Finally, concerning criterion #7, the soundness of the theory was judged based on the citation of theoretical reference(s) to motivate and explain the inclusion of tested independent variables. We checked for potential subjective bias of the quality assessment by measuring inter-coder reliability. We reached at least 70% of agreement for all criteria except for criterion #5 and #9. Disagreements were then discussed and solved for these two.

3 | RESULTS

A schematic that shows the number of articles included and excluded at each stage of the process is presented in Figure 1. A total of 647 articles (February 2019) and 154 articles (March 2022) were judged to have met the initial inclusion criteria and were given a full text screening. After applying further exclusion criteria, we retained 70 articles for our systematic map that investigated factors affecting the voluntary adoption of ecological practices (Supplementary

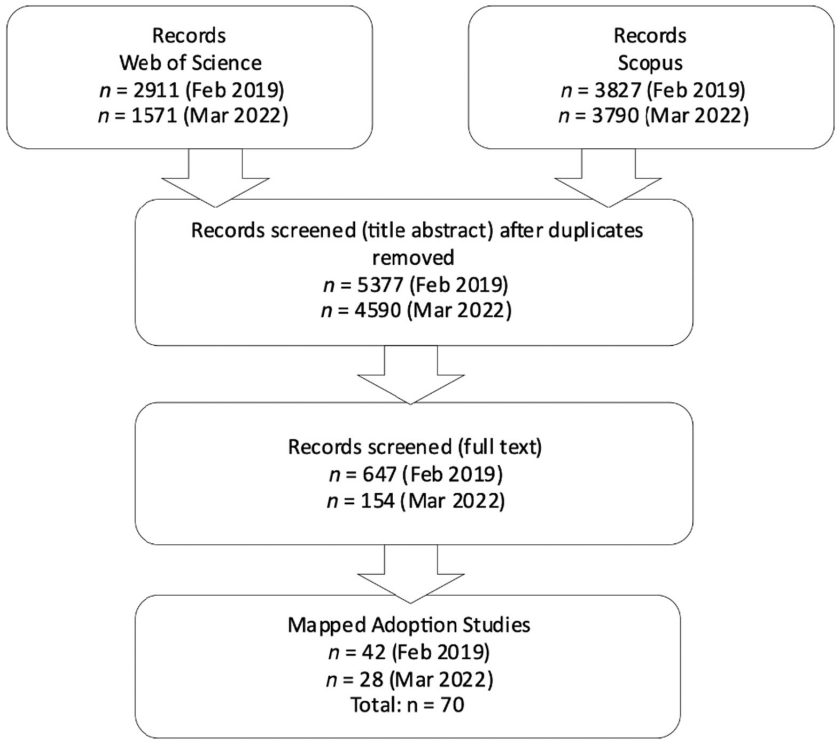

FIGURE 1 Schematic of stages for the systematic map

Material S2). Where the article reported the results of multiple models, each model is recorded separately. There were 110 models reported in our sample.

3.1 | Practice categories

The first variable analysed was how often each practice category occurred. The results are considered by article but where a study investigated practices across multiple categories they are counted separately. Fertilisation and soil management was the most frequently studied practice category ($n=25$), closely followed by precision farming ($n=22$). Crop diversification and rotation ($n=16$) were studied particularly in the last 3 years, whereas organic ($n=14$) was a more commonly studied category prior to 2019. The remaining practice categories were studied fewer than 10 times: pest management ($n=2$), manure and slurry management ($n=3$), landscape features and habitat ($n=8$), livestock management ($n=5$), and weed management ($n=1$). More details of which practices are contained in each practice category can be found in Supplementary Material S1. The systematic map (Supplementary Material S2) also notes further details of the practices.

3.2 | Dependent variable measures and practice count

We found that most studies ($n=55$) employed some sort of categorical measure, primarily a binary yes/no. These included studies on the adoption of the organic systems ($n=13$) not just studies looking at the adoption of single or selected combinations of practices. The remaining studies ($n=15$) used a measure of intensity of adoption as their dependent variable.

