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Review

Understanding changes in reducing pesticide use by farmers: Contribution of the behavioural sciences

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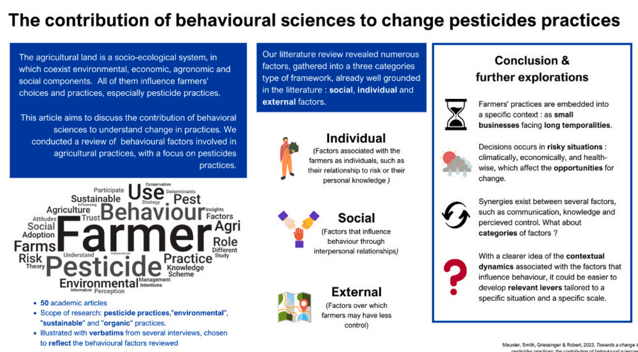
HIGHLIGHTS

- The agricultural land is a socio-ecosystem where many actors and components coexist and influence the agricultural practices on the territory.
- We identify the behavioural factors linked with these components that are involved in changing farming practices.
- We highlight and categorise three types of factors, at several levels: individual, social and external, and attempt to rank them.
- Some factors are even more relevant for changing farming and pesticides practices, and more easily translated into interventions.
- In-depth work on the synergies between these factors and consistent measures are needed in future research.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Pesticide use in agriculture has serious impacts on the environment, biodiversity and human health. Even though these strong negative impacts have been identified for decades, the reduction of phytosanitary products is becoming increasingly urgent. Agricultural land is a socio-ecological system in which environmental, economic, agronomic and social components are closely linked and interact in a non-linear and complex way. As such, it has become evident that pesticide reduction can only be achieved by jointly considering these different elements of the socio-ecosystem.
OBJECTIVE: In this article, we first discuss the behavioural factors involved in changing agricultural practices with a focus on pesticide practices. We then attempt to assess the respective influence of these factors on farming practices. Finally, we analyse how these behavioural factors could be used to induce concrete changes towards the adoption of environmentally friendly practices and question their consideration in future research.
METHODS: To do so, we undertake a literature review: we analyse a wide range of articles using a behavioural science framework. To anchor our work in agricultural reality, we illustrate the review of the behavioural factors using verbatim transcriptions taken from several interviews with farmers. Based on our corpus, we focus on nine

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articles to better understand the relative influences of these factors in the studies and highlight five case studies to explore the activation of these factors through action levers.
RESULTS AND CONCLUSIONS: We identify fourteen factors operating at three different levels: individual, social and external. These factors likely interact with each other, thus enhancing their effect on the changes in agricultural practices. Some behavioural factors described in this review are not explored in the few articles that attempt to compare their importance, thus rendering our understanding of their relative importance only partial. We observe that some factors are more easily translated into levers for changing pesticide practices, although this depends on the scale of the studies and the object of change under consideration.
SIGNIFICANCE: We believe that the behavioural sciences can provide a better insight into the multiple dynamics at play with regard to the changes in agricultural practices and production systems. We hope that this article will not only strengthen the relevance and use of the behavioural sciences to address these issues but will also allow for a more realistic conceptualisation of farming behaviours in future research.

1. Introduction

The use of pesticides as a pest control method in agriculture is currently reaching its limitations. First, pests are becoming increasingly resistant to the products intended to control them (Hobbelen and Paveley, 2014; Hawkins et al., 2019; Gould et al., 2018). In addition, pesticides have major detrimental impacts on the environment. They affect other species not directly targeted by them, thus contributing to the erosion of biodiversity in various ecosystems (Brühl and Zaller, 2019). Pesticides can harm earthworms (Pelosi et al., 2014), natural predators of pests (Sánchez-Bayo, 2021) and pollinators (Brittain et al., 2010; Uhl and Brühl, 2019). Many bird species that feed on these insect populations may subsequently be contaminated (Gill et al., 2014). Aquatic fauna is also threatened through water pollution, including some frog species affected by agricultural pesticides (Brühl et al., 2013; Özkara et al., 2016). Human health is also affected, with several significant links between pesticide exposure and several types of cancers as well as congenital malformations (Melanda et al., 2022). Gaining a better understanding of the impacts of pesticides on human health is a complex process, as it requires information on the periods of exposure to different products and the onset of different symptoms, which can happen several years after exposure (Kim et al., 2017; Blair et al., 2015) and even in urban areas (Md Meftaul et al., 2020). Even though these strong negative impacts have been pointed out for decades, it is now urgent to reduce pesticide use in agriculture.

Different tools could promote this change in agrosystems and thus reduce their dependence on pesticides. Agroecology is one such tool that could facilitate the major transformation of agrosystems towards sustainable and environmentally friendly systems (Duru et al., 2015; Brzozowski and Mazourek, 2018; Bezner Kerr et al., 2022). Agroecology is based on the core tenet that integrating greater biodiversity in and around fields results in agroecosystems being less dependent on synthetic inputs (Altieri, 1999; Frison et al., 2011). Increased biodiversity favours the (re-)establishment of several interactions between organisms that perform ecological services in agroecosystems such as crop pollination by pollinators or regulation of crop pests by pest predators (Altieri, 1999; Bianchi and Van der Werf, 2003; Jonsson et al., 2014). In more practical terms, this involves diversifying crop species and cultivars, mobilising agroforestry, setting up agroecological infrastructure and/or combining livestock and crops.

The negative impacts of pesticide use have been highlighted since the 1960s (Carson, 1962). While the first European regulations on pesticides were enacted in the 1970s, the EU only started extensively regulating pesticide use in the 1990s (Ansell, 2023). In France, the impacts of pesticides on human health and ecosystems led to the 'Grenelle de l'environnement' in 2007 followed by three successive Ecophyto plans. The first Ecophyto plan launched in 2008 aimed to reduce the use of pesticides in agriculture in France by 50% within 10 years. In response to the insufficient results of this first plan and aiming to consider the complexity of these issues, the Ecophyto II plan was launched in 2015 with the goals to reduce pesticide use by 25% and 50% by 2020 and 2025, respectively, as well as the phasing out of glyphosate for its main uses. As the objectives of this second plan also proved difficult to reach, it was followed by the Ecophyto II+ plan in 2020, which strengthened the previous plan by integrating new action levers, in particular the development of collective and territorial levers. The discrepancy between the social and political demands calling for pesticide reductions on the one hand and their actual stable (or increasing) use on the other hand highlights the challenges posed by this change. Although the massive use of pesticides has serious consequences on both ecosystems and human health, and despite the rising social and political momentum, most intensive agricultural systems are still strongly dependent on them today. These observations highlight the need to better understand what underlies the potential changes in order to better identify the levers to be activated or obstacles to be removed.

Pesticide reduction can only be achieved by jointly considering agronomic, ecological, economic and social components (Rebaudo and Dangles, 2013; Lescourret et al., 2015). Agricultural land is a socio-ecological system in which environmental, economic and social components are closely linked (Darnhofer et al., 2010) and interact in a non-linear and complex way (Holling and Gunderson, 2002). Several socio-technical barriers and lock-ins may emerge in this context given that pesticide use is strongly related to various aspects of the socio-ecological system (Hu, 2020). Nevertheless, the emerging behaviour of a community is ultimately the aggregate result of its individual actions. We therefore believe that beyond these major socio-technical factors, the behavioural sciences can make a relevant contribution to understanding these issues. In this respect, the behavioural sciences could be part of the studies exploring changes in agricultural practices from an interdisciplinary perspective.

