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RESEARCH ARTICLE

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Toward a low-pesticide agriculture: bridging practice theory and social-psychological concepts to analyze farmers' routines

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ABSTRACT

Agricultural crop protection (CP) today is under pressure not the least because it strongly relies on pesticides that negatively affect the environment and human health. Policy attempts to induce a transition toward low-pesticide CP have had limited success so far. While the literature has examined these difficulties primarily in terms of farmer decision-making, recent research has begun to highlight the routine nature of farmers' practices as a key aspect of the inertia of prevailing CP practices. Here we propose a framework that bridges practice theory (PT) and social-psychological concepts. We illustrate the relevance of this framework by gauging the relative roles of individual and structural factors as well as mechanisms that (de)stabilize pesticide-use practices. Our analysis is based on data from a survey conducted among Swiss farmers (n=652). Using structural equation modeling, we find that structural factors are more strongly associated with pesticide use than individual factors. Although farmers' personal norms to limit the use of pesticides are activated by values, self-efficacy, and social norms, they do not translate into behavior. Structural factors such as local production conditions and knowledge sourced from private agricultural advisory services appear to inhibit the mediating role of personal norms with respect to pesticide use. We conclude that reconfiguring such structural elements of CP practices may help to disrupt routines and eventually lead to a low-pesticide agriculture. Our findings also highlight the benefits of integrating PT and social-psychological concepts to advance our understanding of routines in CP.

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Introduction

Reducing pesticide use and its risks has become a major policy objective in Europe. The European Union (EU) strives for a reduction of 50% by 2030 (EC 2020) while Switzerland, a non-EU member, has set itself the ambitious target of reducing pesticide risk by 50% by 2027 (FOAG 2021b). Notwithstanding the benefits brought by pesticides such as high crop productivity and food security (Oerke 2006; Savary et al. 2019), their negative impacts on the environment and on human health have been demonstrated around the globe (Alavanja and Bonner 2012; Jones 2020; Tang et al. 2021). In addition, increasing pathogen resistance to pesticides reduces their effectiveness and since fewer new active ingredients of pesticides are developed and approved (Kraehmer et al. 2014), a shift toward low- or eventually no-pesticide use becomes inevitable. Despite the associated policy targets, there is so far little evidence that the agricultural sector is on such a trajectory (Möhring, Ingold, et al. 2020). Neither have pesticide sales in Europe decreased in the last decade (EEA 2019) nor has farmers' usage of them declined (see Hossard et al. 2017, for evidence from France). Furthermore, surface and groundwater contamination are still frequently reported (e.g., in Switzerland, see Spycher et al. 2018; Stehle and Schulz 2015).

Research examining the lack of change among farmers has characterized them as reluctant to change (Burton, Kuczera, and Schwarz 2008; Rodriguez et al. 2009). In sociological work, this disinclination has been linked to farmers' understandings of "good farming" that vary between different (regional) farming subcultures (Vanclay, Mesiti, and

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Howden 1998) or farming styles (van der Ploeg 1994). However, the dominant strand of farmer behavior research in Europe focuses on aspects of decision-making such as attitudes, for example concerning risks (e.g., Kallas, Serra, and Gil 2010) and preferences, for example for the status quo over alternatives (Barreiro-Hurle et al. 2018). Along with other cognitive, normative, and dispositional factors, attitudes and preferences have been frequently found to be associated with farmers' decisions to (not) adopt environmentally sustainable farming methods (Dessart, Barreiro-Hurlé, and van Bavel 2019).

Determinants of (un)sustainable farmer behavior that are not driven by (rational) choice, however, have received relatively little attention. Although routines and habits might delay sustainability transitions, scholars (above all, from the agronomic and economic sciences) and policymakers have seen them as being of only limited relevance for farmer behavior, with a few exceptions (e.g., Bakker et al. 2021; van Duinen et al. 2016; Wittstock et al. 2022). While rural sociology has successfully drawn attention to routinized components of farmer behavior (e.g., Huttunen and Oosterveer 2017; Mengistie, Mol, and Oosterveer 2017), these insights are often neglected when it comes to informing policy (because of a focus on findings showing statistical significance) (cf. e.g., Dessart, Barreiro-Hurlé, and van Bavel 2019). This is a striking issue given that behavioral research on food consumption (e.g., O'Neill et al. 2019; Ulug, Trell, and Horlings 2021) and in other domains such as mobility (e.g., Meinherz and Binder 2020), energy consumption (e.g., Sahakian et al. 2021), and investment (e.g., Lang et al. 2021) has provided compelling evidence for the utility of theorizing (un)sustainable behavior in terms of habitual and routine aspects. Similarly, criticism has been directed at the behavioral farming literature for its tendency to concentrate solely on either structural or individual farmer-related issues, underscoring the need for research that delves into both dimensions simultaneously (Anibaldi et al. 2021; Huttunen 2015; Ranjan et al. 2019).

Against this backdrop, we contribute to filling the gaps in understanding crop protection (CP) as routinized social practices and individual variations within these practices. We add to the emerging strand of research on bridging practice theory (PT) and social psychology, building on an individual-practice framework suggested by Piscicelli, Cooper, and Fisher (2015). This framework draws on Shove, Pantzar, and Watson's (2012) concept of three elements of practice: meanings, competences, and materials. First, meanings refer to the ways in which a practice is understood. This includes cultural conventions, social norms, collective assumptions, and expectations. Second, competences encompass skills and know-how related to a particular practice. Finally, materials refer to all physical resources associated with performing the practice. The social practice of CP can thus be thought of as the interplay of the individual farmers connecting their understanding of suitable CP to the properties of the field, the crops, the available products or techniques, and (their own or external) skills and know-how (Kaiser and Burger 2022). For our analysis, we disentangle the structural part of CP into factors of these three overarching analytical categories and the individual part into factors derived from social psychology.

The goal of this article is, accordingly, to advance a framework for the analysis of the interplay between individual and structural factors in today's routinized pesticide use. Whereas PT's theoretical strength has mainly been demonstrated by qualitative research (see, e.g., Kaiser and Burger 2022 for studying diversity in CP practices), for the empirical illustration here we use survey data from Switzerland and a quantitative approach[1] that enables us to gauge the relative roles of factors and mechanisms that (de)stabilize pesticide-use practices. A better understanding of these roles and mechanisms may facilitate to disrupt routines, many of which slow down the transition toward low-pesticide agriculture in Switzerland as in many other European countries. Switzerland serves as an interesting case not least because pesticides have recently been the subject of two popular ballot initiatives and a related major public debate.

In the following discussion, we briefly review the broader literature on understanding farmers' pesticide-use behavior. We then provide the theoretical underpinnings of the article and lay out a framework that considers individual and structural factors of farming practices. We apply this framework in the third section to an illustrative case using empirical data from a survey among Swiss farmers and structural equation modeling for hypotheses testing and analysis. The results are reported and discussed in the fourth section along with possible implications for disrupting routines in CP. The fifth and final section outlines our conclusions.

Theoretical underpinnings and analytical framework

The following subsections provide a brief review of the broader literature on understanding farmers' pesticide-use behavior, introduce routinization as the theoretical underpinning, and present the article's analytical framework and hypotheses.

Understanding farmers' pesticide-use behavior

Today's agricultural system is characterized by a strong dependency on pesticides, known as the "pesticide treadmill" (van den Bosch 1989) in which one agrochemical establishes the need for another (Guthman 2019). The broader structural aspects associated with this treadmill such as global agrochemical and food markets that transformed on-farm production is taken up by scholars drawing upon an agrarian political economy approach. Pesticide use has, for example, been conceptualized moving beyond the idea of self-responsible individuals who make choices to "understanding how farmers are constrained within an agrarian political economy" (Galt 2013, 337). While keeping these broader constraints in mind is important when analyzing farmers' pesticide use, in this article we adopt a narrower approach focusing on practices and their change instead of agrarian system change.