The systematic map (Supplementary Material S2) also shows how often the dependent variable consists of single or multiple practices. Here we have four categories, one for single practices ($n = 20$), one for between two and five ($n = 17$), one for more than five ($n = 20$) and another for the adoption of an organic system ($n = 13$).[4]

3.3 | Study design and analysis

All the studies in our final sample were correlative. We removed those described as descriptive or monitoring since they do not provide sufficient information about the association between factors of adoption and adoption. However, we should also note that there were no experimental studies within our final sample. We found that most studies conducted some sort of regression ($n = 54$) with the most common subtype being specified as logit or probit. The remaining articles ($n = 16$) used structural equation, path analysis, multiple correspondence, Markov transition or duration analysis models. The retained correlative models therefore do not prove causality whereas a causality type of terminology may have been used in the retained articles. The systematic map also notes whether the conceptual model for the study was derived from a known behavioural model or not. Only 14 studies mentioned that they were explicitly applying a theoretical behavioural model such as the TAM (Davis, 1986) ($n = 2$), Transtheoretical Model ($n = 2$), Random Utility Model (Greene 2003) ($n = 1$), TPB (Ajzen, 1991) ($n = 5$), Value Belief Norm ($n = 2$) as well as a theory of adaptive capacity ($n = 1$) and social cognitive theory ($n = 1$).

3.4 | Sample size and location

The mean sample size was 791, the median was 424, while the smallest was 38 and the largest was 5000. More details on sample size, type of data, methods and behavioural models used by article are provided in S4. Most of the studies were based in the United States ($n = 29$) followed by the UK and/or Ireland ($n = 9$), and Germany ($n = 6$). There were then four from Italy, three from Australia, Canada, and Switzerland, two pan-Europe studies and two from France, New Zealand and Spain. Finally, one each from the Czech Republic, Denmark, Hungary, Moldova and Northern Cyprus.

3.5 | Independent variables

The most included independent variables were from the farm structural and socio-demographic groups (Figure 2). In the farm group, variables relating to land type, farm type, farm size and compatibility with existing practices were included in 40% or more of the models with farm size being the most included in around 75% of models. In the socio-demographic group farmer age and education were the most frequently included. The least included independent variables came from the formal institutional group of variables, as well as identity in the social behavioural group (Table 3).

In terms of variable significance, we first report on variables that are frequently significant (more than 50% of models) but infrequently tested (less than 20% of models). Most of the

[4]One study (Gachango et al., 2015) included organic farming as one of several options that were incorporated into an intensity dependent variable. This was the only case in our sample where adoption of organic farming system was combined with other practices to create a dependent variable, and hence why the count of organic is different for the practice category compared to the dependent variable.

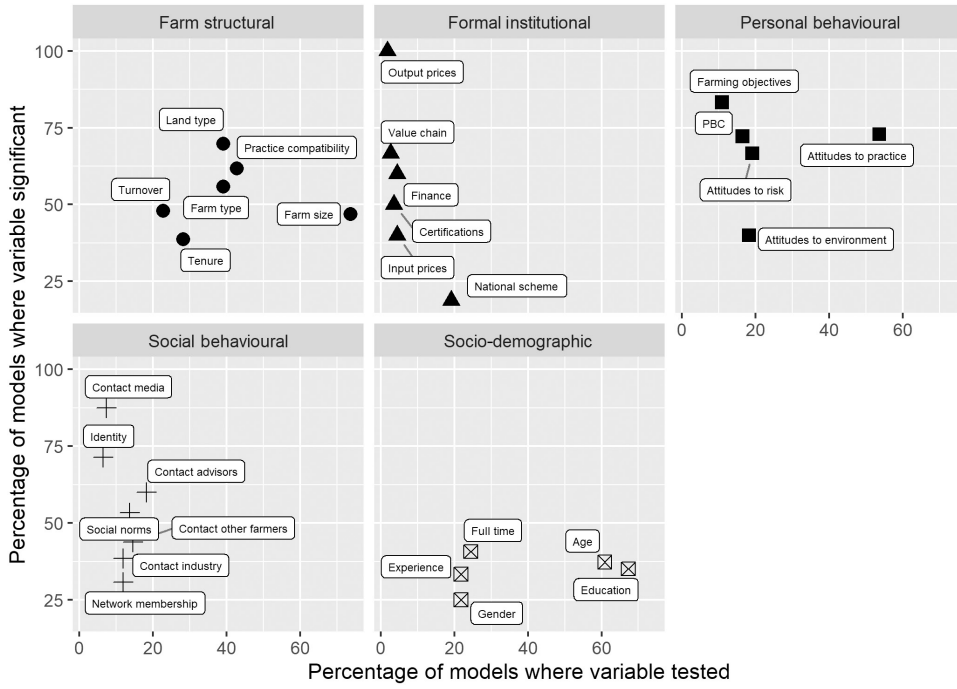

FIGURE 2 Frequency of testing and significance of independent variables (n = 110 – number of models).