Considering people as perfect rational agents can be effective when assessing the best course of action in terms of an individual's self-interest, although it is rarely effective at predicting the course of action of real humans. This discrepancy has been discussed at length by economists, who juxtapose the rational *Homo economicus* to the less predictable *Homo sapiens* (Dessart et al., 2019; Galt, 2013). The divergences can have different root causes: humans do not have perfect knowledge of their environment and their perception and integration of information is skewed to allow them to adapt to most situations quickly and efficiently, but this sometimes fails. For example, we are subject to what is called an 'anchoring bias', meaning that numerical anchors such as the 2 °C warming goal of the Paris agreement can unconsciously influence our perception of climate change: since a 2 °C difference is negligible in our daily lives, this can lead us to underestimate the impact of 2 °C global warming (Mazutis and Eckardt, 2017).

Moreover, humans do not act in a vacuum: relationships and social norms have a substantial influence on behaviour. For example, we may perform certain eco-friendly behaviours such as conserving water and energy simply because everyone does so or because it feels like the right thing to do (Cialdini and Jacobson, 2021). In particular, the idea that people behave in sub-optimal ways and adopt false beliefs because they lack accurate information to inform their decision-making, known as the 'information deficit model', has been increasingly questioned in the past few decades (Arslan et al., 2022). Other models have been put forward

Table 1
Presentation of the 50 articles included in the literature review: first author, date, study location, associated agricultural practices and type of paper (survey, review or case study). The 50 papers are numbered from 1 to 50 and presented by type and then in chronological order. Papers 1 to 40 are surveys, papers 41 to 47 are reviews and papers 48 to 50 (48a, 48b and 48c are three case studies from paper 48) are case studies. The 50 papers were used to identify various behavioural factors, nine papers (8, 19, 21, 24, 29, 30, 31, 33, 35, numbers in grey) were used to assess the respective influence of these factors, and three papers (48, 49, 50) were used to analyse the impact of these factors regarding the concrete changes made to farmers' practices.*

	Article	Location	Type of practice	Type of paper
1	Petrzelka et al., 1996	USA	SAP	Survey
2	Austin et al., 2001	Scotland	General practices	Survey
3	Gravsholt Busck, 2002	England	General practices	Survey
4	Dasgupta et al., 2005	Bangladesh	Pesticides	Survey
5	Michel-Guillou and Moser, 2006	France	EAP	Survey
6	Atreya, 2007	Nepal	Pesticides	Survey
7	McCarthy et al., 2007	Ireland	Organic agriculture	Survey
8	Fielding et al., 2008	Australia	SAP	Survey
9	Gosling and Williams, 2010	Australia	EAP	Survey
10	Kallas et al., 2010	Spain	Organic agriculture	Survey
11	Ahmed et al., 2011	Sweden	Pesticides	Survey
12	Ma et al., 2012	USA	EAP	Survey
13	Togbé et al., 2012	Benin	Pesticides	Survey
14	Fisher, 2013	England	General practices	Survey
15	Ríos-González et al., 2013	Mexico	Pesticides	Survey
16	Jin et al., 2015	China	Pesticides	Survey
17	Sulemana and James, 2014	USA	EAP	Survey
18	Christie et al., 2015	Ghana, Mali	Pesticides	Survey
19	Fan et al., 2015	China	Pesticides	Survey
20	Kuhfuss et al., 2014	France	Pesticides	Survey
21	van Dijk et al., 2016	Netherlands	EAP	Survey
22	Jallow et al., 2017	Kuwait	Pesticides	Survey
23	Walton et al., 2017	USA	Pesticides	Survey
24	Mills et al., 2017	United-Kingdom	EAP	Survey
25	Yoshida et al., 2018	USA	General practices	Survey
26	Zeweld et al., 2017	Ethiopia	General practices	Survey
27	Inman et al., 2018	United-Kingdom	General practices	Survey
28	Mills et al., 2018	England	EAP	Survey
29	Sharifzadeh et al., 2018	Iran	Pesticides	Survey
30	Caffaro et al., 2019	Italia	SAP	Survey
31	Ali et al., 2020	Bangladesh	Pesticides	Survey
32	Gebska et al., 2020	Poland	SAP	Survey
33	Knapp et al., 2021	Switzerland	General practices	Survey
34	Perry and Davenport, 2020	USA	EAP	Survey
35	Bakker et al., 2021	Netherlands	Pesticides	Survey
36	Cullen et al., 2021	Ireland	EAP	Survey
37	Leonhardt et al., 2021	Austria	EAP	Survey
38	Rust et al., 2022	Hungary, United-Kingdom	General practices	Survey
39	Barnes et al., 2022	Europe	EAP	Survey
40	Hu et al., 2022	China	Pesticides	Survey
41	Blackstock et al., 2010	/	General practices	Review
42	Remoundou et al., 2014	/	Pesticides	Review
43	Lastra-Bravo et al., 2015	Europe	EAP	Review
44	Damalas and Koutroubas, 2018	/	Pesticides	Review
45	Dessart et al., 2019	/	SAP	Review
46	Pierrette Coulibaly et al., 2021	/	SAP	Review
47	Siebrecht, 2020	/	SAP	Review
48a	Neumeister et al., 2007 (a)	Netherlands	Pesticides	Case-study
48b	Neumeister et al., 2007 (b)	Belgium	Pesticides	Case-study
48c	Neumeister et al., 2007 (c)	Danemark	Pesticides	Case-study
49	Jørs et al., 2016	Bolivia	Pesticides	Case-study
50	Wuepper et al., 2021	Switzerland	Pesticides	Case-study

* EAP: environmental agricultural practices; SAP: sustainable agricultural practices.

such as the ideological consistency model or models that encourage the co-creation of knowledge by different actors, which can better explain shifts in attitudes (Conner and Armitage, 1998; Kaiser and Müller-Seitz, 2005).

Nevertheless, a disconnection between attitudes and behaviours has been documented, particularly around environmental issues. This disconnection has been addressed by frameworks such as the Theory of Planned Behaviour (TPB): behaviour depends on an individual's intention to perform the behaviour (itself influenced by beliefs, habits, etc.) in addition to perceived behavioural control (how difficult one believes a task to be) and social norms. These frameworks highlight the fact that decision-making does not occur in a vacuum but rather in a social, technological, legal and psychological context. Factors from these different categories can have an influence on beliefs, perceived social norms and the ease or difficulty of performing a specific behaviour. They also show that behaviour is not purely individual but also social. Both the Theory of Planned Behaviour and the related Value-Belief-Norm Theory stress the importance of moral judgements and collective norms when it comes to sustainable behaviour. In the agricultural setting, Mills et al. (2017) integrate these two frameworks and classify the factors influencing the behavioural change of farmers into three categories: willingness to adopt a new practice (influenced by personal beliefs or self-identity, among others), ability to adopt a change (influenced by biophysical and financial factors, for example), and farmer engagement (influenced by intermediaries such as farming networks or local governance structures). The Intergovernmental Panel on Climate

Change (IPCC) points out that at a population level, behavioural change depends on these collective norms and goes through several stages from a few individuals pioneering its early adoption to widespread normative adhesion.