Farmers' practices have been covered extensively in the rural sociology and anthropology literatures. Prominent concepts include those of "good farming" and (regional) farming subcultures (Vanclay, Mesiti, and Howden 1998). These approaches center around the idea that farmers' notion of "good farm management" is regarded as their primary motivation that varies between different groups of farmers. To capture and explain diversity with a set of discrete styles (or strategies) of farming, van der Ploeg (1994) developed the closely related farming-styles approach. From a practice-theoretical perspective, an issue with this approach is that it bases farmers' actions explicitly on goal-oriented, conscious choice. At the same time, there is a lack of empirical evidence for that kind of conscious choice of a farming style (e.g., Howden et al. 1998). There is, however, more recent research building on the "good farming" concept which analyzes how farmers navigate and negotiate shifting identities and practices when transitioning to regenerative agriculture (Miller-Klugesherz and Sanderson 2023). The concept has also been used to examine how various community capitals (Bourdieu 1986) relate to farmer participation in agri-environmental schemes (e.g., Forney, Rosin, and Campbell 2018). Other research on farmers' pesticide use takes a relational approach that extends consideration of agency to nonhumans (Argüelles and March 2023). A common tenet in this literature is to challenge the homogenization of farmers' rationales and behaviors.

Heterogeneity in practices has also been shown in the case of Swiss farmers' CP (Kaiser and Burger 2022). Building on this research, we further adopt the argument that pesticide use is not only diverse but also routinized, that is it does not merely consist of farmers' choices but of contextually bounded, repetitive activities. Considering that the routine nature of farmers' practices may be a key aspect in the persistent levels of pesticide use motivates this article's focus on routinization.

Routinization as theoretical underpinning

Routinization has been approached from two distinct perspectives, often considered as mutually exclusive. On one hand, social-psychological research examines habits and regards them as automatic behaviors that are driven by contextual cues (Verplanken 2005). The basis of action in social-psychological research is individual choice. Accordingly, its unit of analysis is the (mental constitution of the) individual. On the other hand, in sociological research, PT has gained widespread recognition as an approach to study routines and their role in sustainability transitions over the past decade (e.g., Hinrichs 2014). In PT, the essence of social structure lies in routinization. In other words, social practices are routines: routines of "doing something" such as cooking, consuming, or working (Reckwitz 2002). This logic involves people following their daily flow of activities and lacking conscious consideration of the reasons for their actions (Sutherland and Huttunen 2018) which are based on socially shared conventions (Shove, Pantzar, and Watson 2012) or the logic of practice (Bourdieu 1977, 1990). PT, therefore, emphasizes practice as the focal units of analysis, instead of individuals, (Köhler et al. 2019; Reckwitz 2002; Shove, Pantzar, and Watson 2012).

Without neglecting the existing epistemological and conceptual differences between the two approaches, but also without intending to enter the vast theoretical debate on the role of individual versus structural factors in behavior (e.g., Boldero and Binder 2013), we provide two arguments in support of merging both perspectives in an empirically oriented analysis of CP practices. First, other scholars have pursued this line of thought and their works have demonstrated the benefits of employing an integrated approach to analyze routinized behaviors (Kurz et al. 2015 from a psychological perspective; Hess, Samuel, and Burger 2018; Hess et al. 2022 from a PT perspective). Second, each perspective has a weakness where the other one has its strength. While PT emphasizes contextual elements, it largely neglects the role of the individuals who perform or change practices (but are only looked upon as "carriers of practices"), as pointed out for example by Frezza et al. (2019) and Gram-Hanssen (2015).

Social psychology in turn focuses on the individual but undertheorizes contextual elements (also referred to as the "contextual soup"), which are inextricably bound to practices (following PT's understanding of a practice as a routinized "way of doing") (Kurz et al. 2015; Steg, Perlaviciute, and van der Werff 2015).

The literature on sustainable farming practices in particular tends to emphasize individual agency. It has been criticized for its focus on farmer and farm-level characteristics while factors related to political, economic, social, and cultural structures are neglected (Anibaldi et al. 2021; Ranjan et al. 2019). Although the influence of these structural factors may indeed be harder to measure (Anibaldi et al. 2021) than individual factors, there is strong evidence that the adoption of sustainable farming methods depends not only on individual actions but on the wider context (e.g., Schoonhoven and Runhaar 2018). Accordingly, there are good reasons to draw on a theoretical instrument such as PT that takes the contextual factors not as exogenous but as endogenous factors of the unit of analysis. However, as PT often tends to relegate individual agency in practices to the background, it is useful to address this by explicitly incorporating social-psychological concepts, thereby enhancing the analysis of routinized pesticide use.

Analytical framework and hypotheses

In this section, we present how we combine elements from PT and social psychology in our analytical framework (for the measures used in the empirical analysis, see the following section). We derive hypotheses for the relationship between individual factors, structural factors, and pesticide use, and propose a structural model for the analysis of the routinized practices made up of these factors.

Individual factors

Departing from Shove, Pantzar, and Watson (2012) and furthermore building on Piscicelli, Cooper, and Fisher (2015), Piscicelli et al. (2016), our analytical framework positions the individual (or "carrier of a practice" in PT) at the center of the practice. We explicitly acknowledge the interaction between the individual and a specific configuration of material, competence, and meaning elements, thus overcoming the "structure-agency" divide. Through the reproduction of a practice, the individual connects the elements (Piscicelli, Cooper, and Fisher 2015). Hence, the core assumption underlying this framework is that the relationship between the elements is partly mediated by individual traits, preferences, and characteristics. We seek to capture the latter using social-psychological concepts.

Our framework considers four social-psychological concepts: personal norms, objectives, values, and perceived self-efficacy. Norms can be evaluated closely to the behavior in question and should thus be practice specific (Kaiser, Wölfing, and Fuhrer 1999). Values, in contrast, are universal guiding principles in a person's life (Schwartz 1992), assumed to be relatively stable over time (Stern 2000), "trans-situational" (Schwartz 1992) and thus more distant to behavior than norms. Furthermore, we include objectives in our framework to capture the aspirational part of the practice, and we consider self-efficacy as a person's perception of the ease or difficulty with which certain tasks can be performed (Bandura 1977).

Personal norms. The social-psychological literature distinguishes between personal and social norms.[2] Personal norms refer to "a feeling of moral obligation," whereas social norms are defined as "the person's perception of social pressure to act in a certain way" (Klöckner and Blöbaum 2010, 575). Empirical findings suggest, for example, that organic farmers are significantly more concerned about doing "the right thing" (a proxy for personal norms) than conventional farmers are (Mzoughi 2011). We thus hypothesize:

> **H1:** Personal norms to limit the use of pesticides are negatively associated with pesticide use.

Objectives. Farming objectives are those that farmers pursue through their activity. The literature rather consistently suggests that economic farming objectives are negatively correlated with the adoption of sustainable practices (Dessart, Barreiro-Hurlé, and van Bavel 2019). However, farming objectives go beyond economic ones and may include lifestyle and conservation objectives, which were found to be positively correlated with adopting practices such as organic farming (Kallas, Serra, and Gil 2010). In addition, the essence from several decades of research is that farmers will adopt sustainable farming methods if they expect that these routines will help them achieve their objectives (Pannell et al. 2006). We thus assume that both lower-order – or immediate, practice-specific – objectives and higher-order, more long-term objectives are important factors of routinized CP practices. We understand immediate objectives as specific outcomes and processes related to CP that are rather immediately important to a farmer. An example is wanting healthy crops without weed infestations. Our hypothesis is:

H2a: Immediate objectives related to growing healthy crops are positively associated with pesticide use.

Using the examples above, this means that wanting healthy crops without weeds will be associated with heavier use of pesticides. Long-term objectives related to an individual's value system (Pannell et al. 2006; Roccas et al. 2002) may include passing on a viable farm to the next generation and this may involve good soil conditions achieved by using fewer agrochemicals. We thus hypothesize:

H2b: Long-term objectives of passing on a viable farm are negatively associated with pesticide use.

This means that the stronger the objective of farmers are to pass on a viable farm, for example one with good soil conditions, the lower their pesticide use is expected to be.