variables in the social and personal behavioural groups fall into this category, indicating that available evidence for their importance as factors of adoption is positive, but there is not sufficient evidence to make a sound judgement within this sample. Next, we consider those that are frequently significant (more than 50% of models) and frequently tested (more than 40% of models). Here we see very few variables but those we do include attitudes from the personal behavioural group, and compatibility from the farm structural group. Lastly, we consider those that are infrequently significant (less than 50% of models) but frequently tested (more than 50% of models). In this group we mainly find variables from the socio-demographic category including farmer age and education. Although farm size is a variable tested in 75% of models, it was significant in fewer than 50% of cases (Table 3).

3.5.1 | Cognitive personal behavioural factors

Attitudes towards the practice

Attitudes towards the practice were often measured in line with attitudes as defined in the TPB,[5] even though reference was not always made to this model. As would be expected, depending on the practice, the benefits and costs described were different; however, there are common benefit categories. The most common benefit categories we identified were financial, time, environmental and ease of use. Some models used a general attitude, meaning they asked questions about more than one category of benefit. Others only considered benefits from one category—for example, financial—and so are referred to as such.

[5]Attitudes, in the TPB, are defined as a function of personal beliefs concerning the outcome of an action, each outcome being weighted by subjective probabilities that this result will happen (Ajzen, 1991).

TABLE 3 Frequency and significance of independent variables (n = 110 – number of models).

Independent variable category	Variable	Count		Percentage		Count		Percentage	
		Tested	Not tested	Tested	Not tested	Significant	Not significant	Significant	Not significant
Personal behavioural	Attitudes towards the practice	59	51	53.6	46.4	43	16	72.9	27.1
	Perceived behavioural control (PBC)	18	92	16.4	83.6	13	2	72.2	27.8
	Attitudes to the environment	20	90	18.2	81.8	8	12	40	60
	Risk attitudes	21	89	19.1	80.9	14	7	66.7	33.3
	Farming objectives	12	98	10.9	89.1	10	2	83.3	16.7
Social behavioural	Identity	7	103	6.4	93.6	5	2	71.4	28.6
	Social norms	15	95	13.6	86.4	8	7	53.3	46.7
	Network membership	13	97	11.8	88.2	4	9	30.8	69.2
	Contacts with advisors	20	90	18.2	81.8	12	8	60	40
	Contacts with other farmers	16	94	14.5	85.5	7	9	43.8	56.2
	Contacts with industry	13	97	11.8	88.2	5	8	38.5	61.5
	Contacts with media	8	102	7.3	92.7	7	1	87.5	12.5
Formal institutional	Finance	5	105	4.5	95.5	3	2	60	40
	National scheme	21	89	19.1	80.9	3	13	18.8	81.2
	Certifications	4	106	3.6	96.4	2	2	50	50
	Value chain	3	107	2.7	97.3	2	1	66.7	33.3
	Input prices	5	105	4.5	95.5	2	3	40	60
	Output prices	2	108	1.8	98.2	2	NA	100	NA

(Continues)

TABLE 3 (Continued)

Independent variable category	Variable	Count		Percentage		Count		Percentage	
		Tested	Not tested	Tested	Not tested	Significant	Not significant	Significant	Not significant
Socio-demo	Age	67	43	60.9	39.1	25	42	37.3	62.7
	Education	74	36	67.3	32.7	26	48	35.1	64.9
	Gender	24	86	21.8	78.2	6	18	25	75
	Full time	27	83	24.5	75.5	11	16	40.7	59.3
	Experience	24	86	21.8	78.2	8	16	33.3	66.7
Farm structural	Farm size	81	29	73.6	26.4	38	43	46.9	53.1
	Farm type	43	67	39.1	60.9	24	19	55.8	44.2
	Tenure	31	79	28.2	71.8	12	19	38.7	61.3
	Land type	43	67	39.1	60.9	30	13	69.8	30.2
	Turnover	25	85	22.7	77.3	12	13	48	52
	Practice compatibility	47	63	42.7	57.3	29	18	61.7	38.3

