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Understanding diversity in farmers' routinized crop protection practices

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ABSTRACT

Present-day agricultural crop protection relies heavily on synthetic pesticides, which are known to adversely affect the environment and human health. As remediation, European agricultural policies strive for a transition to low-pesticide agriculture. However, these policy efforts have so far shown limited success. We argue that neglecting the diversity of the according routinized practices belongs to the reasons for that limited success. We specifically investigate how farmers' current local crop protection practices differ. Methodologically, the article is based on semi-structured interviews with farmers and crop protection experts as well as on qualitative data from a survey among Swiss farmers. Using practice theory to analyze our data, we identify the *meanings, materials* and *competences* in farmers' practice narratives. From our analysis, five types of routinized crop protection practice emerge, revealing a picture of diversity, also in their responses to current incentive-based agri-environmental policy instruments. This diversity cannot be accommodated by a one-size-fits-all policy approach but rather requires a balanced mix, for example of command-and-control instruments, financial incentives and extension services.

1. Introduction

The adverse effects of synthetic pesticides used in agricultural crop protection (CP) have raised growing public concern. These repeatedly demonstrated effects include environmental damage such as water pollution, a continued decline in biodiversity and soil fertility (e.g., Guntern et al., 2021; Niggli et al., 2020; Stehle and Schulz, 2015a, 2015b) as well as human health risks due to pesticide exposure (e.g., Alavanja and Bonner, 2012). Furthermore, emerging pathogen resistance to pesticides reduces their effectiveness, to which farmers may in turn respond by increasing the dose and frequency of use (Popp et al., 2013). Overall, these effects indicate that present-day industrialized agricultural CP is unsustainable (Buckwell et al., 2020) and calls for a robust transition to low-pesticide agriculture.

European policy efforts to reduce synthetic pesticide use and risks, however, have neither been successful in reaching reduction goals (Hossard et al., 2017; Möhring et al., 2020) nor in inducing a more fundamental transition. European agri-environmental policies (AEP) include regulatory frameworks and "green" direct payments, which constitute a substantial part of farm incomes. This ecological direct payment system consists of mandatory cross-compliance requirements and voluntary agri-environmental schemes (AES). AES have become a key policy instrument for environmental improvement. They are incentive-based and compensate farmers for the profits foregone by the provision of positive externalities and/or for additional costs incurred by the adoption of environmentally sound farming methods (Espinosa-Goded et al., 2010; Uthes and Matzdorf, 2013).

At farm level, these schemes have not attracted support as widely as necessary for a transition. Farmers are dissatisfied with the AES but temporarily accept them, "often because they involve little actual change to farming practices" (Niskanen et al., 2021, p.1). This behavior indicates that current AES are hardly effective in bringing about fundamental change toward more sustainable CP.

In the literature, the difficulties faced by current European AEP have predominantly been assessed from the perspective of farmers' decision making. One important strand of behavior literature uses the Theory of Planned Behavior (TPB) (Ajzen, 1991) as underlying theoretical framework. Because the TPB and related frameworks conceptually base farmers' action on individual choice, many studies emphasize factors such as the individuals' attitudes, values, beliefs, risk perception, uncertainty assessment, preferences, and information availability as determinants for the (non-)adoption of sustainable farming methods (Dessart et al., 2019). A general finding is that financial incentives provided by AEP play an important role in farmers' willingness to adopt

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agri-environmental measures. However, the studies also point out that there is remarkable heterogeneity in farmers' preferences and responses to incentives (Hasler et al., 2019; Lastra-Bravo et al., 2015). The existing financial instruments are one-size-fits-all approaches and tend to overlook that diversity. In addition, behavioral intentions or stated preferences do not necessarily translate into behavior, as multiple studies have shown (see, e.g., Hudson et al., 2012; Kollmuss and Agyeman, 2002; Shove, 2010; Vermeir and Verbeke, 2006; Webb and Sheeran, 2006).

Another strand of literature provides a sociocultural conceptualization of farming. In the concept of (regional) farming subculture (Vanclay et al., 1998), farmers' notion of "good farm management" is regarded as their primary motivation that varies between different groups of farmers. The closely related farming styles approach (van der Ploeg, 1994) has been developed to capture and explain diversity with a set of discrete styles (or strategies) of farming. Although being highly useful for conceptualizing diversity within agriculture, the farming styles concept has been criticized for its methodological flaws regarding its practical application (Vanclay and Lawrence, 1994). Moreover, this concept bases farmers' action explicitly on goal-oriented, conscious choice. However, for that kind of conscious choice of a farming style, no evidence was found in an Australian study (Howden et al., 1998).

We thus argue that while the analyses of the mentioned choice elements of farmer behavior are important and consistent with the paradigm under which incentive-based interventions are set up, taking farmers' practices only as a matter of (rational) choice involves a blind spot. It neglects the significance of the context in which behavior is embedded and pays little attention to the routinized components of behavior. This argument is supported by a growing body of literature on routinized behaviors across different fields of research such as on energy consumption (e.g., Hess et al., 2018; Sahakian et al., 2021), mobility (e.g., Meinherz and Binder, 2020) and investment (e.g., Lang et al., 2021).

In the last decade, practice theory (PT) has become a popular approach to study routinization. According to Reckwitz (2002), PT is a type of sociocultural theory that seeks to understand and explain human action and social order by analyzing the repetitive activities of everyday life (i.e., practices). Two of the PT central claims are that the transition to sustainability requires going beyond individual attitudes, behavior and choice, and that actual practices should be the main units of analysis (Shove et al., 2012). A PT-informed approach provides a conceptual lens to accomplish an in-depth understanding of practices embedded in their particular contexts that also includes "historically and culturally specific trajectories of what people do" (Shove et al., 2012, p.145). Recent studies approaching the malfunctioning of policies from a PT perspective indeed indicate that there is a mismatch between the policies and the actual routinized and heterogeneous practices (e.g., Huttunen, 2015; Sutherland and Huttunen, 2018).