These different factors can be grouped into several categories. Many authors opt for three main categories that broadly correspond to individual, social and external factors. Dessart et al. (2019) provide a framework inspired by the study of behavioural change in the health context, distinguishing between cognitive factors (e.g., knowledge, risk perception), social factors (e.g., social norms) and dispositional factors (e.g., objectives, moral concerns). The IPCC considers a broader scope that includes individual factors (e.g., habits, attitudes), social factors (e.g., social norms, trust, social movements) and structural factors (e.g., technology, institutions). Thus, to better understand behavioural changes in the context of sustainability, it appears that the behavioural sciences should be integrated by considering individuals in their cognitive and social context rather than as atomized and perfectly rational beings.

In this article, we aim to discuss the behavioural factors involved in changing agricultural practices with a focus on pesticide use. We therefore seek to identify and understand these factors. To do so, we first perform a literature review and analyse a wide range of articles using a behavioural science framework. We then discuss the specificity of the identified factors with regard to phytosanitary practices and the fundamental shift required from understanding these factors to actually transforming the systems.

2. Material and methods

2.1. Corpus characteristics

For the literature review on the behavioural factors that impact changes in agricultural practices, we analysed 50 papers (Tables 1 and 2). These 50 academic articles were published in English and French between 1993 and 2022 (Table 1). The material was sourced from 31 different journals, with the most common journal being *Science of the Total Environment* with a total of five articles. Our initial search for articles related to “pesticide use” alone resulted in only 20 articles. We then decided to extend our scope of research to “environmental” and “sustainable” agricultural practices as well as “organic” practices (Table 1).

We analysed the terms used in the titles of the 50 journal articles. We found that ‘farmer’ was the most frequently used word followed by ‘pesticide’. ‘Behaviour’ and ‘environmental’ were also widely used. The following keywords were associated with the different factors: risk, knowledge, social, perception, personality and preference. This is consistent with our goal of studying the behavioural factors involved in adopting farming practices (see the word cloud in Fig. 1).

Three types of articles are discussed in our corpus, namely surveys, reviews and case studies (Tables 1 and 2). Surveys (40 articles) are observational studies based on questionnaires and interviews. Reviews (7 articles) are a description and analysis of the literature on behavioural factors. Case studies (3 articles) focus on the concrete changes in farmers’ pesticide practices in a defined location using different levers that influence behaviour. They focus on the choice or adoption of agricultural practices that reduce or eliminate pesticide use.

2.2. Goals and methodology

The goal of the present work was to search the literature on behavioural sciences (i) to identify the set of behavioural factors impacting farmers’ environmental and pesticide practices, (ii) to assess the respective influence of each factor on farmers’ behaviours and (iii) to analyse how these factors can be used to induce concrete change in farmers’ environmental and pesticide practices.

Method for identifying the behavioural factors affecting farmers’ practices. To reach the first goal, we analysed the entire corpus of 50 articles and ended up with 14 factors. Among the different frameworks used to classify the factors affecting farmers’ practices (IPCC, 2014; Mills et al., 2017; Dessart et al., 2019), the work of Dessart et al. (2019) offers the broadest framework while only focusing on individual behaviour. In our review, we followed their lead while taking into account the fact that farmers’ decision-making occurs in a complex socio-agro-ecosystem. We thus classified the 14 behavioural factors into three main categories: (i) individual cognitive factors (e.g., knowledge, risk perception), (ii) external factors (e.g., knowledge diffusion, farm characteristics) and (iii) social and outside factors (e.g., social norms). Table 2 summarises the 14 behavioural factors studied in the 50 papers of the review.

Method for assessing the respective influence of each behavioural factor. To reach the second goal, we selected nine papers from our corpus (Table 1) that compared different factors. We evaluated their importance or the established a hierarchical model that included some of the factors discussed here (Fielding et al., 2008; Fan et al., 2015; van Dijk et al., 2016; Mills et al., 2017; Sharifzadeh et al., 2018; Caffaro et al., 2019; Ali et al., 2020; Bakker et al., 2021; Knapp et al., 2021) (Table 1a and b). These nine papers were then cross-analysed.

Method for analysing how the behavioural factors can be used to induce concrete changes in farmers’ practices. To reach the third goal, we selected five case studies from three papers (Tables 1 and 2) based on the following criteria: the study focuses on the actual adoption of practices for the reduction of pesticide use in a defined location. The first paper is that of Neumeister et al. (2007), which reports several case studies of pesticide reduction projects in Europe. We chose three of these case studies based in the Netherlands, Belgium and Denmark. The second case study by Jørs et al. (2016) focuses on the impact of training Bolivian farmers in adopting integrated pest management techniques (IPM). The third one conducted by Wuepper et al. (2021) explores the influence of the type of advice (public or private) on farmers’ choice of pesticide strategies in Switzerland. In each of the five case studies, we identified the levers (i.e., interventions or actions aiming to bring about changes in pesticide practices) and detailed the behavioural factors influenced by these levers (i.e., individual, external and social mechanisms and characteristics that affect behaviour). Our aim was to analyse which behavioural factors were brought into play in these concrete cases of transformative studies.

2.3. Acquiring and using the verbatims as material

To anchor our work in agricultural reality, we aimed to illustrate the review of the behavioural factors with verbatim transcriptions taken from several interviews with farmers. These interviews were conducted with local farmers and agricultural stakeholders in a small agricultural region of eastern France (Barrois) between January 2020 and November 2021 (Robert, 2020, TRAVERSéES project). The agricultural land of Barrois, which features field crops and cattle, is currently experiencing problems related to the simplification of its systems, soil impoverishment and climate change (particularly drought problems). To better identify the constraints and levers for change to agricultural practices in the Barrois territory, a serious game representing the Barrois and its farmers was developed (Grohens, 2021, Barbe et al., 2022).

We aimed to highlight the links (or lack thereof) between the literature review, which focuses on sometimes non-situated and theoretical research, and the verbatim transcriptions recorded in the specific territorial context of the Barrois. Wherever possible, the transcriptions were chosen to reflect the behavioural factors reviewed in the present article.

Table 2
Behavioural factors studied in the 50 papers of the review. The factors studied in the papers are shown in bright colour (in green, blue and yellow). If the factors are merely mentioned or their impact is only presumed, they appear in light colour. The 50 papers are numbered from 1 to 50 and presented in the same order as in Table 1.*Pe = Personality, Nr = Relationship with nature, Mt. = Mistrust in information sources, Rt = Risk tolerance, Rp = Risk perception, Kn = Personal knowledge, Pc = Perceived behavioural control, At = Attitudes and beliefs, Cr = Demographic and farm characteristics, Kd = Knowledge diffusion, Ia = Influence of other actors, Nc = Normative context, Si = Social identity, Cm = Communication mechanisms.