There was variation in how attitude variables were constructed empirically. Some studies used single items in a regression (e.g., Lemken et al., 2017), others used multiple items and converted them into a factor before entering them into the regression or path model (e.g., Aubert et al., 2012; Schaak & Musshoff, 2018). Some studies constructed factors using multiple items from the same benefit category to produce, say, a financial attitudes factor (e.g., Morgan et al., 2015), others combined items from different benefit categories to produce a general attitude variable (Mishra et al., 2018). These differences mean that while we have coded an attitudes variable in the systematic map, it is useful to consider the different permutations used and note that care needs to be taken in comparing the importance of different types of attitudes across models.

In Table 4 and Figure 3 we see that financial attitude, or perceived financial benefits for adopting a practice, was the most frequently tested variable yet for every model it was tested in, it was only significant in half of cases. Environmental benefit attitude or perceived environmental benefits of adopting a practice was tested less frequently but was also only significant in around 40% of cases. A general attitude towards the practice, composed of several benefits, was included in just under 40% of models and was found to be significant in around 80% of cases. Ease of use—or sometimes described as complexity or lack of complexity—was the least frequently tested attitudinal variable, but of those models tested around 70% were significant.

Perceived behavioural control

Perceived behavioural control was only tested in three models in our sample. Aubert et al. (2012) found that higher PBC was associated with a higher likelihood of adoption of precision technology while Pino et al. (2017) did not find a significant association between PBC and the adoption of water saving measures, with a path model analysis. Morgan et al. (2015) found, with multiple regressions, that knowledge self-efficacy but not financial self-efficacy was significant in increasing the likelihood of adoption of low emission of agricultural practices.

3.5.2 | Dispositional personal behavioural factors

Attitudes towards the environment

Attitudes towards the environment differ from the environmental attitudes about a practice in that they capture the farmers' concern for the environment in general compared to the perceived environmental benefits they believe a practice will bring. In terms of their measurement we should note that three of the studies in our sample that found a significant result (Laepple, 2010; Laepple & Kelley, 2015; Laepple & van Rensburg, 2011) were by the same

TABLE 4 Frequency and significance of attitudinal variables towards the practice ($n = 32$ – number of models testing at least one attitudinal variable).

	Count		Percentage		Count		Percentage	
Variable	Tested	Not tested	Tested	Not tested	Significant	Not significant	Significant	Not significant
General attitude	23	36	39	61	18	5	78.3	21.7
Financial attitude	29	30	49.2	50.8	15	14	51.7	48.3
Ease of use	13	46	22	78	9	4	69.2	30.8
Environmental benefit attitude	20	39	33.9	66.1	8	12	40	60

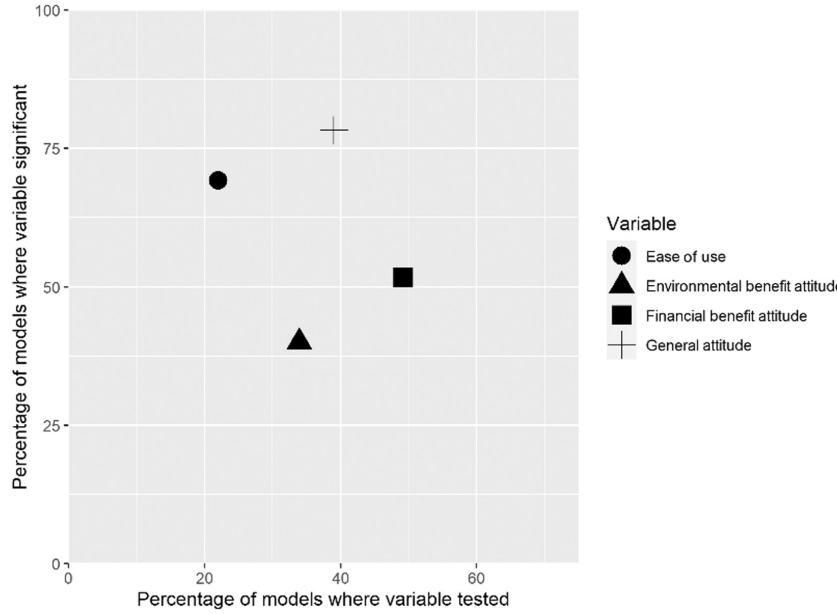

FIGURE 3 Frequency and significance of attitudinal variables.

author, and two of these studies used the same data with the same two-item measure. The fourth study to find a significant result was Best (2010), who used the mean of nine items describing different aspects of environmental concern.