Values. Although values may be culturally shared, their prioritization may differ among individuals (Steg et al. 2014). Studies on values in environmental psychology are mostly based on two of Schwartz's (1992, 1994) value categories: self-transcendence and self-enhancement. Empirically, it has been shown that pro-environmental behavior is positively correlated with values of self-transcendence, such as biospheric and altruistic values, and negatively correlated with values of self-enhancement, such as egoistic values (Karp 1996; Klöckner 2013; Steg et al. 2014). Recent studies suggest that, on average, farmers rate self-transcendence values as more important than self-enhancement values (Baur, Dobricki, and Lips 2016; Dobricki 2011; Graskemper, Yu, and Feil 2022). This is explained by a "deeply rooted striving for the welfare of people and nature, to do something meaningful like, in the case of the farmers, food production" (Graskemper, Yu, and Feil 2022, 20). Nevertheless, the cited studies found considerable variation in the value profiles of farmer clusters, and we thus expect that different levels of self-transcendence values can explain variation in pesticide use. However, the literature suggests that values may not directly drive behavior. Instead, values are expected to form the root of personal norms (Klöckner 2013; Klöckner and Blöbaum 2010). We therefore hypothesize:

H3a: Self-transcendence values are positively associated with personal norms to limit pesticide use.

In addition, values were found to guide the selection and filtering of information (Stern and Dietz 1994), which then influences the development of factors such as long-term objectives. Hence, we further hypothesize:

H3b: Self-transcendence values are positively associated with the long-term objectives of passing on a viable farm.

Perceived self-efficacy. A person's perception of the ease or difficulty with which certain tasks can be performed relates to the social-psychological concept of perceived self-efficacy (Bandura 1977). The belief that one is able to realize a certain behavior overlaps substantially with what Ajzen (1991) calls perceived behavioral control in the theory of planned behavior. Perceived behavioral control "refers to a person's experience of having total control of a situation or being, at least partly, controlled by other people or situational conditions" (Klöckner and Blöbaum 2010, 575). In line with the theory of planned behavior, we expect that if farmers believe that they know how to limit pesticide use and value autonomy in exerting control over CP decisions, then these beliefs should be associated with a lower level of pesticide use and vice versa. In a prior study on the use of preventive measures against pests, Knapp, Wuepper, and Finger (2021) found that locus of control, a concept that is also very similar to self-efficacy, is one of the two best adoption predictors. Other research suggests that farmers' self-efficacy or perceived behavioral control drove their intentions to adopt low-emission agricultural practices (Morgan et al. 2015), innovative nutrient-management practices (Gao and Arbuckle 2022), and unsubsidized agri-environmental measures (van Dijk et al. 2016). Thus, our hypothesis is:

H4a: Self-efficacy is negatively associated with pesticide use.

Concerning the role of self-efficacy or perceived behavioral control, we further draw on the norm-activation model (Schwartz 1977; Schwartz and Howard 1981), which postulates that "the acting person must experience some amount of perceived behavioral control to activate the personal norm" (Klöckner and Blöbaum 2010, 575). A meta-analysis of empirical studies confirmed that personal norms are predicted by perceived behavioral control (Klöckner 2013). Accordingly, we hypothesize:

H4b: Self-efficacy is – mediated by personal norms – negatively associated with pesticide use.

Structural factors

Drawing on Shove, Pantzar, and Watson's (2012) practice framework, we categorize structural factors into the three overarching analytical elements of meanings, competences, and materials.

The meaning element of crop-protection practice. In line with research on general pro-environmental behavior, we assume that variations in the level of pesticide use indicate diverse conventions and expectations (Burton 2004a). Normative influences are expected to be particularly relevant in the farming sector, "an industry known for its conservative nature and which is heavily imbued with status symbols" (Burton 2004b, 363). In particular, farmers' perceptions of others' expectations are likely to push them toward a certain behavior (Dessart, Barreiro-Hurlé, and van Bavel 2019). Furthermore, social-psychological models postulate that social norms impact behavior in two ways – directly and mediated by personal norms (Klöckner and Blöbaum 2010). Empirical research supports this mediation (e.g., Klöckner 2013). Our hypotheses thus are:

> **H5a:** Social norms about the necessity to reduce pesticide use are negatively associated with pesticide use.

> **H5b:** Social norms about the necessity to reduce pesticide use are – mediated by personal norms – negatively associated with pesticide use.

The competence element of crop protection practice. In our practice theoretical conceptualization of CP, competences refer to the skills and knowledge that farmers need for performing CP. Low-pesticide CP means using more preventive or mechanical methods, which requires a high level of specific knowledge. This knowledge-intensive aspect of low-pesticide CP has been demonstrated to be one of the reasons why farmers do not widely consider it (Möhring, Ingold, et al. 2020). Extension (advisory services) are an important source of such specific knowledge. Prior research has identified (easy access to) extension services and training as strong predictors of farmers' adoption of different sustainable farming practices (D'Emden, Llewellyn, and Burton 2008; Kallas, Serra, and Gil 2010; Raza et al. 2019). Moreover, the type of pest management employed by farmers is influenced by whether they receive advice from public or private extension services. According to a recent Swiss study (Wuepper, Roleff, and Finger 2021), farmers who were advised by public extension services were more likely to use preventive measures, while those advised by private extension services were more prone to use synthetic pesticides, specifically insecticides in the cited study. Against this background, we expect that if farmers source their knowledge on CP primarily from a specific type of extension service – for example a private extension service, this can explain variation in pesticide use. We thus hypothesize:

> **H6:** Knowledge sourced from private extension services is positively associated with pesticide use.

The material element of crop protection practice. For CP, materials include physical resources (e.g., farm size and location, crops cultivated), financial resources (e.g., income), time and labor resources (e.g., full- or part-time farming), and the distribution channels of agricultural products. These resources form so-called "objective situational constraints or facilitators" (Tanner 1998) and are expected to be particularly relevant for explaining non-behavior (Klöckner and Blöbaum 2010), such as not refraining from pesticide use. Examples include the location of the farm within a certain agricultural zone, along with its implications for the given production conditions. We accordingly examine whether our data supports the following hypothesis:

> **H7:** Favorable production conditions according to the agricultural zone are positively associated with pesticide use.

Referring to the example above, this means that farms located in zones with comparatively better production conditions (e.g., valley zone) will take advantage of these factors and strive to produce more, presumably by using more pesticides.

Figure 1 illustrates the direct effects between variables implied by our hypotheses. Additionally, we tested for two indirect (and total) effects. First, we tested for the indirect effect of social norms on pesticide use with personal norms as a mediator variable. Second, we tested for the indirect effect of self-efficacy on pesticide use with personal norms as a mediator variable. The total effects were calculated as the sum of direct effects and indirect effects (Coulacoglou and Saklofske 2017).

Materials and methods

This study draws on earlier in-depth exploration using interviews with farmers (for details on the interview procedure and contents, see Kaiser and Burger 2022). It uses survey data collected from Swiss farmers and applies structural equation modeling for data analysis.