Growing interest in analyzing agricultural routines by means of PT notwithstanding (see, e.g., studies by Bellet, 2018; de Krom, 2015; Kasunic, 2015; Parks and Brekken, 2019), so far little research on CP exists that can provide a nuanced understanding of farmers' actual practices and the variations within those practices. An exception is the investigation of pesticide use practices in Ethiopia through the lens of PT (Mengistie et al., 2017). Other recent studies examined practices related to CP, such as fertilization (Huttunen and Oosterveer, 2017), as well as soil cultivation, fertilization and harvesting as parts of cultivation practices (Huttunen, 2019). Two other pieces of research provide a PT perspective on the transformation process from non-organic to organic farming (Freyer and Bingen, 2012; Sutherland and Darnhofer, 2012). However, hardly any research exists that focuses explicitly on current CP practices in European countries. We expect to not only gain a differentiated picture of CP practices by using PT, but to identify reasons explaining the mismatch between the existing policies and the existing practices.

Against that backdrop, the study addresses the following core research question: How do farmers' current CP practices differ? The overarching goal of this paper is to better understand current CP as it is practiced by local-level actors. To do so, we adapt a conceptual PT framework (section 2) and carry out an empirical study on farmers' CP practices (method described in section 3); we analyze the current CP practices by disentangling them into three elements of practice, namely *meanings, materials* and *competences* (section 4); we identify systematic differences in CP practices performed at farm level (section 4); and we discuss possible implications of our results for a better alignment of practices and policies (section 5).

By exploring the application of PT when capturing differentiation in current CP practices, we contribute to the literature on understanding farming practices. Our study highlights the potential benefits of considering routines and diversity in CP practices in the design of effective and acceptable policy instruments for the sustainability transition.

2. A practice theoretical perspective on crop protection

The actual practice is the main unit of analysis in PT-based research. A practice is defined as a routinized type of behavior, or simply as a way of "doing something"—such as a way of cooking, of consuming or of working (Reckwitz, 2002). Routinization as a core aspect of practice approaches originates from Bourdieu's (1977; 1990) reflections on what the basis of human action is. He observed that for the most part, people are not acting rationally, i.e., in response to incentives provided by policies or to norms and rules set by society. Instead, he described the logic of practice as the basis of people's actions. People follow "the daily flow of activities including both improvisation and routines without conscious consideration of the reasons behind the action" (Sutherland and Huttunen, 2018, p.36).

Practices can be approached in two analytically distinct ways, as entities and as performances (Reckwitz, 2002). Practice-as-entity refers to what people generally understand to be and hence recognize as the practice in question, without actually performing it. It provides, so to speak, a pattern that people then fill out and reproduce when they perform the practice (Shove et al., 2012). Practice-as-performance means the observable expression of the practice in the specific setting of time and place (Spurling et al., 2013). Because every performance is unique, there are slight variations between the performances of the same practice-as-entity.

Practices are generally thought of as a composition of several elements that are connected to one another and mediated by practitioners (Warde, 2005). These elements include, broadly speaking, a material, a bodily, a mental and a knowledge dimension (Reckwitz, 2002; cf. also Shove et al., 2012; Warde, 2005). Values, norms, skills and the like are thus considered attributes of practices rather than of individuals (Reckwitz, 2002; Shove et al., 2012). The role of individuals in the practice is likewise not that of actors; they are instead understood as the *carriers* of practice, or practitioners. When in our case, farmer-practitioners perform the practice of CP, their understanding of suitable CP gets connected to the properties of the field, the crops, the available products or techniques and the farmers' skills and know-how.

A widely established PT framework is that provided by Shove et al. (2012), according to which a practice is made of three overarching categories of elements, namely *meanings, materials* and *competences*. This analytical tool has been used in several analyses of farming (sub)practices, other than CP. For example, it turned out to be useful for exploring differentiation and change in agricultural fertilization practices in Finland (Huttunen and Oosterveer, 2017), different animal husbandry practices in Canada (Bassi et al., 2019), and organic food production and consumption in the Philippines (Sahakian et al., 2017). Moreover, the analytical tool has been used to study practice–policy disconnections, for example between forest-based practices and current forestry policies in Europe (Sutherland and Huttunen, 2018). Connecting PT with policy coherence analysis, Huttunen (2015) conducted a study on land clearance practices in Finland. By identifying the different elements of practices, she demonstrated the possibility to detect the main issues that

cause the experienced policy incoherence and poor policy functioning.

This outcome also displays a different stance on the relation between policy and practice (Shove et al., 2012). In the behavioral approach, policy is strictly represented as an "external influence on the factors and drivers of behavior" (Shove et al., 2012, p.143), whereas PT scholars urge to reconsider the role of policy. They argue that both policy and policymakers do not only intervene from the outside but are in fact also embedded in the system of practice they target. The embeddedness results from policy and policymakers "facilitating, or hindering, the availability and circulation of the elements" (Shove et al., 2012, p.147) that constitute the practices. In agriculture, examples for such elements may include publicly promoted ideas about what it means to be a farmer, official policy objectives like food sovereignty (*meanings*); direct subsidies, state-supported technological innovations, agricultural laws and regulations (*materials*); research, farmer education and training (*competences*).

Following this line, we do not take the practice–policy mismatch as object of research in this study. Instead, we adopt the assumption that the policy environment is partly immanent in the practices and thus comes into view via the analysis of practice elements, which also enables an interpretation of the sensitivities to the policy instruments used. Whilst PT is attributed difficulties in leading to concrete suggestions for transition policy interventions (Rauschmayer et al., 2015), it has proven useful in uncovering the structure of practices, their dynamics and their differentiation. Hence, we expect that analyzing CP through the lens of PT will contribute to a better understanding of CP practice as a general entity and as performance, including its variations. In addition, this approach promises to lend itself well to locating policies in the ways they are embedded in different types of practices.

In the following, we draw on Shove et al.'s (2012) PT framework of three dimensions for the study of CP practices. We operationalize *meanings* as the ways in which CP is understood, which includes values, norms, wants and emotions associated with CP. A typical meaning related to CP is that of "healthy plants". *Materials* refer to mainly physical elements related to performing the practice. In the case of CP, these involve, for example, pesticides, fields, tools and machinery but also labor resources and the distribution channels of agricultural products with their quality and quantity requirements. *Competences* mean the skills and knowledge needed for performing the practice, such as knowing when and how to apply pesticides or beneficial organisms on particular crops (see Table 1).