Of those papers that did not find a significant result, a mixture of ways was used to measure attitudes towards the environment (Howley, 2015, Mase et al., 2017, McCann et al., 2015, Morgan et al., 2015, Tiffin & Balcombe, 2011, Ulrich-Schad, Brock, & Prokopy, 2017). Regardless of the measures used, the evidence for the importance of environmental attitudes for adoption, at least in terms of a direct relationship, is weak.

Farming objectives or risk attitudes

In terms of measurement, farming objectives are synonymous with farming orientations. This is perhaps best demonstrated by Howley (2015), whose study developed four farming orientations from a principal component analysis based on 14 statements relating to farm objectives. The orientations were productivist, environmentalist, lifestyle and innovator. Howley (2015) found only the relationship between productivist objectives to have a significant association with practice adoption where those who aligned with productivist objectives were less likely to convert land to forestry. Kallas et al. (2010) found, with duration analysis, that organic farmers expressed higher relative preference for environmental and sociocultural objectives compared to economic objectives. The three studies based on the 2008 Irish organic data found mixed results (Laepple, 2010; Laepple & Kelley, 2015; Laepple & van Rensburg, 2011). Tosakana et al. (2010) investigated profit orientation with regression analysis and found that it had a positive association with adoption of both gully plugs and buffer strips but only for certain slope types.

As for risk attitudes, Kallas et al. (2010) show that farmers who are less risk averse are more likely to convert to organic farming. Contrastingly, Ramsey et al. (2019) found that farmers are more likely to use cover crops and no tillage practices if they believe that the implemented practice will reduce yield risks. On the contrary, Kreft et al. (2021) found that risk aversion does not play a significant role on adoption of mitigation measures to reduce greenhouse gas emissions.

3.5.3 | Social behavioural factors

Network memberships or sources of information

Different informational sources or network memberships were tested for adoption in the mapped literature. Laepple (2010), Laepple and Van Rensburg (2011), Tiffin and Balcombe (2011) and Laepple and Kelley (2015) found that knowing other organic farmers had a positive significant impact on adoption of organic farming whereas media were detrimental for adoption. However, connection to other farmers did not significantly influence the adoption of precision farming in the study of Watcharaanantapong et al. (2014), and media also had a detrimental impact. The role of advisors on adoption of precision farming had a statistically significant positive impact on adoption (Ulrich-Schad, García, et al., 2017; Watcharaanantapong et al., 2014) and for the quantity of commercial fertilisers applied (Williamson, 2011). However, their role is not statistically significant for adoption of landscape features in the study of Garbach and Long (2017).

Social norms

Concerning organic farming, both Best (2010) and Kallas et al. (2010) found a positive influence of farmers' perceptions of societal opinions (family, colleagues or formal networks) on their adoption. In contrast, the study of Gao and Arbuckle (2022) do not find a statistically significant impact of perceived local expectations about conservation on adoption of nutrient management practices.

Identity

In the mapped literature the psychological concept of identity could refer to stewardship (Hilimire & Greenberg, 2019), rural occupational identity (Groth-Joynt et al., 2020) or productivist and conservationist identity (Walpole & Wilson, 2022). With binary logistic regressions, Hilimire and Greenberg (2019) found that stewardship had a significant and positive role on adoption of water conservation practices. Groth-Joynt et al. (2020) rather measured rural occupational identity as a composite measure of 11 different items, which was significantly associated with adoption of fertilisation and soil management practices. Finally, Walpole and Wilson (2022) tested for potential mediation effects of identity and found that conservationist identity had an indirect positive significant impact on cover crop adoption through higher perceived effectiveness whereas productivist identity had a negative impact on adoption through lower perceived feasibility and effectiveness.

3.5.4 | Formal institutional factors

Input or output prices

As an example of input prices, Williamson (2011) found that nitrogen prices were negatively associated with nitrogen use and therefore encouraged farmers to use nitrogen more carefully and implement better management techniques. As for output prices, Kallas et al. (2010) found that the higher they were, for farmers who were credit restricted, the more likely they were to convert to organic farming.