Article	Pe	Nr	Mt	Rt	Rp	Kn	Pc	At	Cr	Kd	Ia	Nc	Si	Cm
1									green			green		
2	green					light green		green						
3	light green							light green	light green					
4					green	green			light green	light green				
5		light green				light green		green						
6						green		green	green	light green				
7							green	green				green	green	
8							green	green				green	green	
9		green												
10				green				green	green		light green			
11	light green							green	light green					
12									green					
13														
14			green							green	light green			
15			light green		green	green								
16			green							green	green			
17								green					green	
18						green			green	light green	light green			
19			light green			green		light green	green		green			
20												green		
21							green	green				green	green	
22					green	green		green			green			
23								light green		light green				
24							green	green	light green		light green	green	green	
25		green									light green			
26							green	green		light green	light green	green		light green
27								green				green	green	
28	light green								light green					light green
29					green	green			green					
30							green	green		green		green		
31			green		green	green			green		green			
32						green			green					
33	green			green			light green		green					
34							green		green				green	
35							green	green				green		
36									green					
37									green					
38			green							green				light green
39													green	
40					green	light green					light green	light green		
41									blue	blue	blue	blue		blue
42					blue	blue		blue						
43			blue					blue	blue	blue	blue			blue
44					blue	blue	light blue	blue						
45	blue	light blue		blue	blue	blue	blue	light blue	light blue	light blue		blue	light blue	light blue
46			blue			light blue	light blue	light blue		light blue	blue	light blue		
47				light blue	light blue	blue		light blue	light blue	blue	light blue	blue		blue
48a			light yellow			light yellow				yellow	yellow	light yellow		light yellow
48b			light yellow			yellow				yellow	yellow	light yellow		light yellow
48c						yellow				yellow	light yellow	light yellow		light yellow
49						yellow				yellow		light yellow		yellow
50			light yellow							yellow	yellow			

As such, they do not constitute measurement items. The interviews did not specifically seek to investigate the identified behavioural factors, which emerged naturally during the conversations. The verbatims associated with the different reviewed factors were then used to illustrate our review and facilitate its understanding.

3. Review of behavioural factors

Our literature review yielded 14 different behavioural factors that we classified into three categories: individual factors (e.g., knowledge, risk tolerance), external factors (e.g., demographics, knowledge diffusion) and social and outside factors (e.g., social norms). We first detail the findings relating to these 14 factors before discussing their comparative importance and describing the case studies in which some of these factors were successfully used as levers for behavioural change.

3.1. Individual factors

3.1.1. Personality

Personality traits are often described using the 'Big Five' dimensions: extraversion, agreeableness, conscientiousness, emotional stability and openness to experience (Roberts and Yoon, 2022). Personality factors can influence farming behaviours: high scores for extraversion, openness and conscientiousness lead to a higher probability of farmers engaging in environmentally oriented behaviour (Austin et al., 2001). Openness may also be linked to projection by 'coping with incomplete information or uncertain future' (Denissen and Penke, 2008, p. 1288). Openness can also represent curiosity and a willingness to explore new ideas (McElroy and Dowd, 2007). Interestingly, the verbatims from our interviews support this hypothesis, as more dogmatic farmers tended to project much less feasible pro-environmental practices on their farm in the future.

> 'The future [in farming] will be an everlasting cycle'.

> 'If chemistry doesn't work, we'll be forced to switch to mechanical means of control'.

As described by Dessart et al. (2019), resistance to change is linked to personality traits such as low openness, cognitive rigidity and short-term focus. Additionally, pessimistic projections about the future correlate with negative attitudes about ethical farming practices (Sulemana and James, 2014). A more internal locus of control* is associated with the use of preventive measures such as the adoption of hail for example (Knapp et al., 2021). It is still unclear how projection and resistance to change are linked, as greater projection is associated with a greater intention to resist change in organisational contexts (Bovey and Hede, 2001; Erwin and Garman, 2010).

3.1.2. Relationship with nature

Farmers have a particular relationship with the natural areas on which they depend for their livelihood. Farm management and its economic sustainability are linked to the control of natural elements, with farmers reporting that their human-nature relationship plays a role in their management approach (Yoshida et al., 2018). Furthermore, farmers' decision-making and practices have long been closely connected with the shaping of the agricultural landscape (Gravsholt Busck, 2002). Accordingly, the adoption of pro-environmental practices depends on farmers' relationship with their environment (Gosling and Williams, 2010; Michel-Guillou and Moser, 2006; Sharifzadeh et al., 2018; Yoshida et al., 2018).

> 'When I started (farming), I liked it. Now we're always in the fields with the sprayer, [getting angry] there's no more life in the fields, so I decided to do something else'.

Farmers' environmental concerns may thus influence their adoption of pro-environmental farming practices, as nature relatedness is a predictor of one's involvement in environmental groups and self-identification as an environmentalist (Nisbet and Gick, 2008). Moreover, farmers who are willing to preserve the environment or have a sense a moral obligation towards the environment are more prone to adopt organic farming practices (Kallas et al., 2010; McCarthy et al., 2007).

3.1.3. Mistrust in information sources

Mistrust plays an important role in pesticide practices, as it can hamper knowledge transfer (Fisher, 2013), notably through the persuasion processes discussed below. Indeed, farmers tend to place limited trust in pesticide retailers and the government (Fan et al., 2015; Ali et al., 2020), which contributes to their inadequate behaviours regarding pesticide use. This lack of trust may hand in hand with the rejection of the advice of technical experts and may be due to differences in the perceived economic risks and interests of farmers and authorities (Ríos-González et al., 2013). Landholders deal with information and knowledge depending on their trust in retailers: lower pesticide use is associated with accurate information and a trustworthy information provider (Jin et al., 2015).

> 'Extension practitioners have cultivated fear through ignorance'.

> 'Elected representatives don't have the technical skills necessary to help landholders'.

In the context of limited relationships between farmers and authorities, trust represents a key issue for increasing the likelihood that the knowledge and information thus shared will be considered useful by farmers (Fisher, 2013). An effective socio-technical arrangement dedicated to pesticide use and the empowerment of local farmers, for example, could help increase trust about information (Togbé et al., 2012, p. 69). Additionally, the more trust farmers place in institutions, the better the association is between their intention to adopt and actual adoption of sustainable agricultural practices (SAP) (Pierrette Coulibaly et al., 2021).

3.1.4. Risk tolerance

Risk tolerance – or risk aversion – is defined as 'the willingness to engage in behaviours in which the outcome remains uncertain with the possibility of an identifiable negative outcome' (Irwin Jr., 1993, p. 11). Risk tolerance is inherently linked to risk perception, as the notion of risk preference (Grable, 2008) is defined as a person's tendency 'to be attracted or repelled by alternatives that he or she perceives as more risky over alternatives perceived as less risky' (Weber and Milliman, 1997, cited by Grable, 2008, p. 4). We will discuss the influence of risk perception later on. This section is specifically dedicated to risk tolerance as a dispositional factor involved in farming practices.

> [About spraying insecticides]: 'I'll shoot on sight if necessary!'