Table 1
Operationalization of an elements approach to practice theory for empirically studying farmers' crop protection.

Element	Operationalization
Meanings	Accounts of farmers' personal values as well as norms, wants and emotions specifically associated with crop protection and production
Materials	Accounts of all resources related to performing crop protection and production: physical resources such as tools, machinery, crop protection products, fields; financial resources (e.g., subsidies); time and labor resources (e.g., full- or part-time farming, additional workforce); distribution channels of agricultural products
Competences	Accounts of the skills and knowledge needed for performing crop protection and production, farmers' perceptions of the ease or difficulty of performing certain tasks of crop protection (i.e., their self-efficacy)

3. Data and methods

For the analysis of current CP practices, we opted for a qualitative multimethod research design[1] (Mik-Meyer, 2021) given our interest in revealing the contextually bounded routines. We use three different datasets from Switzerland. We collected two datasets through in-depth, semi-structured interviews, first with six farmers and then with five CP experts. Interviews are suitable instruments to capture the complexity of individual practices (Miller and Glassner, 2021). As a third dataset, we use qualitative data from a survey among Swiss farmers, which includes answers to open-ended questions (OEQs) from 450 farmers.

Switzerland is an interesting case for the exploration of agricultural CP practices for several reasons. First, the Swiss government has invested much effort to promote multifunctional, sustainable agriculture (Mann, 2018). As a result, Switzerland has one of the highest levels of agricultural subsidies in Europe (Federal Statistical Office, 2021b). The minimum standard a farm must fulfil to be eligible for direct payments is defined in the cross-compliance regulations (*proof of ecological performance [PEP]*). Moreover, and this is a second reason, a range of other production forms emerged whose added value is additionally compensated by market price premiums. These production forms include integrated (labelled as *IP-Suisse*[2]), extensive (*Extenso*[3]), organic (*Bio Suisse Knospe*[4]) and biodynamic (*Demeter*[5]) production. Third, Swiss agriculture is characterized by a few specificities. With an average size of 21.15 ha farmland (Federal Statistical Office, 2021a; Federal Statistical Office, 2021c), Swiss farms are small in international comparison, and family farms remain the dominant business type. This aspect is relevant for our study because family farms are often expected to be favorable in terms of farm sustainability (Contzen and Forney, 2017). Furthermore, it is likely that the farmers whom we interrogate are at one and the same time both the farm managers and the laborers who work on the fields. Another specificity are the high costs of agricultural production, caused by topographic conditions and a high domestic wage level, requiring border protection policies for agricultural products (Gray et al., 2017). Fourth, Swiss agriculture has always been influenced strongly by the environment and society (Kölliker et al., 2008). CP in particular is high on the country's public agenda and addressed by several popular initiatives[6] (see, e.g., an impact assessment of the *Initiative for clean drinking water* by Schmidt et al., 2019). Even when ultimately rejected by citizens, as it was the case with two recent pesticide initiatives, such initiatives trigger the executive to make counter proposals of which a majority has been accepted in the past. Huber and Finger (2019) thus showed Swiss popular initiatives' ability to increasingly stimulate agricultural policy. It is important to note here that although we use the case of Swiss farms to study current local CP practices, our research question remains a generic one.

3.1. Data collection

In total, we conducted 11 interviews in four Swiss cantons, ensuring the consideration of regional differences. The main objective of the interviews was to explore how and why CP is performed in a particular way (see interview topics in Appendix A.3). We recruited the

[1] Multimethod research is research that uses multiple forms of qualitative data (e.g., interviews and observations) or multiple forms of quantitative data (e.g., survey data and experimental data) (Creswell, 2015, p.3).

[2] www.ipsuisse.ch.

[3] For more information on the Swiss *Extenso* program, see, e.g., Finger and El Benni (2013).

[4] www.bio-suisse.ch.

[5] www.demeter.ch.

[6] Recent initiatives include the *Initiative for clean drinking water* and the *Initiative for a Switzerland without pesticides*, upcoming is the *Biodiversity initiative* (Federal Chancellery, 2021).

Table 2
Identified types of crop protection practice and related key meanings, materials and competences.

Type of crop protection (CP) practice	Meanings (Norms, values, wants, emotions)	Materials (Tools, machinery, fields, human resources, distribution channels)	Competences (Knowledge, skills, self-efficacy)
"Old school" CP	• Personal identity is determined through the farm, its fields, animals, farm products • Attachment to old norms: A "good farmer" keeps fields clean and has high-yield crops • Productivism: idea of scarcity and production for national food security • Control, risk reduction—pesticides as necessity • Autonomy	• Strong reliance on cost-efficient off-farm inputs, high outputs • Crop treatment plan, principle of damage threshold • Production aligned with *proof of ecological performance* to receive a base amount of direct payments while limiting dependence on them • Distribution through wholesale • Reliance on import restrictions—protection of domestic production against cheaper import products • Full-time farming	• Reliance on established CP methods • Solid, "old school" vocational training • Consulting CP advisors in cases of doubt regarding pests and diseases
Market-oriented, lower-input CP	• Strategic, pragmatic farm development—produce what market demands • Aiming at high (quality) yield while tolerating pests and diseases up to certain level • Striving to reconcile ecology and economy based on inner conviction • Desire to align production with societal demands, using less pesticides is imperative	• Lower off-farm input, high quality output farming • Preventive CP measures—"more prevention, less escalation" • Ownership or rental of efficient machinery and mechanical equipment • Production for labels, earning price premiums • Direct payments as "insurance" for higher risks/lower yields associated with production system • Full-time farming	• High skill levels, high degree of professionalism • Entrepreneurial skills • Learning, development • Willingness to seek help from peers/ advisors, in training courses • Participation in projects that offer access to know-how and testing of new methods and technologies • High self-efficacy
Cost- and workload-minimizing CP	• Striving for cost-effective CP and efficient work organization • No strong farmer identity, farming not profit oriented but for maintenance of the land, more of a hobby	• Extensive production, producing only what can be done in a simple and time-extensive way • Strong focus on gaining direct payments, enabling farm maintenance with lower yields • Often part-time farming, plus off-farm employment • Optional support through family labor • Limited time available for mechanical CP work	• Ability to optimize the combination of production costs, workload, direct payments and product revenue • Vocational training completed part-time
Outsourcing CP to contractors	• Focus on core business and farming interest such as livestock, dairy • Simplify farm operations	• Rather high off-farm input, high output farming • Contractor needs to deliver quality work—clean fields, tight control over pests and diseases • Applying pesticides is generally profitable for contractor • High fixed costs for farmer—reducing pesticide use is a risk • Often small cultivated area, investing in machines unprofitable • High overall workload	• Low skill levels in the area of CP • Facing increasing complexity through CP requirements, regulations, and techniques • Reliance on CP (firm) advisor and contractor as a means to professionalize • Lack of interest in crop production as the core business, and competences are in livestock/dairy
Agro-ecological CP	• Agroecological principles, idea of regenerative agriculture • Holistic approach: aiming for healthy soils, healthy plants, healthy humans and healthy animals • Simplicity • Critical of common short-term profit orientation and general lifestyle of modern society • Following own strong convictions rather than yields and profits	• Low off-farm input, low output farming • Often rigorously refraining from the use of pesticides, or use of few bio-pesticides • As little as possible heavy machinery on the fields • Small-scale production, using mixed crops, resistant varieties • Working within natural cycles • Regional direct marketing (or via organic labels) • Often part-time farming, plus off-farm employment	• High skill levels in a range of areas • Ability and willingness to use preventive measures; to observe, understand, experiment, learn and develop • High creative competence • Recognition that nature is a complex system with its own rhythm, is not always controllable; change takes time