Survey design, sample, and procedures

Our survey data were collected in Switzerland which is an interesting case for studying pesticide-use practices. Swiss agriculture is characterized by small-scale

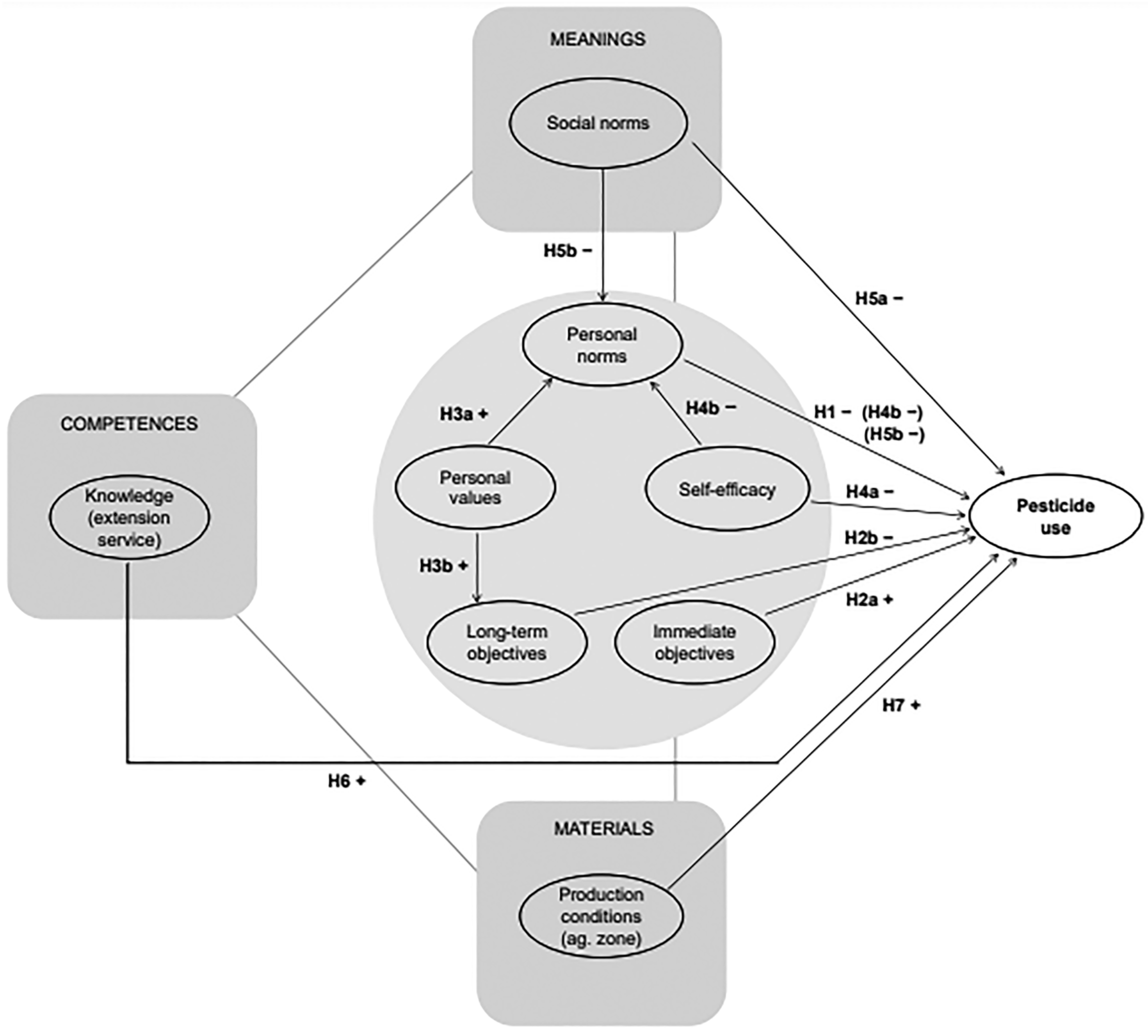

Figure 1. Proposed structural model and hypotheses. No causal interpretation is implied by the structural pathways in the model.

farming in intensively used multifunctional landscapes. Although Swiss farms are small by international comparison, they supply 57% of all energy consumed from food as expressed in the national self-sufficiency rate (FOAG 2021a). However, they are also estimated to produce external costs of 271 million Swiss francs (CHF or US$322 million) with the use of pesticides alone (see Schläpfer 2020 for details on how these costs were assessed). The associated negative effects have been taken up by two recent popular ballot initiatives that aimed to introduce stricter pesticide policies. The initiatives were ultimately rejected by Swiss voters but have spurred a large public debate (Finger 2021). Like in many other European countries, this has placed additional pressure on farmers to change their practices.

The survey was conducted online with the tool Unipark and as a paper-and-pencil survey by regular mail between November 2020 and January 2021. It is part of a larger research project on agricultural CP in Switzerland and consisted of 45 questions (see Supplementary Material) that covered a range of topics surrounding farmers' CP practices, their perspectives on CP, and its broader context. Despite the limitations of self-reported data, this survey allowed us to gather data that are not available in official farm databases.

The sample consisted of 2,155 Swiss farms with arable farming (for details on the sampling procedure, see Supplementary Material). The survey produced a total of 652 usable responses, which corresponds to a response rate of 30%. Participants of the following agri-environmental projects[3] were covered in the final sample: Berne Plant Protection Project[4] (49.7%), PestiRed[5] (8.6%), 3 V pilot project[6] (2.7%), and other agri-environmental projects (4.4%), as well as non-project participants (31.6%).[7] The survey respondents represented the Swiss farm population well in terms of gender, age, and production system (organic vs. non-organic) (see Table 1). The average farm size in our sample was larger than the national average (27.6 hectares vs. 21.2 hectares), and the median household-income category was slightly below the average income.[8] The

Table 1. Descriptive statistics for selected socio-demographic and farm indicators.[9]

Indicator	Survey respondents (*N* = 652)[10]	Farm-population characteristics[11] (*N* = 49,363)
Gender (%)		
Male	92.5	93.4
Female	3.1	6.6
Age group (%)		
20–29 years	4.4	NA[12]
30–39 years	18.7	14.0
40–49 years	27.5	27.3
50–59 years	36.8	35.9
60–69 years	11.2	NA
70–79 years	0.2	NA
Canton (%)		
Berne	79.9	20.5
Geneva	0.8	0.8
Glarus	4.1	0.7
Solothurn	7.4	2.7
Thurgau	1.7	5.0
Vaud	4.8	7.3
Farm size (mean area under cultivation in hectares)	27.6	21.2
Household income (CHF)[13]	75,001–100,000 (median category)	108,800 (mean)
Production system (%)		
Non-organic/conventional (w/ or w/o proof of ecological performance)	84.1	84.7
Organic	15.0	15.3

majority of farms in the sample (79.9%) are located in the canton of Berne, owing to field access facilitated by the Berne Plant Protection Project and the authorities involved in this project. Respondents completed the survey in German (85.7%) and French (14.3%).

Measures

Here we present how we measure the outcome and explanatory variables (see Table 2 for an overview of all survey constructs and measurement items used in the final model).

Outcome variables

We surveyed two commonly employed pesticide-use indicators: the number of applications per pesticide type and expenditures on pesticides. The number of pesticide applications was assessed per pesticide group (synthetic chemical insecticides, biological insecticides, synthetic chemical fungicides, biological fungicides, and herbicides) (Spycher et al. 2013).[15]

The average number of pesticide applications for all pesticide groups was 6.74 (SD = 7.49, min. = 0, max. = 47, $n = 575$). This number is in line with findings from other Swiss studies, which reported an average of 6 to 7 treatments per season on wheat fields (Bürger, de Mol, and Gerowitt 2012) and 7 to 7.5 for the cultivation of potatoes (Bystricky et al. 2015). The pesticide group most applied was fungicides with on average 3.08 applications (SD = 4.67, min. = 0, max. = 29, $n = 529$). Herbicides were on average applied 2.79 times (SD = 2.01, min. = 0, max. = 12, $n = 548$) and insecticides 1.41 times (SD = 2.38, min. = 0, max. = 21, $n = 512$). For all three groups, the distribution was highly skewed as expected.

For the second indicator, expenditures on pesticides, respondents were asked how much they had spent on CP products per main crop over the last crop year (in CHF) (Finger and El Benni 2013; Möhring, Dalhaus, et al. 2020). A key strength of this measure is that it does not down-weigh the use of biological pesticides (Möhring, Dalhaus, et al. 2020). Taking the total expenditures for the farms' three main crops, the average total expenditure per farm was 1,059 CHF (SD = 1374, min. = 0, max. = 8500, $n = 506$). Again, we observed a strong skewness of the indicator.[16]

Explanatory variables

The explanatory constructs of our model were estimated by using single or multiple items. The selection of items for each measurement model was informed by theoretical considerations and previous empirical findings.

Individual factors. To measure norms, we developed four items taken from previous research and based on Cialdini, Reno, and Kallgren (1990) concepts of personal, descriptive, and injunctive norms. Personal norms were assessed with one item ($M = 6.14$, SD = 1.25, $n = 629$) that has been adapted from a validated scale.