Finance or national scheme

Concerning subsidies, conservation payments are found to encourage farmers' adoption of precision technologies in the study of Lambert et al. (2015) whereas conversion subsidies do not have a statistically significant impact on conversion to organic in the study of Latruffe and Nauges (2014). However, in the latter study, the proportion of AES subsidies received by the farm was found to positively influence conversion. In contrast to Latruffe and Nauges (2014),

Mala and Maly (2013) found a higher uptake of organic farming as the rate of subsidies for organic farming grew.

Value chain

As for factors involving different dimensions of the value chain for organic farming, Khaledi (2010) found that satisfaction with marketing or use of the Internet for marketing were positively associated with adoption, although marketing costs were found not significant. Taus et al. (2013) found that selling through community supported agriculture did not have a significant impact on conversion to organic farming.

3.6 | Quality criteria

Quality criteria applicable to quantitative observational studies were applied to each of the studies in our sample with a maximum score of 14. We found that only one of the 70 studies met this maximum score. Table 5 provides a summary of the mean and standard deviations (SD) for each of the criteria as well as the final score. Studies scored on average the lowest on the theory-related criteria (#4 and #7) and on the potential omitted variable bias (#9) whereas studies had on average the highest score regarding analysis-related criteria (#10, #11, #12, #13), identified research questions (#1), existing research acknowledged (#3), and outcome variable measured reliably (#8).

We did not detect a strong change in quality over the years. Although there was a slight upward trend, there were high mean scores in 2010, 2015 and 2022 and low mean scores in 2011 and 2016 (Table 6). The seven studies from 2011 scored zero on the behavioural variables' measurement (#5) and had an average low score on the motivated theory criteria (#7) while the five studies from 2010 relatively scored slightly better on these criteria. We did notice that there was a trend towards improved use of behavioural theory and, relating to that, improved measurement of independent variables over time (Table 6).

4 | DISCUSSION

4.1 | Summary of results

Our results and identified research gaps concern studies with observational data. We find that farm structural and socio-demographic variables have been more extensively studied in this literature than personal behavioural, social behavioural and formal institutional variables. Despite this relatively higher frequency of testing, we found that socio-demographic variables and half of the farm structural variables (tenure, farm size and turnover) were insignificant more often than they were significant. This reflects the findings in the reviews of Borges et al. (2019) and Burton (2014). Based on Diffusion of Innovation Theory (Rogers, 1995) we might expect that the importance of farm structural factors would differ by practice, so although we do not see the same level of importance of farm structural factors across all practice types, we might for some practices. Precision farming reviews have, for example, previously emphasised the importance of farm size for the adoption of precision farming (Pierpaoli et al., 2013). We did find that for the precision models testing this variable ($n=32$) versus non-precision models ($n=49$) that farm size was significant in 56% of cases compared to 41%. This suggests that for some categories of variables, inclusion of farm structural, if not socio-demographic variables, are important. Compatibility of practices, often included in the empirical model as a variable that asked about existing on-farm practices and infrastructure, was tested in around 40% of papers, it was only significant in just over 50%.

TABLE 5 Quality assessment results.

Area	Criteria number (#)	Criteria	Score range	Mean	SD
General	1	Are the research questions addressed by the study clearly identified?	1/0	0.93	0.26
	2	Are the hypotheses addressed by the study clearly identified?	1/0	0.59	0.50
	3	Are related existing research acknowledge?	1/0	0.91	0.28
	4	Are related theories acknowledged?	1/0	0.53	0.50
Method	5	Were behavioural/attitudinal variables measured in a reliable way?	0/1/2	0.64	0.8
	6	Is the sample population representative of the population of interest and is it relevant in the context of the research question?	1/0	0.73	0.45
	7	Was the selection of explanatory variables based on sound theory?	1/0	0.53	0.50
	8	Were outcome measures reliable? i.e., were they validated or subject to QA process?	1/0	0.96	0.20
	9	Were there likely to be confounding factors not controlled for?	1/0	0.59	0.50
Analysis	10	Were the analytical methods appropriate?	1/0	1.00	0.00
	11	Were multiple explanatory variables considered?	1/0	0.91	0.28
	12	Were confidence intervals and/or *p* values for the effect estimates given or calculable?	1/0	0.90	0.30
	13	Were the estimates of effects size given or calculable?	1/0	0.97	0.17
Final score			Max 14	10.11	2.29