interviewed farmers via two agri-environmental projects, *PestiRed*[7] and *3V pilot project*.[8] Five out of the six farmers were male, one was female. This male–female ratio is approximately representative for Swiss agriculture. Interviewees were aged between 36 and 48 years and represented farms of various sizes, forms of production, and locations in the cantons Solothurn and Thurgau, where arable farming is dominant. All were mixed farms that combine arable and livestock or dairy farming (see Appendix A, Table A.1).

We also interviewed five CP experts (see Appendix A, Table A.2), of whom four were male, one was female. Four of these experts were representatives of cantonal offices (Berne, Thurgau, Zurich). Delivering extension services to farmers and teaching farmer apprentices, they maintain close contact with different kinds of farms and thus possess an overview over the reality of CP practices throughout their cantons. The fifth expert interviewed was a scientist specialized in plant pathology and innovative cropping systems. *Agroscope* facilitated field access to these experts.

We carried out face-to-face interviews with farmers in February to March 2020 and with CP experts in August 2020. All interviews were conducted in (Swiss) German with a separate interview guide used for farmer and expert interviews. The interviews lasted between 45 and 90 min; they were audio-recorded, transcribed and anonymized.

Saturation was reached through additionally drawing on qualitative data from a survey on agricultural CP in Switzerland. We surveyed farmers from November 2020 to January 2021, both online with the tool *Unipark* and by mail. The sample consisted of 2155 Swiss farms with arable farming and produced 635 useable responses. For the purpose of this qualitative study, only the answers to three OEQs were relevant. Thus, we constructed a subdataset of 801 written answers from 450 respondents for inclusion in the analysis. Descriptive statistics for this subsample and the survey questions are presented in Appendix B. The three OEQs were distributed throughout the questionnaire, so we could analyze the answers independently from each other and not as a sequence.

[7] www.pestired.ch.
[8] www.projekt3v.ch.

3.2. Data analysis

We analyzed the data in a three-step procedure, deploying qualitative content analysis in *MAXQDA* (Rädiker and Kuckartz, 2019). In a first step, we coded the interview data along the three overarching elements *meanings, materials* and *competences* and the corresponding subcodes as described in section 2 (cf. Table 1). Further subcodes were added as elements emerged during the iterative coding process (Silverman, 2020). We thus observed significant variations in the ways CP is performed. In a second step, we inductively identified the patterns in CP practices by grouping the descriptions containing similar elements, and linkages between elements, together. These elements and their linkages form what is "typical" for the practice variant, such as the attachment to certain norms together with a distinct set of skills and the use of certain CP products. In the third step, we used the data from the survey OEQs to validate the typology of practices. The responses to the OEQs were coded according to the pre-identified CP practice types.

The data from the interviews and survey OEQs were analyzed in their original language, which was either German or French. After the analysis, a small sample of representative quotations, presented in section 4, was translated to English by the authors.

4. Results: current crop protection practices

Most study respondents shared the general understanding of what CP is and why it is done. Protecting their crops in one way or another is of great importance to all farmers, because in agricultural cultivation, many preventive measures can be taken but beyond a certain point, pests and diseases are no longer controllable. CP then represents one of the main possibilities to influence crop yield in qualitative and quantitative terms. For many farmers, protecting their crops with synthetic substances reduces risk. Further common characteristics in all accounts of CP practice were, for example, the dependence on the weather, pest pressure and the general regulatory framework within which the practices exist. These aspects describe CP practice as a general entity.

Despite these commonalities, however, CP as it is performed cannot be captured as one uniform practice. The narratives of the actual farm-level CP practices displayed important variations, revealing a picture of diversity. By analyzing the data according to the method described in section 3.2, we distilled the observed diversity into five distinct types of current CP practice. We named these according to the main logic of each practice type as follows: "'old school' CP," "market-oriented, lower-input CP," "cost- and workload-minimizing CP," "outsourcing CP to contractors" and "agroecological CP" (Table 2). These types vary in terms of the meanings ascribed to CP, the materials used for CP, the competences available to their practitioners and how these elements are linked. Within each type, there are variations of performance, but the differences are bigger between the types than within. Table 2 presents the categorized key characteristics of the different CP practice types. Below we describe each type in more detail, paying attention to three aspects: the intertwinement of the meanings, materials and competences that constitute the CP practices; the rationale for using certain elements; and how the policy environment translates into each practice type.