Immediate objectives were measured by asking respondents to state the importance they personally attribute to a list of nine aspects of agricultural production (see Supplementary Material for the survey). From this list, the item "healthy crops" ($M = 5.73$, SD = 1.28, $n = 637$) was used as a proxy in the final model, because no validated scale exists. Long-term objectives were measured with the item "pass on viable farm" ($M = 6.09$, SD = 1.42, $n = 645$).

We measured values using a shortened version of the item battery from Steg et al. (2014). Respondents were asked to rate the importance of nine values (16 in the original version) as guiding principles in their life. To assess how well these items measured the four value orientations, we conducted a confirmatory factor analysis (Kline 2015) (see results in Supplementary Material, Table S1). A root mean squared error of approximation (RMSEA) of 0.100 and a standardized root mean squared residual (SRMR) of 0.060 suggested an acceptable model fit. Altruistic and biospheric value orientations correlated with $r = 0.55$. In the

Table 2. Survey constructs and measurement items.

Latent construct	Indicator/ manifest variable	Question	Scale	Reference
Pesticide use	Number of applications of • insecticides, including biological insecticides • herbicides • fungicides, including biological fungicides	Please indicate the number of applications of crop-protection products (according to product group) over the last crop year for your three main crops.	≥0	Spycher et al. (2013)
	Total expenditures on pesticides in CHF	How much did you spend on crop-protection products per main crop over the last crop year?	0–10,000[14]	Finger and El Benni (2013); Möhring, Dalhaus, et al. (2020)
Personal norms	Personal norm	I see myself as obliged to limit the use of crop-protection products to a minimum.	From 1 to 7 1 = Not at all true 7 = Completely true	Cialdini, Reno, and Kallgren (1990)
Values	Self-transcendence:	Please indicate how important, in general, each of the following aspects is for you personally:	From 1 to 7 1 = Not at all important 7 = Very important	Steg et al. (2014)
	Altruistic value 1	Social justice		
	Altruistic value 2	Being helpful		
	Biospheric value 1	Living in harmony with nature		
	Biospheric value 2	Protecting the environment from pollution		
Immediate objectives	Healthy crops	How important are the following aspects of agricultural production for you? A healthy crop population without weed infestation	From 1 to 7 1 = Not at all important 7 = Very important	
Long-term objectives	Pass on viable farm	Please indicate the extent to which you think the following statements on the main duties of the farmer are true. My duty as a farmer is to… …pass on a viable farm to the next generation.	From 1 to 7 1 = Not at all true 7 = Completely true	
Perceived self-efficacy		Please indicate the extent to which the following statements on competences to act in crop protection are true for you:	From 1 to 7 1 = Not at all true 7 = Completely true	Bandura (1977)
	Self-efficacy: own decisions	For me, it is important to be able to make my own decisions about crop-protection measures on my farm.		
	Self-efficacy: reduce pesticides	I know how I can reduce the use of crop-protection products on my farm.		
	Self-efficacy: reduce impacts	I know how I can reduce the negative environmental impacts of crop-protection activities.		
Meanings: Social norms	Injunctive norm 1	My family members expect me to limit the use of crop-protection products to a minimum.	From 1 to 7 1 = Not at all true 7 = Completely true	Cialdini, Reno, and Kallgren (1990)
	Injunctive norm 2	Most of my acquaintances expect me to limit the use of crop-protection products to a minimum.		
Competences: Knowledge	Private extension services (dummy)	Which sources do you use to provide yourself with information on which you base your decisions in crop protection? Crop-protection firms	0 = no, 1 = yes	Wuepper, Roleff, and Finger (2021)
Materials: Local production conditions	Zone: valley (dummy)	In which agricultural zone is your farm located?	0 = no, 1 = yes	
Socio-demographic and farm characteristics	Age (class midpoints)	Age: I belong to the following age group…	Under 20, 20–29, 30–39, 40–49, 50–59, 60–69, 70 or older	
	Higher education (dummy)	What is your highest vocational or academic qualification? *[List provided]*	0 = no, 1 = yes	
	Total household income (class midpoints)	What was your household's total earned income last year (including direct payments and income from nonagricultural sidelines)? (In CHF)	≤50,000, 50,001–75,000, 75,001–100,000, 100,001–125,000, 125,001–150,000, >150,000	
	Organic production (dummy)	According to which guidelines do you produce crops? *[Multiple answers possible]*	Organic (Bio Suisse), Demeter	
	Farm size (total utilized agricultural area)	What acreage do you farm?	(In hectares of utilized agricultural area)	
	Online response mode (dummy)		0 = no, 1 = yes	

measurement model for values, we thus used the survey items for altruistic values ("altruistic value 1" [$M = 5.60$, SD = 1.30, $n = 644$] and "altruistic value 2" [$M = 6.17$, SD = 0.90, $n = 643$]) and biospheric values ("biospheric value 1" [$M = 6.08$, SD = 0.99, $n = 643$] and "biospheric value 2" [$M = 6.31$, SD = 0.91, $n = 644$]) to measure the construct self-transcendence values.

Self-efficacy was measured with a multiple item scale that asked respondents to indicate the extent to which a set of statements on competences to act in CP are true for them (own scale, based on Bandura 1977). The three items "self-efficacy: own decisions" ($M = 6.21$, SD = 1.08, $n = 640$), "self-efficacy: reduce pesticides" ($M = 5.79$, SD = 1.22, $n = 633$) and "self-efficacy: reduce impacts" ($M = 5.85$, SD = 1.15, $n = 630$) were used in the final model as indicator variables for the latent construct self-efficacy.

Structural factors. The structural factors measured are categorized into the three overarching analytical elements of meanings, competences, and materials.

The meaning element of CP practice: social norms. Two types of social norms were assessed, descriptive norms ("what most others do") and injunctive norms ("what most others approve or disapprove") (Cialdini, Reno, and Kallgren 1990, 1015). The two injunctive norm items "injunctive norm 1" ($M = 4.84$, SD = 2.03, $n = 622$) and "injunctive norm 2" ($M = 4.74$, SD = 1.88, $n = 621$) were highly correlated with $r = 0.76$ (see Supplementary Material, Table S2) and thus used to measure the latent construct social norms.

The competence element of CP practice: knowledge. For knowledge, we asked the survey participants where they source information for making their decisions in CP. Building on the earlier reported finding that farmers who were advised by public extension services were more likely to use preventive measures while farmers advised by private extension services were more likely to use synthetic pesticides (Wuepper, Roleff, and Finger 2021), we used the dummy variable "private extension services" (360 = yes, 288 = no) as a proxy for the kind of knowledge investigated here.

The material element of CP practice: local production conditions. For our analysis, the resources mentioned above can all be regarded as relevant materials. However, owing to their heterogeneous measurement in the survey, they could not be captured in the latent construct for materials in the model. We thus took the farm's agricultural zone (valley: 354 = yes, 285 = no) as a proxy for local physical conditions and crops cultivated.

In Switzerland, agricultural land is divided into three zones: valley, hill, and mountain zone. In the mountain and hill zones, agriculture faces more difficult production conditions (FOAG 2020). From agronomic studies, we know that farms with better soil properties work on higher input and output intensity levels (e.g., Burth et al. 2002). On sites where the yield potential is smaller, as it tends to be in the hill and mountain zones, farmers are more likely to use low-cost CP, for example according to the principles of integrated pest management (Bürger, de Mol, and Gerowitt 2012).[17]

Concerning crops cultivated, we know that the quantity of pesticide use differs substantially across crops (Finger et al. 2017). While the data for the proxy valley zone may not be sufficiently fine-grained to capture the accurate material factors that explain variations in pesticide use, we tested our model with subsamples of farms that cultivate different crop groups. The results suggested that, in our sample, crops that are known to be pesticide intensive (such as potatoes, sugar beets, and rapeseed) are often grown in the valley zone but rarely in the hill and mountain zones. This finding indicates that the valley zone may indeed be an appropriate proxy for the type of crops cultivated.

The range of missing values on all model variables varied between 0.6% and 22.4%. For all latent constructs for which we used single indicators in the model, we had to fix their loadings to 1, which equates to the assumption that they have been measured without error.