Risk tolerance can affect sustainability practices in farming: it affects management and decision-making on the farm, which depends on the farmer's strategy and personality (Siebrecht, 2020). Risk aversion is reported as a common characteristic among farmers, causing them to take strong measures against perceived threats such as pests and diseases, which often results in the application of large amounts of pesticides (Hu et al., 2022). By contrast, farmers with a higher risk tolerance are more likely to adopt organic farming over a shorter period of time (Kallas et al., 2010). Risk aversion is also associated with the entrepreneurial decisions on the farm (Knapp et al., 2021).

3.1.5. Risk perception

Risk perception differs between individuals and between places (some European countries are less risk-tolerant than others; Rieger et al., 2015). It is therefore only logical that some farmers engage in alternative farming practices considered 'risky', while others remain more reluctant.

Fig. 1. Word cloud of the terms found in the titles of the 50 articles included in the literature review. Words appear larger or smaller depending on their occurrence in the titles. Words that occur less than three times as well as linking words (e.g., within, towards, between) are excluded. One title was translated from French to English.

> 'I'm not yet ready to take the plunge until my yields are secured'.

When farmers perceive threats such as pests and diseases as high risk, they in turn see alternative control techniques as inefficient, making more reluctant to adopt them (Hu et al., 2022). Additionally, farmers may misperceive the health impairments associated with pesticides and their toxicity (Dasgupta et al., 2005). However, higher levels of knowledge and risk perception about pesticides do not automatically result in safer practices and behaviour (Remoundou et al., 2014). For example, the majority of farmers in Kuwait are more concerned about the risks related to their yields than about the pesticide-related risks to their own health, which have no effect on their practices (Jallow et al., 2017). The effect of risk perception can mediate the effect of other factors on the intention to adopt alternative control practices, which is mediated by several parameters, including the projected effort and performance associated with these practices (Hu et al., 2022).

3.1.6. Personal knowledge about farming practices and pesticide uses

To integrate sustainable practices, farmers need to understand how they work and comprehend the specific steps and decisions to be taken on the farm that will lead to their implementation (Siebrecht, 2020). Being aware of the existence of sustainable practices is quite different from understanding such practices, as knowledge refers to a real understanding of the mechanisms and concepts associated with the object (Damalas and Koutroubas, 2018). For example, farmers are often aware of the negative effects of pesticides on the environment and human health, although very few of them have an in-depth knowledge of how they affect their crops and the body (Fan et al., 2015).

> 'I need to understand why I'm doing this'.

A high level of knowledge about pesticides is significantly linked to risk reduction for human health (Ali et al., 2020). Additionally, in-depth knowledge about the processes and decisions required to implement sustainable practices is essential in order to combine satisfying yields with a reduced impact on the environment. Thus, greater knowledge about these issues is associated with the more frequent use of alternative practices on the farm (Gebska et al., 2020).

3.1.7. Perceived behavioural control

Engagement towards sustainable practices is also linked to farmers' perceived control over a specific issue. Perceived control can be defined as how much landholders perceive the execution of a particular behaviour to be in their own control and how difficult or easy it appears to adopt a specific practice. It is associated with external and internal obstacles such as knowledge and economic or biophysical resources (Zeweld et al., 2017). Perceived control has a significant effect on the adoption of sustainable practices (Caffaro et al., 2019) and is associated with other variables such as personal efficacy or perceived difficulty.

> 'I feel like I am too limited financially to engage in sustainable farming'.

Farmers who have implemented sustainable practices on their farms feel more capable of handling issues about water quality, which in turn influences their engagement (Michel-Guillou and Moser, 2006). In a broader sense, farmers who believe that their actions can benefit the environment are more willing to engage in agro-ecological schemes (AES) (Ma et al., 2012).

3.1.8. Attitudes and beliefs

Attitude is defined as 'a relatively enduring and general evaluation of an object, person, group, issue or concept on a dimension ranging from negative to positive' (American Psychological Association, 2020). A positive attitude towards economic reasoning and conventional farming practices were correlated with a higher use of pesticides 20 years ago (Petrzelka et al., 1996).

> 'When you are sick, you go to the doctor and ask for medication; well here, it's the same thing'.

> 'Herbicides are necessary, you can't do without them'.

Regarding pesticides, farmers consider them to be an efficient and cost-effective tool that requires limited efforts to regulate pests and increase crop yields (Damalas and Eleftherohorinos, 2011). Therefore, most farmers associate a reduction in pesticide use with a reduction in crop yields and profits (Fan et al., 2015). Additionally, there is a significant relationship between a reduction in yields and a higher risk perception of reducing pesticide use among farmers (Bakker et al., 2021). The attitudes of farmers and local inhabitants differ with regard to pesticides, as locals believe that they are more hazardous and less valuable (Ahmed et al., 2011).

3.2. External factors

3.2.1. Demographics and farm characteristics

Several demographic variables correlate with the adoption of particular agricultural practices such as pesticide use. Variables such as gender (Atreya, 2007), education level and age (Muñoz-Ulecia et al., 2021) influence farming behaviours. Farm-related goals associated with the objectives of landholders also affect the adoption of AES: for example, 'profitability-oriented farmers' participate in AES at a lower level than 'nature-oriented farmers' (Leonhardt et al., 2021). Farm size does not have a direct effect on AES participation, as data from the last 20 years shows that the likelihood of participation increases with farm size at a decreasing rate (Cullen et al., 2021). However, extensive farms are most likely to participate, suggesting that these projects should be redesigned to encourage the participation of intensive farms (Cullen et al., 2021).

3.2.2. Knowledge diffusion

Understanding how farmers gain access to new information is crucial in order to better comprehend their decision-making processes. Traditional extension services such as farmer field schools often relay simple and easy-to-use knowledge about pesticide application and fertilisers (Jørs et al., 2016). Gender roles and knowledge disparities may also influence agricultural practices, as shown by Christie et al. (2015) in Ghana and Mali. For example, farmers trained in IPM may share their knowledge with their neighbours, resulting in the greater use of IPM by neighbouring farmers (Jørs et al., 2016).

> 'We share knowledge and skills when we interact in group discussions'.

Social media is a growing source of agricultural information and digital relationships, leading to communities of practices with their own 'influencers' (Rust et al., 2022). These new resources for information and interaction could affect the abovementioned factors, especially trust, communication and influence of the normative context.

3.2.3. Influence of other actors from the socio-ecosystem

Along with farmers, the Chamber of Agriculture, pesticide retailers, farmers' cooperatives, extension agents and companies are also part of the agricultural socio-ecosystem. They can affect farmers' behaviour in multiple ways by transferring information, knowledge and training, for example. Here, we will discuss issues partially related to trust (cf. 3.1. above) but in a broader social context.

> 'Cooperatives are pressuring farmers to treat their plots'.

> 'Parents, the Chamber of Agriculture, agronomists, it's the same thing: they know what they're doing and we're just crazy'.