4.1. "Old school" crop protection

In this CP practice type, the skills used are visible in farmers' general reliance on established methods and the use of CP products according to a crop treatment plan or a strategy developed at the beginning of the farming season. This strategy is based on the farmer's own experience and advice from a CP firm consultant:

> "[…] we work according to the *proof of ecological performance*, and I have … uh … yes, in the meantime also experience, and one has …, with the crop protection advisor I sit together and look at what … which crops we grow and what diseases are there that could come? And … after that I go and, and order certain things, because I know it's coming anyway, right? For example, the late blight last year […]" (Farmer 3)

As required by the PEP, with which most conventional farmers align their production, farmers consider the damage threshold at the time they decide about individual CP measures throughout the cultivation season. Alternative CP methods are rarely considered because they are perceived as too risky for crop yields. And farmers who mainly practice this CP type measure their performance as farmers through product yield; their core purpose is to produce while personal health, leisure and family are secondary. This approach is in line with the productivism to which the sector has been pushed in the past by politics and the powerful chemical industry (expert 2; expert 4). "Old school" CP practitioners perceive one of their core material elements, synthetic pesticides, as a great relief because a large effect—maintaining high-yielding crops—can be achieved with little effort. This is important because the harvest is typically sold through wholesale trade and thus must meet strict quantity and quality requirements.

Farmers also emphasize the importance of domestic production for the country's food sovereignty and as a condition to maintain the added value of Swiss farmers' products. This would ideally allow them to be relatively independent from direct payments, the associated bureaucracy, and controls through the authorities. For these farmers, direct payments should be "a little extra" but not an essential part of income that paralyzes farmers and limits their autonomy.

"Old school" CP practitioners have been educated and trained to keep their fields clean. Even if it does not always make sense economically, this is what "a good farmer" does:

> "[…] 15 years ago, that was definitely the farmer who had no weeds, who had clean fields, who had high yields. That was the good farmer, definitely. […] There are still some of those who still hold exactly those values." (Farmer 2)

Farmer 5 describes it as normal to "just do weed control." This and other product applications are likely also caused by the rather low cost of synthetic pesticides (including a reduced value-added tax rate), relative to product revenue. The meaning of clean fields and the fear of significant crop loss trigger a reflex to spray pesticides when a pest or weeds make a field look poor, as reflected in this farmer's statement:

> "I also know a lot of colleagues who can't sleep anymore if they don't have a standing stock in the grain crops that is like a carpet and there suddenly comes a weed somewhere in a corner." (Farmer 2)

However, moving toward more environmentally sound production plays a role in this practice type as well. Farmers stress the principle "as little as possible, as much as necessary" with regards to the use of pesticides. They do neither want to poison consumers nor the environment but produce food and use their fertile land for production:

> "We actually had the goal to ecologize without lowering the calories. […] we don't sacrifice arable land at the expense of wheat, right, because if we now … well, I mean, you earn more with it than with such a sh … wildflower strip. Yes, and for me it means, I think we have to ecologize on the areas where we can't produce." (Farmer 6)

A major concern exists regarding imports and the unequal competition with producers from abroad. Similarly, the top-down promotion of new technologies in agriculture is questioned:

> "I think it's a bit difficult now in agriculture with the […] technologization and mechanization, […] that a lot of people are now again earning money, and in fact a basic job is moving away from the farmer to the contractor because they can no longer afford the machines […] Yes, and work that you perhaps enjoyed doing […]." (Farmer 6)

The presented strong meanings surrounding the "old school" CP

practice type are also said to be reinforced and publicly represented through farmers' associations. Some interviewed farmers criticize the associations for their tendency to whitewash the method of synthetic CP while neglecting that there are major interests of the chemical industry behind it.

4.2. Market-oriented, lower-input crop protection

The overall idea in this practice type is the market-oriented, strategic development of the farm. This is mainly done via producing for labels and programs, such as *Extenso, IP-Suisse* or *Bio Suisse*, which form core material elements. The farmers thus can take advantage of price premiums, so they "can turn their ecological added value into money in the marketplace" (survey respondent 151). The CP practice is derived from the strategic farm orientation and is pragmatic in the sense that farmers adapt their CP to (predicted) market demands:

> "Herbicide-free cropping variants have a lot of potential. Crops produced in this way are increasingly being absorbed by the market. One will have to get used to residual weeds." (Survey respondent 45)

So, a characteristic meaning in this practice type is to aim at high-quality yields and at the same time tolerate pests and diseases up to a certain level. This meaning also finds its expression by the view that "[i]t is more important to maintain consumer confidence than to maintain a non-transparent chemical industry" (survey respondent 28). Many farmers have a high awareness of the problems synthetic CP causes and thus see it as imperative to reduce it. They strive to reconcile economy with ecology and their own health. Farmer 2 says on applying pesticides in the beginning of his farming career:

> "I always had to convince myself to hook up the sprayer to the tractor in order to apply these substances, because I had the feeling that, yes, after the fifth hectare with a tractor that has the cabin open and so on, I always had the feeling that I no longer had the same feeling in my stomach or a bit of a headache in the evening or something. […] Those were the unconscious thoughts and actions, I never liked doing it."

An inner conviction is at times needed to defend one's choices in the wider farmer community, where a change toward more ecological production may be subject to gossip (e.g., "he's just doing it for the money"). In general, practitioners want to align their production with societal demands and the zeitgeist. Taking preventive measures ("more prevention, less escalation") as well as continuously learning and testing alternatives is part of their understanding of doing CP. The latter is also motivated by "wanting to have a say" in the development of a new, more sustainable and less industry-dependent CP system.

An important difference in the meaning element to the "old school" CP type is that a high yield level or clean fields are no longer very important. High yields do not matter much anymore because a substantial part of farm income "unfortunately", as farmer 1 adds, stems from direct payments. This material element functions as a sort of "insurance policy" for the higher risks and/or lower yields associated with more ecological production. Clean fields have lost their relevance for farmers practicing this CP type because of the machinery available today, as farmer 2 illustrates with an example:

> "Today we have such efficient and good machinery that it no longer matters if there are a few weeds in it. In the past, you couldn't dig up a hectare of potatoes with a lot of weeds. Today this is not a problem at all."