Control variables

As control variables, we used the socio-demographic factors age (age class midpoints) (median class midpoint = 44.5, $n = 644$), higher education (dummy) (306 = yes, 338 = no), and total household income class (median class = 75,001–100,000, $n = 617$). Furthermore, we controlled for farm characteristics such as organic production (dummy) (98 = yes, 551 = no) and farm size in hectares of utilized agricultural area ($M = 27.56$, SD = 18.96, $n = 639$) and for online-response mode (287 = yes, 365 = no). The variable gender was not meaningful owing to the extreme gender imbalance in the sample.

Analytical strategy

The hypotheses formulated above imply that there are multiple interrelations of individual and structural factors of pesticide use. The proposed conceptual model contains latent constructs that need to be estimated from observed variables. Covariance-based structural equation modeling allowed us to simultaneously analyze the relationships among several observed and latent variables, using factor and path analysis (regression analysis). This flexibility is one of the key strengths of structural equation modeling (Gefen, Straub, and Boudreau 2000; Hox and Bechgen 1998). The model was estimated in R version 4.1.2 (R Core Team 2021), using the package *lavaan* (version 0.6–9; Rosseel 2012).

We followed Kline (2015) and first assessed each of the measurement models and the structural model separately. The analysis reported in this article is mainly confirmatory and theory driven. We conducted a few data-driven post hoc modifications to improve the model fit, reflecting our aim to further develop a theoretical framework for studying agricultural practices.

We applied maximum likelihood estimation with robust standard errors and corrected test statistics to adjust for the non-normality of our data (Kline 2015). Moreover, we chose full information maximum likelihood as the missing data-estimation approach (Enders 2001).

The model fit was assessed with the RMSEA, the comparative fit index, the Tucker–Lewis index, the SRMR, and the chi square to df ratio (Kline 2015; Schermelleh-Engel, Moosbrugger, and Müller 2003) (see Table 3). For reliability and validity analysis, we used Cronbach's alpha to measure the internal consistency and reliability of the scales, composite reliability to measure the internal relation degree among the indicators, standardized factor loadings and average variance extracted to test the convergent validity of the measurement model, and the square root of the average variance extracted of latent variables to test the discriminant validity.

Results and discussion

Overall, the fit indices obtained for the estimated model indicate acceptable to good fit (Table 3; for a comparison of fit indices with alternative models tested see Supplementary Material, Table S3). The robust RMSEA and SRMR were in the range of a good fit. Failure to reach a good fit across all fit indices could be attributed to model complexity, a relatively small sample size and violation of the assumption of normal distribution for the outcome indicators.

The data showed good reliability and validity (see Supplementary Material, Tables S4 and S5). The variables in the model explained 30.5% of the variation in pesticide use, as implied by the value of R^2. This value did not exceed the threshold of 0.33 recommended by Chin (1998), which could be due to the use of proxies for four of the latent variables. R^2 is thus not further interpreted here.

Figure 2 displays direct effects, and Table 4 further includes indirect effects of the partially mediated variables social norms and self-efficacy and provides an overview of the hypotheses. We report standardized coefficients (see Supplementary Material, Table S6 for unstandardized coefficients).

Factors and mechanisms associated with pesticide use

The results suggest that there is no significant direct association between personal norms to limit pesticide use and actual pesticide use. Hypothesis H1 is not supported by the data. We discuss this finding together with the findings on the role of personal norms as a mediator variable further below.

Immediate objectives related to growing healthy crops were positively (0.10) and long-term objectives of passing on a viable farm were negatively (−0.14) associated with pesticide use, lending support for hypotheses H2a and H2b, respectively. The positive association of the desire to have a healthy crop population without weed infestation (immediate objectives) with pesticide use could be attributed to an (anticipated) increase in workload on the farm and potential lower product quality in the case of weed infestations, although farmers could also use prophylactic methods to control weeds. If we consider that farmers combine practice elements in a way that helps them to achieve their objectives, then our finding is in line with Möhring and Finger (2022), who reported that farmers "who expect a higher yield loss or higher production risks under pesticide-free production and those who expect higher investment risks in machinery (i.e., for mechanical weed control) are less likely to adopt"

Table 3. Goodness-of-fit indices.

	Robust chi^2/df	Robust CFI	Robust TLI	Robust RMSEA	SRMR
Estimated model	2.583	0.935	0.912	0.051	0.048
Recommendations (Kline 2015; Schermelleh-Engel, Moosbrugger, and Müller 2003):					
Acceptable fit	≤3	0.90 ≤ CFI ≤ 0.95	0.90 ≤ TLI ≤ 0.95	≤0.10	<0.10
Good fit	≤2	0.95 < CFI ≤ 1.00	0.95 < TLI ≤ 1.00	≤0.05	<0.05

CFI: comparative fit index; TLI: Tucker–Lewis index; RMSEA: root mean squared error of approximation; SRMR: standardized root mean squared residual.

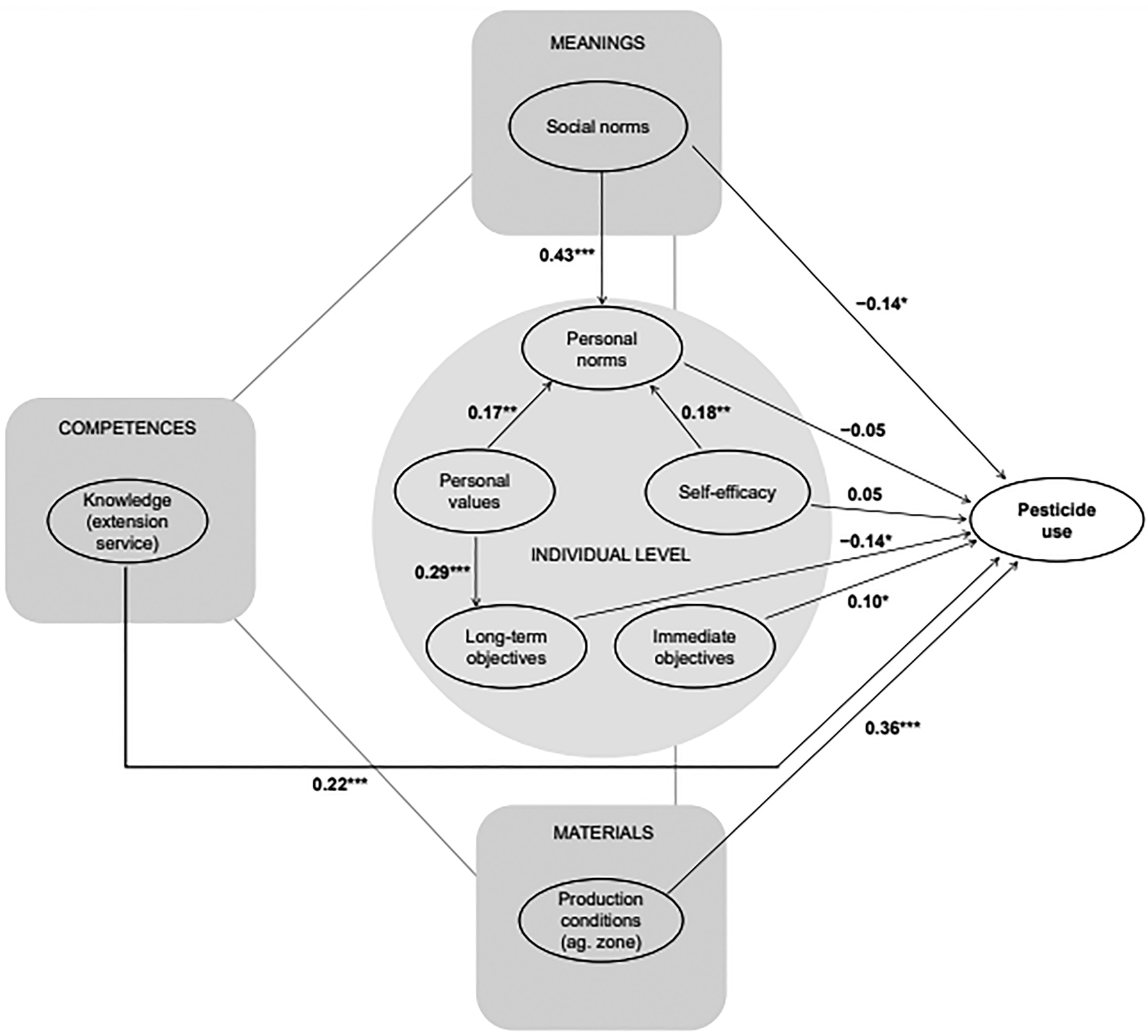

Figure 2. Results of the structural equation modeling with respect to the tested hypotheses. Displayed values are standardized parameter estimates for direct effects. Significance levels in the structural model: ***$p < .001$, **$p < .01$, *$p < .05$. No causal interpretation is implied by the structural pathways in the model.