Various studies show the close relationship between the excessive use of plant protection products and the influence of pesticide retailers. Promoting the excessive use of pesticides may represent an opportunity for these companies to make more profits (Ríos-González et al., 2013). It is also possible that the retailers themselves do not have adequate knowledge about the potential risks of pesticides, leading to the transfer of incomplete or inaccurate advice to farmers (Jin et al., 2015), as the manufacturers determine the doses required to optimise the pesticide effect and reach an acceptable residual dispersion. In a similar way, these actors may provide too much information about which products to use or too little information about the potential hazards and safety measures to be taken (Fan et al., 2015). Moreover, farmers with more social capital may be more willing to engage in AES; this capital can be reinforced by interventions such as extension services (Lastra-Bravo et al., 2015).

Influence from other actors can also take place through partnerships between farmers and governments to facilitate the implementation of agricultural practices (Smith et al., 2020). Studies have also highlighted that crop protection strategies may vary depending on the type of advisors: advisors from the public sector tend to promote preventive strategies, while those from the private sector are more likely to favour pesticides (Wuepper et al., 2021, Neumeister et al., 2007). These insights may partly explain the mistrust of farmers who feel under pressure from extensionists.

3.3. Social factors

3.3.1. Normative context

Social norms dictate the type of behaviour that is socially valued or considered appropriate in a given context. A distinction should be made between injunctive norms (i.e., what I think others expect from me), and subjective norms (i.e., what I perceive as normal in others) (Nugier and Chekroun, 2021). The influence of a norm on people's behaviours and attitudes is determined by its salience within a reference group (e.g., farmers, neighbours, family). Additionally, behavioural change tends to persist over time when the behaviours are supported by social norms (Ayer, 1997; Blackstock et al., 2010; Mills et al., 2018). Indeed, the changes need to be embedded in a normative context, otherwise they are likely to fade over time.

> 'When I made the transition to organic farming, people called me crazy. I had to seek support from other areas where organic farming is more developed'.

Subjective norms can be activated in many ways. The intention to reduce pesticide use in the Netherlands was heavily influenced by the behaviour of other farmers called 'referents' (Bakker et al., 2021; Perry and Davenport, 2020). Farmers could observe, whether openly or not, the positive results on a specific practice related to low pesticide inputs. Farmers' decision-making about whether to adopt a technology-driven method is likely to be oriented towards reference groups with experience. These results highlight the crucial impact of farmers' groups, collective training and other types of agricultural networks (Bakker et al., 2021). Additionally, farmers with a high perception of subjective norms and the awareness of consequences tend to have a positive attitude towards SAP (Pierrette Coulibaly et al., 2021).

Injunctive norms are activated by highlighting a specific behaviour adopted by other landholders. In the French region of Languedoc-Roussillon, the Common Agricultural Policy provided winegrowers with the opportunity to obtain subsidies by engaging in a pesticide reduction programme. One study showed that highlighting whether other winegrowers chose to adopt these practices had a substantial influence on their own decision-making (Kuhfuss et al., 2014).

3.3.2. Social identity

For some landholders, their image in society is a stronger determinant for engaging in sustainable practices than their pro-environmental stance (Michel-Guillou and Moser, 2006). The social identity of farmers is, for example, defined by the characteristics of the groups from which certain behaviours are derived (Tajfel, 1982; Fielding et al., 2008). Farming practices associated with social identity can be reinforced over time and repeated depending on how farmers perceive themselves (Mills et al., 2017).

> 'I don't want any sprayers in my fields. That way, my neighbours won't have any doubts'.

> 'The farmers in DEPHY [network of farmers seeking to reduce pesticide use], they're all like me'.

Social identity influences farmers' motivation to engage in subsidised and non-subsidised sustainable practices in a significant way (McCarthy et al., 2007; van Dijk et al., 2016). Connections have also been shown between social identity and attitudes towards ethical environmental management practices (Sulemana and James, 2014). Although engaging in subsidised AES and organic schemes may be motivated by a 'pre-determined' ecological identity, this participation enables the development of a stronger ecological identity beyond economic motives (Barnes et al., 2022). Better insights into farmers' attitudes, beliefs and the specific behaviours associated with their reference group might help interventions to inspire their social identity and therefore lead to a change in practices. Nevertheless, farmers who are not part of a specific group or network may be difficult to reach (Mills et al., 2017).

3.3.3. Communication mechanisms

It is necessary to gain better insights into how farmers are exposed to new information, knowledge or training. The effectiveness of a message (e.g., harmful impact of a particular farming practice or production method on the environment) can be affected by various factors. For example, if the source of the message is perceived as reliable, the message will have a greater impact (O'Keefe, 2006).

> 'You need to have recognition in a certain domain of farming to be taken seriously by others'.

As similar experiences or life paths are considered to be factors of reliability, farmers tend to assimilate information given by other farmers or experts in their domain (Blackstock et al., 2010; Walton et al., 2017). The quality, relevance and framework of the message are all essential: farmers should not feel infantilised or receive a 'top-down' type of message. Communication focused on forecasting risks for crops, human health and the environment would be an effective management tool based on social interactions between stakeholders (Calliera and L'Astorina, 2018). At the farm level, expert and trusted advice is required so that farmers engage in agro-ecological practices (Inman et al., 2018).

4. Comparing the importance of different behavioural factors

Table 2 above shows the behavioural factors studied in the 50 articles of the review. The most frequently identified factors are personal knowledge of alternative practices (Kn), attitudes and beliefs (At) and farm and farmer characteristics (Ch). Reviews naturally include the highest number of factors studied. Interestingly, some factors were more specific to the case studies such as knowledge diffusion (Kd) and communication processes (Cm). The five case studies include almost the same factors, thus suggesting that some of the factors may be easier to mobilise in practice than others.

In addition to analysing the different factors mentioned in the 50 articles considered in this review, here we present the analyses of the nine papers that compare the factors and their importance or establish a hierarchical model that includes some of the factors discussed here (Fielding et al., 2008; Fan et al., 2015; van Dijk et al., 2016; Mills et al., 2017; Sharifzadeh et al., 2018; Caffaro et al., 2019; Ali et al., 2020; Knapp et al., 2021; Bakker et al., 2021).

Among the nine papers, three measured behaviours or intentions regarding pesticide use (Fan et al., 2015; Ali et al., 2020; Bakker et al., 2021), five assess behaviours or intentions regarding sustainable agriculture practices such as establishing wildlife habitats on farms (Fielding et al., 2008; van Dijk et al., 2016; Mills et al., 2017; Caffaro et al., 2019; Knapp et al., 2021), and one determines the factors influencing the choice of different pesticides (Sharifzadeh et al., 2018).

Five of the eight studies focusing on behaviours and intentions analysed them using a framework related to the TPB with a few modifications: two added a social identity component to the TPB (Fielding et al., 2008; van Dijk et al., 2016), one included the identity and personal norms from the Value-Belief-Norm framework (Mills et al., 2017) and one added a component relating to exposure to different information sources (Caffaro et al., 2019). Finally, one paper used the reasoned action approach, which further subdivides the elements of the TPB model (e.g., attitudes have two components, namely strength of behavioural beliefs and outcome evaluation) (Bakker et al., 2021).