Regarding personal behavioural factors we found stronger evidence for the importance of cognitive or proximal types of attitudinal variables which were tested in over 50% of models and significant in nearly 75% in comparison to dispositional types of attitudes, which (except for attitudes to the environment) were significant in more than 50% of models but included in 20% or less. This differs to the findings of Baumgart-Getz et al. (2012), who found that attitudes were typically insignificant, but that environmental awareness was significant in the adoption of best-management practices in the United States. In our sample we acknowledge that there is a more extensive evidence base for cognitive/proximal attitudes that connect closely to the practices in question (Baumgart-Getz et al., 2012; Sok et al., 2021); however, we can see there is potential for inclusion of dispositional attitudes in future studies. It will be particularly interesting to test whether there are differences in the importance of dispositional factors when we consider what influences adoption intensity, or the adoption of multiple practices across

TABLE 6 Mean quality criteria with largest standard deviation over time.

Year	General theories Max = 1	Measurement Max = 2	Sound theory Max = 1	Confounding Max = 1	Overall score Max = 14
2010	0.40	1.20	0.40	1.00	11.60
2011	0.43	0.00	0.29	0.43	8.86
2012	0.67	0.67	0.67	0.33	10.00
2013	0.50	0.00	0.00	0.50	9.50
2014	0.50	0.00	0.50	1.00	9.50
2015	0.83	0.67	1.00	0.83	11.33
2016	0.00	0.00	0.00	0.50	8.50
2017	0.50	0.60	0.60	0.60	10.30
2018	0.33	0.67	0.33	1.00	10.33
2019	0.46	0.91	0.46	0.55	10.09
2020	0.67	1.22	0.67	0.22	10.11
2021	0.43	0.71	0.43	0.57	10.29
2022	1.00	1.00	1.00	0.67	11.00

different aspects of farm management versus single practices (Dessart et al., 2019). This is particularly relevant if we move to an outcomes-based method of monitoring farm environmental performance compared to a practice-based approach. We found, for example, that for single practice models, attitudes to the environment were only significant in 28.6% of studies compared to 46% of studies where the adoption of multiple practices was considered, though risk attitudes and farming objectives showed the opposite.

As for social factors, influence of media and identity are significant in at least 70% of models and influence of advisors and social norms in at least 50%, though they are tested in less than 20% of models. This finding lends some support to the Individual-Social-Material (ISM) model (Darnton & Evans, 2013) and the TPB (Ajzen, 1991) which emphasise the importance of societal influences on individuals' decision-making. Results for formal institutional types of factors indicate that they have received little attention in the literature mapped in this paper, with less than 20% of models testing them. Since evidence for observational studies is lacking, conclusion on their significance is not interpretable and further research is needed to investigate their impact. Nevertheless, participation in a national scheme, which was investigated in 20% of models, shows poor significance. In comparison, relatively richer evidence has been found for farm structural and socio-demographic factors. More specifically, among farm structural variables, farm type, land type and practices compatibility seem to play a role for adoption, as being significant in at least 50% of tested models.

From a temporal perspective, we do not find clear temporal patterns of evidence across factors except for the formal institutional factor of finance which has been less tested over time. Social norms and identity appear as two variables that have mostly been considered in recent years, which hints for future research to better investigate the impact of these variables.

4.2 | Gaps and future research

Fertilisation and soil management practices together with precision technologies were the most studied farming practice categories, organic farming came third, but with a significant decline in interest in recent years. Studies looking at adoption of other farming systems such

as conservation agriculture, agroforestry or agroecology are absent in our review. Research investigating factors of adoption for other ecological types of farming systems than organic is therefore needed. In particular a focus is needed on whether there are different factors of adoption for large, farm-wide changes versus factors for adoption of single practices.

Most of the papers considered in this mapping were focused on Europe (53%) although many used data from the United States (35%), the rest being sourced from Australia, New Zealand and Canada. More precisely, 32 of the 70 articles were about the EU. Policy insight drawn from this literature mapping should therefore be considered with this limitation in mind. Furthermore, most studies that focused on the United States mainly relied on census data without collecting psychometric data, which calls for better inclusion of personal behavioural, social behavioural and formal institutional variables, which we know to be relevant, as the results of this study and other reviews highlight (e.g., Dessart et al., 2019).