Table 4. Structural results (standardized coefficients).

Path		Standardized path coefficient	Standard error	z	Hypothesis
H1:	Personal norms → Pesticide use	−0.05	0.053	−0.946	Not supported
H2a:	Immediate objectives → Pesticide use	0.10*	0.043	2.410	Supported
H2b:	Long-term objectives → Pesticide use	−0.14*	0.058	−2.364	Supported
H3a:	Values → Personal norms	0.17**	0.054	3.095	Supported
H3b:	Values → Long-term objectives	0.29***	0.047	6.158	Supported
H4a:	Self-efficacy → Pesticide use	0.05	0.050	1.024	Not supported
H4b:					Not supported
Indirect effects	Self-efficacy → Pesticide use (Mediator: Personal norms)	−0.01	0.010	−0.916	
Direct effects	Self-efficacy → Personal norms	0.18**	0.053	3.378	
	Personal norms → Pesticide use	−0.05	0.053	−0.946	
H5a:	Social norms → Pesticide use	−0.14*	0.057	−2.504	Supported
H5b:					Not supported
Indirect effects	Social norms → Pesticide use (Mediator: Personal norms)	−0.02	0.022	−0.953	
Direct effects	Social norms → Personal norms	0.43***	0.039	10.984	
	Personal norms → Pesticide use	−0.05	0.053	−0.946	
H6:	Knowledge → Pesticide use	0.22***	0.038	5.785	Supported
H7:	Materials → Pesticide use	0.36***	0.037	9.685	Supported

Significance levels in the structural model: ***$p < .001$, **$p < .01$, *$p < .05$. $N = 652$.

(p. 9) pesticide-free production. Furthermore, our finding may point to a dilemma facing farmers: clean fields without weeds were for a long time a symbol of "good farming," and this ideal still persists in a part of the farming community (Sutherland and Darnhofer 2012).

Self-transcendence values were positively associated with personal norms (0.17) and with long-term objectives (0.29). This provides support for hypotheses H3a and H3b.

In contrast, the associations of self-efficacy with pesticide use were not statistically significant. This applies to both the direct effects and the partial mediation via personal norms, whereas the results suggest a positive association of self-efficacy with personal norms (0.18). Hypotheses H4a and H4b are not supported by the data. This contrasts the findings of prior studies on the adoption of sustainable farming methods as indicated above. It resonates, however, with the broader literature that has shown that farmers' individual knowledge (which relates more to our measure of self-efficacy, i.e., farmers' beliefs that they know how to reduce pesticide use and how to reduce the negative environmental impacts) does not translate directly to their practices (Galt 2013).

In line with our expectations, the results imply that social norms concerning the necessity to reduce pesticide use are negatively associated with actual pesticide use (−0.14). Hypothesis H5a is supported. Even though the size of the coefficient was only medium, this finding is in line with research that found a direct effect of social norms, not on farmers' behavior itself but on their intentions to convert to organic farming (Läpple and Kelley 2013) and to adopt mixed cropping (Bonke and Musshoff 2020). The association of social norms with personal norms (0.43) was considerably larger than the direct association of social norms with pesticide use. However, personal norms were not significant as a mediator variable. The other coefficients in the model were robust to the exclusion of the variable personal norms as a mediator (see robustness checks in Supplementary Material, Table S7). Thus, hypothesis H5b is not supported.

Our results related to hypotheses H3a, H4b, and H5b support the idea that personal norms are activated by a number of other individual factors. They are thus in line with previous empirical research, which has shown that personal norms are predicted positively by social norms and self-transcendence values, and negatively by perceived behavioral control (or self-efficacy) (Klöckner 2013; Klöckner and Blöbaum 2010).[18] Other research, based on the theory of planned behavior, also suggests that personal norms mediate the effects of social norms and perceived behavioral control on intentions (the outcome variable in the study) (Wauters, D'Haene, and Lauwers 2017). Our analysis suggests that in the case of pesticide use, social norms, self-transcendence values, and self-efficacy indeed activate farmers' personal norms. However, we found no statistically significant association of personal norms with pesticide use. Although activated, personal norms do not appear to translate into pesticide-use behavior.

There are at least two possible explanations for this finding. First, there may be a measurement problem with the variable, which is highly skewed. The majority of respondents indicated complete agreement with the item statement.[19] Because our data are self-reported, there might be social desirability bias (Kaiser, Wölfing, and Fuhrer 1999; Vesely and Klöckner 2020), considering that pesticides have a negative image in the non-farming population and farmers are under public pressure to demonstrate that they (are willing to) reduce pesticide use (Huber and Finger 2019). Second, there may be a barrier between personal norms and pesticide use that our model does not capture. Barriers discussed in the literature relate to context elements and include environmental conditions (e.g., pest and weed pressure; Möhring and Finger 2022), market factors (e.g., retailers' requirements regarding quality and quantity of products supplied), and excessive regulation and sanctions that can inhibit farmers from acting upon their own intrinsic motivation because they are no longer self-determined and do not feel valued enough (Frey 2007).

As hypothesized, knowledge – operationalized as seeking information from private extension services – was positively associated with pesticide use and had the second largest direct effect (0.22). Hypothesis H6 is supported. This finding is in line with the study by Wuepper, Roleff, and Finger (2021). As similar results are reported in other empirical studies (e.g., Feola and Binder 2010; Schoell and Binder 2009; Thrupp, Bergeron, and Waters 1995), it could even be a relation that is stable across cultural and geographical contexts.

The largest effect was found for the factor materials. Materials was operationalized with the valley zone as a proxy for favorable local production conditions and crops grown and was positively associated with pesticide use (0.36), supporting hypothesis H7. This measure for the material element has some shortcomings such as being too rough to adequately reflect the meaning element in PT. Nevertheless, the finding appears in line with agronomic research mentioned above which shows that on land with higher yield potential farming is typically more intensive and vice versa. Our finding provides a first indication of the large role that this structural element plays in pesticide use practices vis-à-vis the other, especially individual, factors tested.

The inclusion of control variables resulted in high model complexity, which is penalized by the chi-square-based fit indices that we used to assess the model fit (Kline 2015). In an alternative model (see Supplementary Material, Table S7), we controlled for additional socio-demographic and farm factors. Organic production was negatively associated with pesticide use (−0.14), and total household income was very weakly positively associated with pesticide use (0.09). The coefficients of the variables farm size, farmer age, higher education, and online response mode were not statistically significant. The other coefficients in the model were robust to the inclusion of these variables, except for the coefficient for social norms, which was not significant anymore.

Implications for disrupting routines in crop protection

Our findings suggest a misalignment between farmers' pesticide use and a part of the individual element of CP practices. A reason for this appears to be that individual agency is partly constrained by context factors related to the material and competence elements, thereby creating a behavioral lock-in (Maréchal 2010) and inert practices. Although we did not directly study interventions, our practice-based approach and the empirical findings reveal possible entry points for disrupting routines in CP practices.