The remaining three studies did not use a specific theoretical framework: two focused on protective pesticide behaviour (e.g., reduction in pesticide use, personal protection equipment, secure storage of pesticides) using explanatory variables related to pesticide knowledge and trust in information sources such as the government and retailers (Fan et al., 2015; Ali et al., 2020). The last paper investigated the use of preventative measures such as nets based on risk preferences, self-efficacy and locus of control (Knapp et al., 2021).

The two articles distinguishing between different regions and crop types (Fan et al., 2015; Ali et al., 2020) found that these variables had the greatest impact on pesticide protective behaviour. Although they did not use the TPB framework, both found that knowledge of pesticide use was a major behavioural factor, a construct that can be linked to attitudes in the TPB.

Not all articles using the TPB were in agreement: two found that attitudes and perceived behavioural control were the most impactful variables (Fielding et al., 2008; Caffaro et al., 2019), while another two found that variables related to social norms were most impactful (van Dijk et al., 2016; Bakker et al., 2021).

5. Analysis of case studies for changing practices: Use of behavioural factors

Our literature review provides numerous insights into the behavioural factors that potentially impact the shaping of farmers' practices. However, understanding the tangible impact of these factors on the actual transformation of agricultural practices is crucial in order to understand the contribution of the behavioural sciences to the transition pathways of territories. Here, we explore the links between the individual, social and external factors and the levers for action that lead to practical changes in farming practices. For this purpose, we analysed five case studies (Table 1) taken from three articles in our corpus. These studies highlight concrete results with the implementation of alternative practices regarding pesticide use when given different strategies for initiating change.

We selected a publication by Neumeister et al. (2007), which reports several case studies of pesticide reduction projects in Europe. We selected three of the case studies based in the Netherlands, Belgium and Denmark that were the most relevant to our research. These three projects involved a wide range of levers for action that were sometimes similar. In particular, the involvement of local stakeholders facilitated the creation of groups of farmers and test farms, the delivery of independent agricultural advice through the creation of content relating to alternative practices and the possible obtaining of quality labels through the adoption of new practices and knowledge tests. The results were positive in each case, with the development of labelled products based on alternative practices in Belgium and sold in more than 120 outlets nationwide and improved knowledge of the risks of inputs on the natural environment accompanied by reduced pesticide use in Denmark.

The second paper by Jørs et al. (2016) studies the impact of training Bolivian farmers and the diffusion of this knowledge regarding the adoption of IPM techniques. The training involved 14 theoretical and practical courses on IPM as well as coaching on sharing this acquired knowledge with neighbouring farmers. The study thus examined how this knowledge of IPM would be shared with neighbouring farmers. This localised research was conducted from 2002 to 2009. The trained farmers improved and maintained their knowledge. It yielded positive results in terms of farmers' adoption of new practices. Neighbouring farmers who did not undergo training also improved their knowledge and adopted new agricultural practices.

The third case study was recently conducted by Wuepper et al. (2021). It was based on a survey performed in Switzerland between 2016 and 2018. The study explored the influence of the type of agricultural advice (public or private) on the farmers' choice of pesticide strategies. This study showed a significant difference in the choice of strategies depending on the type of advice, as advice from public extension services was associated with a reduction or even non-use of pesticides unlike the advice given by actors in the private sector.

The studies of Jørs et al. and Neumeister highlight the impactful levers for action that rely on some factors identified in our review, as the impact of knowledge and its diffusion are mobilised as part of training, field trips or the creation of content relating to alternative practices. Thus, the cross-analysis of these studies suggests not only that knowledge about alternative practices to conventional phytosanitary products is essential for initiating change but also that the source of this knowledge and the way in which this knowledge is transmitted are likewise crucial. Jørs et al. further showed that more precise knowledge is more likely to be diffused.

The above studies show that modifying the farm advisory system seems to be effective in encouraging the adoption of new practices. Agricultural advice that is independent of the conventional agricultural world and that includes more diversified actors with different types of proposals appear very useful (Wuepper et al., 2021; Neumeister, 2007, in the Denmark case study). This can be linked to the significant impact of actors in the socio-ecosystem, as discussed in our review of the factors.

The importance of the involvement of independent stakeholders from the existing agricultural industrial system could be viewed from the perspective of the farmers' social environment. This also points to the importance of mistrust (vs confidence) in advisers, as mistrust as a factor can limit the impact of agricultural training, for example. Furthermore, this illustrates the underlying social dynamics at work such as the influence of the normative context within groups of farmers adopting the same practices. Although these influences have not been measured in the literature, the existence of these factors seems crutial. Drawing on these factors could thus increase the effectiveness of the levers for action.

Although the case studies are quite diverse in terms of their location and type of crop production, the levers for action are quite similar and quite effective in each of the case studies. They are, however, mobilised in different ways, probably leading to greater relevance in each context. For example, knowledge diffusion is mobilised by boosting leverage from certain actors in the socio-ecosystem who provide training and advice to farmers (Neumeister, 2007, Wuepper et al., 2021) at local and national scale. Knowledge diffusion can also be promoted by training a smaller group of farmers in a localised area and monitoring the impact of this training on neighbouring practices over time (Jørs et al., 2016). Both approaches show positive results in terms of the adoption of new agricultural practices, although the notion of spatial scale could impact the ease and relevance of activating more individual factors with the aim to adopt new practices.

6. Discussion

Our literature review provides insights into the behavioural factors that impact the shaping of farmers' practices. We detail three different types of factors depending on whether they relate to the individual characteristics of farmers such as personality traits, whether they arise from external considerations such as the presence of different actors in the socio-ecosystem or whether they involve the social dynamics between farmers. Many of these factors are illustrated by the verbatims that we collected from a specific small community of French farmers.

Moreover, few studies have specifically tried to measure the relative importance of these factors or to establish a hierarchy; those that did attempt to do so tend to use specific theoretical frameworks such as the TPB.

We then described several case studies that aimed to change farmers' pesticide practices. While our description is not exhaustive, it is interesting to observe that these case studies draw on similar factors, particularly knowledge. We will discuss the relevance of these findings as well as the aspects that warrant further investigation in the future.

6.1. Synergies and antagonisms between behavioural mechanisms: Working with different types of factors and variables

The review revealed multiple types of behavioural factors that may influence changes in farming practices and the adoption of more environmentally friendly practices. This reinforces the idea that adopting alternative practices results from a range of different considerations (Adnan et al., 2019) and that regardless of the farming system considered, no single factor can reliably predict the adoption of alternative practices (Delaroche, 2020). In addition, the intention to adopt pro-environmental behaviour is significantly influenced by 'problem awareness' (i.e., being unaware of the existence of solutions), which subsequently influences the impact of other individual or social mechanisms (Gifford and Nilsson, 2014).

Let us now provide an example of the interaction of various factors. The level of knowledge directly influences the degree of perceived control as well as the attitudes towards choosing environmentally friendly behaviour (Bamberg and Möser, 2007). Regarding the 'synergy' between factors regarding the adoption of pro-environmental farming practices, the communication mechanisms lead to more detailed knowledge regarding innovation among farmers (Mase et al., 2015; cited by Adnan et al., 2019), although they are also significatively linked to attitudes and perceived control, which are likewise positively linked to the adoption of alternative practices (Caffaro et al., 2019). These interactions may be reflected in the relationships between farmers and other actors in the socio-ecosystem (especially the advisory system) and, put into perspective, they represent a synergy between two factors that influence behaviour (i.e., communication mechanisms and influence from other actors) and between two 'types' of factors (i.e., social and structural).