It is not even necessary to own tools and machinery, because farmers increasingly create and make use of possibilities to rent those (e.g., hoeing equipment for mechanical weed control). A downside of more mechanical CP work, however, is often a higher labor input, which can be difficult to handle despite many practitioners being full-time farmers. After all, they are, in contrast to many "old school" practitioners, also striving to maintain a good work–life balance.

Although farmers producing for organic labels seem to appreciate that they do not need to worry about whether to use synthetic pesticides or not (because organic certification does not permit the usage), they also admit that "[…] sometimes you have to watch something going down the drain where the conventional farms still have a number of options" (survey respondent 213). Nevertheless, these practitioners generally have a high self-efficacy and focus on areas in which they are competent, which also means they exert a high degree of professionalism. Additionally, they are willing to seek help from extension officers, advisors, in training courses or agri-environmental projects, and from peers. Farmer 2 explains: "I'm lucky to have two to three very good organic farmers around me, and I can rely on picking up the experience and know-how they have; that puts me at ease."

4.3. Cost- and workload-minimizing crop protection

This CP practice type is organized around the idea that CP (and crop production in general) must be cost effective and not require a particularly large amount of work. Hence, corresponding practitioners usually opt for production in line with the PEP and participate in other low-barrier programs, above all *Extenso*. As a consequence, on the material level, they can economize on labor input per financial output, and they qualify to receive direct payments. Direct payments compensate for the lower yields of extensive production. Expert 4 explains: "You have to work more efficiently, and through the *Extenso* programs you can then 'sell' your hours at a higher price." This statement points to a key competence in this practice type, which is the ability to optimize income by balancing production costs, workload, direct payments, and product revenues. It can, for example, result in planting wildflower strips if the market prices for wheat are lower than the biodiversity payments that can be gained through the subsidy system.

Many practitioners farm part-time and in addition have an off-farm employment. They often already acquired their formal knowledge in vocational training completed in part-time farming. It may be that their farming is less professional, more of an income-generating hobby, which also relates to a comparatively weaker farmer identity. Farmers mostly carry out CP works themselves and do not use contracting. However, this does not result in low-pesticide CP, because the *Extenso* program still permits the use of herbicides. Not only is it easier "to just spray when there is a problem" (expert 3), but farmers also have limited capacities to perform mechanical weed control in the appropriate time windows due to being only part-time on the farm. As survey respondent 183 puts it: "Refraining from the use of herbicides would be possible in many cases, but sometimes the last 'kick' to organize a hoe is missing. With a herbicide it is done faster and easier, after all." Another typical way to keep costs down in CP is having the retired father still working some hours to supplement his pension, "or as occupational therapy" (survey respondent 198), doing work that is not profitable.

4.4. Outsourcing crop protection to contractors

Practitioners representing this type usually have a contractor taking care of the CP on the farm, who functions as an external resource. The contractor tends to keep tight control over pests and diseases and relies on synthetic inputs. Using these inputs is generally profitable for a contractor. For the farmer, the outsourcing involves high fixed costs, so that a change in the CP strategy, such as reducing pesticide use, would be economically risky. The meaning behind the outsourcing is to simplify farm operations, and/or it is related to a lack of farmer interests and competences in crop production. Usually, the farm's focus lies on a different branch such as livestock or dairy, and crop production is only done because rotation crops are required on the fodder-producing land, for example. The tight link between the material and competence elements becomes evident in these two farmers' statements:

> "As I am not involving myself enough with chemical crop protection, I rely on the recommendations of the crop protection advisor and on the contractor." (Survey respondent 42)

> "I discuss the application of pesticides with *Landi* [agricultural retail business] at the beginning of each year. The aim is to keep the usage low. *Landi* is in close contact with the crop protection advisors. Depending on the crop and the weather, they often find the right way with a lot of experience. They know their trade, and the results convince not only me but also many other farmers in the valley. So, they look after well over a hundred hectares in the region." (Survey respondent 75)

Facing increasing requirements, regulations and techniques that render CP even more complex, some regard the reliance on contractors for CP as a means to professionalize. Contractors are well acquainted with the details of water protection regulations and guarantee compliance. An important material element may also be an often small cultivation area. Investing in own machines for CP is not profitable then. This as well as a high overall workload due to animal husbandry is connected to entrusting a contractor with the farm's CP.

4.5. Agroecological crop protection

In this practice type, CP is based on or oriented toward agroecological principles[9] and regenerative agriculture. An often expressed meaning and objective in this holistic approach is that of healthy soils that make CP redundant and bring about healthy plants, healthy humans and healthy animals. Practitioners ally with nature instead of fighting it. "I want to work restoratively, not lethally" (survey respondent 22) is a typical phrase reflecting this approach.

Criticism toward short-term oriented, capitalist farming and the general lifestyle of modern society is part of this practice type: "Food should provide for our nourishment and not have to serve as a commodity in exchange for money or even as an object on the stock market" (survey respondent 22). Practitioners place the emphasis in farming on their own strong convictions rather than on yields and profits, as expressed by survey respondent 84 in his approach of CP that results in "fewer yields, but in return there is a tomorrow for humankind." This statement also reflects the general way of thinking about the farm in generations.

In a material dimension, food production takes place on a small scale, preferably using mixed crops and resistant varieties. If farmers use CP inputs, these are organic inputs (e.g., copper products, compost preparations, horn manure and horn silica, soft soap dilutions or beneficial organisms). As little as possible is done with heavy machinery to protect the soil. The harvested products are often sold regionally via direct marketing and are not necessarily certified organic. Farmer 3, who currently works on a change toward agroecological farming, explains why organic certification would not make sense to him:

> "I could switch to organic now, could take it totally easy. That would also be an option that might not work badly but, but the organic market is full in many places, isn't it? And, just as I said, I don't see organic as better per se."