First, one of the primary routes to bring about change in practices is the reconfiguration of practice elements (Shove 2014; Shove, Pantzar, and Watson 2012) "such that less sustainable elements…become systematically less prominent and alternative, more sustainable, elements are promoted" (Kurz et al. 2015, 122). This does not mean that an unsustainable material element (e.g., the use of pesticides or the cultivation of per se pesticide-intensive crops) can simply be replaced by a more sustainable element (e.g., preventive CP measures or the cultivation of less pesticide-intensive crops). Instead, a change of material elements in CP will likely be accompanied by a co-evolution of other elements, here for example, knowledge. Transformation is not only a substitution of unsustainable materials by more sustainable. It is a reconfiguration of the practice. Regarding knowledge, for example, most farmers may not have previous experience, knowledge, or a supportive social network for replacing pesticide use by preventive methods or introducing new crops into their crop rotation. This appears to limit their agency. In our model, we have operationalized the knowledge element with the use of private extension services by way of example, and this has been positively associated with pesticide use. We thus point to tailoring training and extension to different groups of farmers to make it easier, more attractive, and common to use public and independent instead of private extension services. This is relevant considering that private extension is likely driven by off-farm interests (Stone 2016) and reinforces a strong belief in technological innovations as a panacea for issues such as pathogen resistance (Dentzman 2018). A change in structural elements available to farmers will not inevitably lead to farmers following and altering their behavior. Instead, PT emphasizes the recursive relationship between (individual) agency and structure – in other words, that human action and social structure are mutually co-constructed (Giddens 1984). This mutual relationship highlights the importance of alternative practices that are first performed in niches.

Second, the development and upscaling of pesticide-free niches may be a further entry point for disrupting routines in CP. (Groups of) individuals can be change agents and develop niches in otherwise dominant routines. These niches are considered potential forces to reconfigure socio-technical regimes in the context of a sustainability transition (e.g., Bui et al. 2016) like the one toward low-pesticide agriculture. In line with our findings concerning the role of individual versus structural factors, we suggest that potential change agents are not only farmers but also non-farm actors in the agri-food chain that influence practices at the farm level. Examples may be retailer and label organizations that set up pesticide-free production programs, as recently seen for bread wheat in Switzerland,[20] but also, as other studies suggest (e.g., Baur, Dobricki, and Lips 2016), agri-environmental schemes designed in a way that highlights the added value for society and the environment in the long run (and are therefore in line with farmers' self-transcendence values and personal norms).

Conclusion

In this article, we laid out an integrated framework that bridges PT and social-psychological theory to study current routinized CP practices. Using this framework allowed for an empirical illustration to investigate the relationship between individual and structural factors of CP practices on Swiss farms in a novel way. We found a positive association of materials, knowledge, and immediate objectives of farmers' CP practices with pesticide use. Conversely, social norms and long-term objectives were negatively associated with pesticide use. The personal norm to limit pesticide use to a minimum appeared to be activated by values, self-efficacy, and social norms but did not translate into behavior. Our findings suggest that individual agency is constrained by structural factors. Two possible strategies for disrupting routines were pointed out. First, to reconfigure practice elements and, second, to develop and scale up niches that can help to change the prevailing pesticide regime, paving the way toward low-pesticide agriculture.

We close with reflections on the limitations of this study and the resulting directions for future research. First, linking the two theoretical approaches requires more robust theoretical foundations. The relevant existing literature discusses the epistemological and conceptual differences of the approaches which cannot be delved into in this article. However, the empirical evidence established here may be useful for further advancing the theoretical base for bridging PT and social-psychological approaches. Second, the integrated framework we propose could only be tested illustratively. To advance it further, more empirical testing and data is required. Third, for our empirical illustration we adopted existing scales where available (e.g., to measure values and norms). While this has the advantage that the scales are validated, it restricted our ability to capture differences in people's understandings of, for example, what it means to reduce pesticide use to a minimum. A similar limitation is that we used self-reported pesticide expenditures and numbers of pesticide applications, which may be mere approximations by survey respondents. Future research on pesticide use should consider drawing on more accurate register data from suitable databases (see, e.g., the database used by Finger and El Benni 2013). Fourth, we considered several types of pesticides (fungicides, insecticides, and herbicides) for our two pesticide-use indicators. However, we did not cover growth regulators and seed dressing, which are also frequently used in (extended) CP. Similarly, we could only include structural factors in an illustrative manner in our model. Additional explanatory factors could be included in future studies. For example, crop insurance may be a relevant factor because it was found to lead to higher farm-level pesticide use (Möhring, Dalhaus, et al. 2020). Fifth, we suggest that future research additionally focuses on alternative and (sometimes ostensibly unrelated) adjacent practices, with which the practice in question may be interwoven and codependent. A particularly relevant interaction has been shown between pesticide use and fertilizer application (Bürger, de Mol, and Gerowitt 2012). Finally, the focus of this article is on Swiss farmers due to the case examined. The findings may therefore not be generalizable beyond Switzerland but they may inform future research in other local contexts.

Notes

1. PT scholars often take qualitative research methods as the one and only appropriate toolbox to study practices. It would go beyond the scope of this article to rebut this claim here. It suffices to point out that there are PT-based studies with a quantitative research design (Hess et al. 2018, 2022) and that if the interplays of meanings, materials, and competences make up the cement of societies, it should be possible to analyze that cement independently of how individuals conceive and experience the practices.
2. Cf., for example, theory of planned behavior for social norms (Ajzen 1991), norm-activation model for personal norms (Schwartz 1977; Schwartz and Howard 1981), and Value-Belief-Norm Theory (Stern 2000).
3. These three agri-environmental projects are part of the larger research project mentioned earlier.
4. http://www.weu.be.ch/de/start/themen/landwirtschaft/pflanzenschutz/berner-pflanzenschutzprojekt.
5. http://www.pestired.ch.
6. http://www.projekt3v.ch.
7. In addition, 2.9% were treated as missing values.
8. This slight discrepancy is not contradictory because the household income comprised both farm and non-farm income (Jan et al. 2021).
9. Comparison of the survey subsample used in our analysis with official farm-population statistics.
10. Because of missing survey data, not all variables add up to 100%.
11. For official figures for the year 2020, refer to the Federal Statistical Office (2021a, 2021b).
12. Data only available for year 2016; some age classes were not available (NA) because they were composed differently (AGRISTAT 2017).
13. Note that the same measures of central tendency were not available for these data.
14. The coefficient for the original values was divided by 1,000 to adjust for the different scale of this indicator
15. We furthermore asked for the number of uses of beneficials (Nützlinge) in crop protection. However, because beneficials are not a CP product that causes environmental loads, we did not consider it as a pesticide use indicator. For the analysis, the synthetic chemical insecticide and the biological insecticide group were combined into one group for insecticides; the same was done for fungicides. This step was taken because the factor loadings for the biological groups were low in the initial model, which may be due to the comparably large number of zero values (369 zero values for biological insecticides and 397 zero values for biological fungicides). However, it has been highlighted that biological pesticides should not be disregarded because, in fact, their toxicity can be of similar or greater degree than that of chemical pesticides (Dewhurst 2001). Thus, instead of dropping the biological pesticide indicators, we decided to use combined categories and proceed with three indicators, namely, insecticides, herbicides and fungicides.
16. A problem with this indicator is that some respondents stated the expenses per hectare instead of in total. We identified these cases (n = 24) and assigned the indicator a missing value because the correct numbers could not be obtained with the available data. Furthermore, extreme outliers that

were found to be implausible were excluded from the analysis, using a cutoff at 10,000 CHF. We re-ran the analysis including expenses above the cut-off and found only minimal changes in the parameter estimates.
17. For an overview of integrated pest management principles, see for example https://ec.europa.eu/food/plants/pesticides/sustainable-use-pesticides/integrated-pestmanagement-ipm_en.
18. Note that the study by Klöckner and Blöbaum (2010) used the scale in inverse direction to our scale.
19. The statement provided was: I see myself as obliged to limit the use of crop protection products to a minimum.
20. See the non-organic, private–public standard for pesticide-free wheat production in Switzerland that is currently introduced by the producer organization IP-SUISSE (see.g. the study by Möhring and Finger 2022).

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Data availability statement

The data is available from the first author upon reasonable request.

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