Our findings also point out a limited use of theoretical frameworks based on behavioural theories, or behavioural models, in the adoption literature, with only 20% of our sampled literature applying such models. This links to the reliance of census data mentioned above and a lack of psychometric data collected. We nevertheless observe that these models are being increasingly used over time as most were applied after 2017, with only two studies using such models in 2011 and 2012. Models were applied to adoption of various practice categories, predominantly to fertilisation and soil management but also crop diversification and rotation, livestock management and precision agriculture. However, none of them were applied to adoption of organic farming. Finally, among studies applying behavioural models, 60% of them lack the temporal dimension of adoption where data were collected at a single point in time (Supplementary Material S4), which parallels the common intention–behaviour gap (Sheeran & Webb, 2016) criticism often applied to some behavioural models including the TPB.

Regarding the measurement of independent variables, we found a wide range of measures for cognitive and dispositional behavioural variables, from single-item to multiple-items constructs that were converted into a factor before being included into regression models or path analysis. Studies using more than one indicator for measurement of independent variables were given a higher score during the quality assessment, given that reliability for behavioural constructs is better when constructs are measured with several items (Hair et al., 2014). Inconsistencies in measurement of behavioural constructs such as environmental awareness and farmer attitudes has been highlighted by previous reviews (Baumgart-Getz et al., 2012). Although there were still a wide range of measures used, the use of multi-criteria measurement appears to have improved over time, at least in the last 4 years. Studies that work to develop reliable constructs for general attitudes and beliefs could be very useful contributions to the literature on adoption, as none of the papers included here cite significant measurement development as part of their analysis.

Finally, it is worth noting that the results of this systematic map are based on quantitative literature. Qualitative literature was excluded from our mapping to better compare and summarise the results. Independent variables that can be more difficult to quantify and test statistically, are therefore missing from our analysis. The role of qualitative research is, however, undeniable to advance theory and knowledge to better understand factors that drive or hinder farmers' adoption of ecological practices. Another limitation from our systematic mapping is the absence of the direction of the effect of factors, stemming from our broad topic focused on a wide range of practices. In the same vein, results presented in Figure 2 are not disaggregated by types of practices and may therefore reflect some imbalance as different types of adoption may be driven by different types of factors (see Supplementary Material S5). Finally, as only peer-reviewed articles were mapped, potential publication bias could inflate the proportion of significant factors with respect to reality.

5 | CONCLUSION

We reviewed the literature on factors associated with the voluntary and non-contractual adoption of ecological practices from 2010 to 2022, using a systematic map approach. Summarising the literature, we provide a comprehensive overview of the existing evidence regarding factors that have been tested in this literature. Insights provided here form a useful basis for the formulation of future research questions and are informative to policy, advisors and other stakeholders by highlighting the strength of the current evidence when it comes to factors that are associated with uptake of voluntary and non-contractual adoption of ecological practices. Based on our results we point to areas where future research is needed to better understand farmers' uptake of ecological practices and thus for formulation of efficient policy to support uptake. In particular, we find that factors associated with adoption of practices that potentially lead to more thorough environmental changes to the agricultural systems, such as agroforestry and agroecology have not received much attention so far in the literature. This limits current policy insight related to how adoption of those practices can be encouraged. We also found that personal behavioural, social behavioural and formal institutional variables have been under-researched in the existing literature. Given their potential role in encouraging adoption, more work is needed in this area to further understand how uptake can be supported. In this regard, we finally emphasise that there is a need to use more comprehensive behavioural theories to study farmers' adoption behaviours.

Although our results point to areas where future research is needed, some implications can be drawn for policy based on the existing literature. The often-insignificant role of socio-demographics calls for an untailored approach to agri-environmental policy when it comes to farmers' personal characteristics. In contrast, some farm structural variables were often found significant, such as land type, farm type and practice compatibility, which justifies a tailored policy in regard to more structural aspects of the farm. Although these implications exclude the adoption of AES in this study, our results highlight the insignificant role of belonging to AES and other national schemes for adopting ecological practices, which may question their policy relevance for ecological transition.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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