6.2. Comparing the relative importance of behavioural mechanisms

Among the 50 articles reviewed here, nine explicitly compared the relative importance of behavioural mechanisms or sought to establish a hierarchy between several factors (Fielding et al., 2008; Fan et al., 2015; van Dijk et al., 2016; Mills et al., 2017; Sharifzadeh et al., 2018; Caffaro et al., 2019; Ali et al., 2020; Knapp et al., 2021; Bakker et al., 2021). The majority used the TPB, as it is a well-established model with a strong explanatory power (Armitage and Conner, 2001; Steinmetz et al., 2016). No single behavioural variable was consistently found to be more influential in the articles: all components of the TPB (attitudes, perceived behavioural control, social norms) were found to have a strong impact. It is interesting to note that the two most influential articles in this subset explored the impact of material conditions such as crop type or geographical region (Fan et al., 2015; Ali et al., 2020): this stresses the importance of considering the socio-agro-ecosystem as a whole, as the pathways towards sustainable agriculture are strongly dependent on these material conditions.

It can also be noted that the TPB, though powerful, does not encompass all behavioural determinants of behaviour: these articles do not allow us to compare the importance of the elements included in the TPB with other elements such as risk preference or trust in information sources. Moreover, many behavioural factors described in this review are not explored in the few articles attempting to compare their importance, thus making our understanding of their relative importance only partial.

Constructs from several behavioural theories are sometimes combined to reach a better level of conceptual explanation such as the TPB and the Value-Belief-Norm theory (Delaroche, 2020; Lu et al., 2022). However, since the theories link several variables but do not consistently use the same variables, it is difficult to generalise the results about the actual adoption of alternative practices. The meta-analysis conducted by Lu et al. (2022) showed that it was crucial to differentiate between the intention to perform a certain behaviour and the actual adoption of practices, as they are influenced by different factors.

6.3. Specificity of farmers and changes in agricultural practices

Most farms in the world are family-run and have few or no employees outside of the farmer's family, with smallholder farms accounting for 60% of arable land (Lowder et al., 2021). The situation of farmers is thus highly specific, as it can be studied from the perspective of both individuals and businesses (Ducos and Dupraz, 2007). However, farmers account for more than a quarter of the world's population, while nearly half of the world's habitable land is devoted to agriculture (FAO, 2014). Farmers therefore have a disproportionate impact on their proximate environment (e.g., pesticide use, biodiversity management) and on the more global environment (e.g., water usage, agricultural runoffs).

As small business owners, farmers have to make decisions in high uncertainty conditions and take risks more frequently than the general population does (Hannus and Sauer, 2020; Roe, 2015). Risk exposure can be mitigated through government subsidies, especially in developed countries (Roe, 2023). Compared with most other businesses, farms also have the specificity of being more closely linked to a specific place: land comprises a large part of their capital and specific pedoclimatic characteristics are crucial to determine the types of viable agricultural operations and their implementation. As such, farmers play a particular social role in the communities in which they live. They may see themselves as stewards and protectors of the land as well as businesspeople and landowners who may do as they please (Burke and Running, 2019). This particular social role of farming means that farmers may be motivated by both economic factors and environmental factors related to land attachment and nature connectedness. Indeed, farmers identify with nature more than the general population does and tend to be more concerned about the environment.

Moreover, farms are very often transmitted from generation to generation, and indeed, farming is the most inherited occupation in many countries (Laband and Lentz, 1983; Lobley, 2010). This means that farming practices are often learned in informal, familial or local settings just as much as in formal education, and that childhood experiences can have a greater impact on farming practices than in other types of professional practices. For example, childhood experiences of exposure to dangerous practices can shift farmers' perception of the risk involved (Sorensen et al., 2008).

6.4. Better mobilising of behavioural factors to favour the adoption of alternative practices: Impact of the local context and conceptualisation of farmers' behaviour

In our corpus, the case studies aiming to change practices and reduce pesticide use mostly relied on the use of external and social factors (Table 1). Individual behavioural factors are probably inherently more difficult to translate into action levers at a scale involving numerous stakeholders, where the use of more external factors can create more favourable conditions for change. In this case, individual and social factors can provide a better understanding of the farmers' reactions to certain levers: for example, risk tolerance, perceived control, mistrust or attitudes are factors that can affect the success of specific interventions.

In the case of an intervention at a smaller spatial scale, the consideration of individual behavioural factors may probably more easily be translated into action through targeted barriers and levers. The study of Akenroye et al. (2021) is particularly relevant in this respect, as it shows that certain behavioural factors (e.g., attitudes, risk perception, knowledge) are linked to a taxonomy of barriers (e.g., lack of knowledge, limited financial resources, perceived ease or difficulty of certain tasks) that hinder the adoption of SAP in coffee growing in the Nyeri county in Kenya.

As shown by the literature review and case studies, some factors may have an impact in many different situations, but farmers' practices and behaviours remain highly context-dependent, as shown by Feola et al. (2015). Their study shows that to describe and study farmers' behaviour in research, it is crucial to link their decision-making (i.e., factors influencing their behaviour) to their specific pressures and temporal dynamics while considering them simultaneously. These may include climate damages such as drought, frost and hail or pedoclimatic conditions, as soil characteristics can determine the type of crops optimised in a given geographic area (Tóth et al., 2020) and the specific pests that go with it. We can also cite the cultural context of each region and country as well as the variable agricultural market prices or government policies and subsidies that affect the type and quantity of crops that can be grown and sold (Lerner et al., 2013; Lee et al., 2016; Kovacs, 2021).

By linking farmers' behavioural responses to the specific pressures and temporal dynamics that affect their practices at various scales and by gaining a clearer idea of the socio-ecosystem in which they operate, it is easier to develop levers tailored to their situation that rely on specific factors in priority, thus probably improving their impact.

7. Conclusion

This article intended to shed light on the behavioural factors that affect farmers' changes of phytosanitary practices. The review revealed multiple types of factors that influence changes in farming practices and the adoption of environmentally friendly systems. In this respect, the behavioural sciences make an important contribution that could be included when tackling issues currently faced by the agricultural system. It is crucial to go beyond the consideration of farmers as rational agents taking into account the context in which the change occurs, whether agronomical, social, geographical, economic or temporal, as this setting has a powerful influence over the change. Moreover, beyond the understanding of mechanisms, taking action is a necessary step with different perspectives of action undertaken at various levels, from local agricultural advice, formation and networks to the implementation of national programs and policies. It would be interesting to consider the notion of facilitating conditions as a trigger for the effectiveness of specific behavioural factors. Without support, the necessary drastic reduction in pesticide use will be arduous and the agroecological transition will remain difficult.

CRediT authorship contribution statement

Elliot Meunier: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Pauline Smith:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. **Thibaud Griessinger:** Conceptualization, Investigation, Methodology. **Corinne Robert:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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