Practitioners may be part-time farmers and pursue an additional off-farm employment. Nevertheless, a high skill level in CP-related areas is common, as well as the ability and willingness to use preventive measures, to observe and understand natural processes:

> "My question concerns, whenever possible, the 'why.' Why is the plant sick, why exactly is this weed germinating, what is it trying to tell me, what exactly is happening in the soil?" (Survey respondent 22)

> "With regenerative agriculture, one tries to take the weeds out of their function, that means one no longer regards the weeds as an enemy, but regards them as a cry for help from the soil, which tells us: 'Hey, with this plant I can dissolve these nutrients, so that it more or less works out,' right? […] I try to bring in more diversity so that I can create this balance so that the weeds no longer need to dissolve the nutrients in the soil, right?" (Farmer 3)

This practice type thus draws on a lot of knowledge and creative competence that enables working with the plants and soil in a simplistic manner.

In summary, we found a range of practice types that exhibit systematic differences across the three practice elements *meanings*, *materials* and *competences* and their intertwinements. Although farmers may use several types of CP practice in parallel, for example on different fields or crops, one type seems to be predominantly practiced on each farm. The identified five types of CP practice thus illustrate how diverse current local CP practice is.

5. Discussion

In this discussion, we first focus on the diversity of practice types and the associated dynamics in CP practices. We then discuss our findings concerning the (mis-)alignment of CP practices and AEP, as well as possible policy implications.

5.1. Diversity of practice types

The finding of a range of distinguishable types of practice from the Swiss case is empirically consistent with the literature, in particular with the PT-based identification of five distinct fertilization practices in Finland (Huttunen and Oosterveer, 2017), four types of farm development pathways driven by corresponding farming practices (Huttunen, 2019) and seven "bundles" of farming-related forestry practices in Finland and the UK (Sutherland and Huttunen, 2018). The distinction we made between the CP types runs along similar lines as in Huttunen and Oosterveer's (2017) clustering of fertilization practices and thus supports the creation of such distinct types.

Three types of farming—*non-organic, organic*, and *transforming towards organic*—have been studied using an elements approach by Freyer and Bingen (2012). In their detailed account of the *non-organic type*, we find many characteristics that are in accordance with those that we have identified in the *"old school" CP* practice type. Our typology offers a further nuancing of the *non-organic practice type* into *outsourcing CP to contractors* and *cost- and workload-minimizing CP*, in addition to *"old school" CP*. Also, Freyer and Bingen's *organic type* is reflected in what we further distinguished in *market-oriented, lower-input CP* and *agroecological CP*.

The elements identified in CP practices also resonate with those found in previous work on soil conservation in Swiss agriculture (Schneider et al., 2010). Although in their study, the authors did not explicitly apply PT (nor an elements framework), they essentially used very similar categories, notably that of *meaning*, which is well reflected in the used life-world concept (Schütz and Luckmann, 2003). However, they only distinguished between farmers adopting and non-adopting no-tillage while investigating further types was beyond the scope of their article.

The existing PT literature explains the differences between the respective practice types in terms of the "diverse and hierarchically organized purposes in farming which contributed to different elements and their linkages in the performance of the practices" (Huttunen and Oosterveer, 2017, p.191). This explanation echoes our observation that an overall idea guides each CP practice type, and that this idea is influenced by the general purpose of the farm or its core business areas.

The typology we developed is also in line with the farming styles literature, in particular with the major ideal types (innovative, middle of

[9] For an overview of the elements of agroecology, see FAO (2018).

the road, progressive, resource limited–personal, resource limited–structural, and traditional) identified in an Australian study (Howden et al., 1998). Furthermore, the authors explain the differences in farming styles in a similar way, i.e., "as outcome of specific strategies of the actors" (van der Ploeg, 1994, p.19). While our study coincides with these prior studies in revealing distinct types, the features making up the types are different.

Our research has shown that the usual differentiation of CP types into organic and non-organic, based on a farm's technical production form, obscures further important differences in actual CP practices and hence also in pesticide use levels. A specific element, such as organic certification, can be central to more than one CP practice type. We identified organic certification as a possible material element in both the *agro-ecological* and the *market-oriented* way of doing CP. In the first case, organic production would be carried out because of a holistic, sometimes idealistic approach to farming and often include renouncing from any pesticide use at all. Or, in the second case, a strong emphasis would be placed on the price premiums and market demand for organic products. CP then usually includes the use of organic pesticides according to label regulations.

5.2. Dynamics in crop protection practices

It seems remarkable that within the same institutional framework, a wide range of differing CP practice types has emerged. One explanation given for this is that it offers farmers the opportunity for social differentiation (Warde, 2005). Farmers practicing mainly *market-oriented, lower-input CP*, for example, partly emphasized differentiating themselves from those persistently practicing *"old school" CP*. Their need for social differentiation presumably evolved in response to the social pressure for change that our respondents highlighted. It is this pressure for change to which van der Ploeg (1994) refers when explaining farmers' cultural repertoires. Many farmers are aware of the problems associated with synthetic (and to a lesser extent also with some forms of organic) CP and acknowledge that conventional CP is inherited and largely driven by a powerful chemical industry. Attempts of breaking with the conventional CP system involve continuous development, bifurcation and fragmentation of CP practices (Schatzki, 2002). As several respondents of our study emphasized, the former (perceived) general unity lived in the farming community has eroded in the recent past along with a fragmentation of "good farming" ideals. The subcultures concept (Vanclay et al., 1998) already entails the idea that a wide range of meanings of "good farming" exist because these are social constructs and thus are expected to vary between different groups of farmers, between and possibly within regions. This fragmentation of ideals was also described by Sutherland and Darnhofer (2012) and is reflected in fragmented practice types or "diverging trajectories" as found in the farming styles literature (van der Ploeg, 1986).

It seems reasonable to regard the diversity of CP practices we found as a reflection of the dynamics of CP practice. Just as each performance of a practice slightly transforms it, the multiplication into distinct parallel practice types can be interpreted as a manifestation of accumulated incremental change that then becomes more substantial (Warde, 2005). Adopting an argument made by Huttunen and Oosterveer (2017), we propose that the practice approach to studying CP exemplifies that incremental change in existing CP practices is relevant, also with respect to a wider transition.

5.3. Crop protection practice types and agri-environmental policy

Returning to this article's point of departure—the need for a transition to low-pesticide agriculture—we argue that CP transition policies must be able to make offers to farmers of all CP practice types. Given the heterogeneity and dynamics in practices, the shift of a system cannot be accomplished as a whole but in segments, each with its own development pathway (Wüstenhagen et al., 1999). This requires well-targeted and acceptable policy measures. However, the design of such measures is difficult (Huttunen, 2021) because the control over how elements are combined by practitioners is usually not with the institutions that provide for the development and circulation of these elements (Shove et al., 2012).

Testing sensitivities to policy instruments was not part of our research design. However, from a practice theoretical perspective, AEP is not only an external factor to the practice studied but translates into different elements. Our results thus allow for an interpretation of which CP practice types are responsive to direct financial incentives as the current dominant policy instrument and which ones are not.

In the *cost- and workload-minimizing CP* type, subsidies as a *material* element are crucially embedded in the practice. Yet, practitioners adopt individual schemes only if the expected benefits surpass the efforts required. Rather responsive is also the *market-oriented, lower-input CP* type, where financial incentives are important both as agri-environmental payments and as price premiums granted by the market.

In the practice type that *outsources CP to contractors* and in *"old school" CP*, financial incentives may still play a role but for many farmers (ideally) to a much lesser extent. In these practice types, the PEP is often fulfilled to receive a base amount of direct payments, but the conditions of further AES tend to do not fit in well with the meanings, material realities and competences available to farmers. Farmers may thus perceive them as pushing for culturally inacceptable practices, which was identified as a cause for non-adoption of AES in prior studies (Burton et al., 2008; Schneider et al., 2010; Vanclay and Lawrence, 1994). If society still desires a lower input of pesticides, in the short run these groups may be convinced by using command-and-control instruments (Pedersen et al., 2012), such as bans of substances that seem too toxic for their use on today's farmland. Abandoning quasi-subsidization of pesticides in the form of reduced value-added tax and moreover introducing a steering tax as so far done in Sweden, Norway, Denmark and France (Böcker and Finger, 2016) is another policy option. An important pillar for bringing about change in CP practices is the strengthening of farmer competences in (preventive) CP via research, education and public extension services. Evidence in favor of the latter has been provided by Wuepper et al. (2021). Their study found that Swiss farmers who are advised by public extension services use substantially more preventive measures, whereas farmers who are advised by private extension services use more pesticides. In terms of encouraging engagement with extension activities, Hall et al. (2019) recommend addressing social factors that influence farmers' engagement with extension, for example "the perception that extension activities are designed for younger and less experienced farmers" (p.206).

Equal attention should be paid to the partly policy-induced key purpose of *"old school" CP*, that is, protecting crops to produce the maximum and feed the nation. To induce a change in a meaning element is a difficult task (Huttunen, 2015) that involves a devaluation of the cultural values associated with this practice type (Sutherland and Darnhofer, 2012). It also links to aspects of the wider food system (e.g., dietary habits).

Finally, in *agroecological CP*, incentive-based AEP does not appear to translate into the practice elements. The CP measures promoted through AES are too basic and too short-term oriented; they do not include agroecological long-term measures such as establishing agroforestry. For practitioners of this type, it may be helpful to intensify the use of extension services as a policy instrument. In the extension literature, this issue has long been addressed with recommendations like using "group extension and other approaches that promote shared learning" (Vanclay and Lawrence, 1994, p.84), including discussion groups, "master classes" for advanced farm managers, and expert speakers or facilitators in a topic area (here: agroecology) from the regional level who can support farm managers (Hall et al., 2019). These recommendations are increasingly taken up in agri-environmental projects based on co-creation (for Switzerland, see, e.g., the project *PestiRed* mentioned in section 3.1).

Despite these advances in agri-environmental project design, incentive-based schemes are still used as the main AEP instrument, representing a one-size-fits-all approach that is grounded in theories of rational action and choice. The economic incentives are embedded, and thus create responses, to varying degrees in the CP practice types. In light of this observation, it would appear that they can only work well under some circumstances, but we cannot generally rely on them. It is reasonable to conclude that the range of distinct, routine-based CP practice types cannot be accommodated by a one-size-fits-all policy approach. Our findings thus provide a clear indication that current AEP is insufficiently targeted to the actual practices and that this shortcoming results in a substantial practice–policy mismatch, which requires further research.

Our insights support the view that an understanding of heterogeneous local practices is key to intervening in their dynamics, or, as Huttunen (2021) puts it: "When we want to change […] practices, it is relevant to clarify what we actually are changing." A PT approach is useful in developing the detailed systematic account needed to be able to align policy instruments with the everyday reality of practitioners. Too simplistic accounts risk suggesting one-dimensional policy solutions that are unable to serve different groups or result in undesired outcomes (de Krom, 2015).

6. Conclusions and outlook

This study aimed to advance our understanding of current CP practices and point to possible implications for the development of agricultural policies. PT provided the theoretical approach and was operationalized through a three-elements framework. With this tool, we analyzed the structure of Swiss farmers' current CP practices and showed that they differ systematically in the *meanings*, *materials* and *competences* used and in the ways these elements become intertwined in farmers' performances of CP. Moreover, the five identified types of CP practice helped to uncover the varying degrees to which the mainly employed incentive-based, one-size-fits-all policy interventions such as AES translate into practice elements. Currently, indications for a strong response to this policy approach are only visible in two out of the five identified CP practice types (*cost- and workload-minimizing CP* and *market-oriented, lower-input CP)*. The responses from farmers practicing *"old school" CP* and *outsourcing CP to contractors* appear to be limited, whereas practitioners of *agroecological CP* are unlikely to be supported by current AEP. This finding suggests that in the Swiss case, policies are insufficiently aligned with three out of five CP practice types.

Even though we have used Swiss farms as a case, our findings and their implications are not restricted to Switzerland. Applying the PT approach that we used to other European countries would likely result in a different kind of typology than the one from Switzerland. However, we have provided a wider argument for the assumption that heterogeneity in practices cannot be accommodated by a one-size-fits-all policy approach, as was also discussed, for example, in the context of energy behavior governance (Bornemann et al., 2018; Burger et al., 2015). This article thus lays the foundation for a more differentiated view on CP practices in the design and evaluation of policies. In general, policymakers can build on this research by considering that farmers' CP is not always based on choice but also displays routines that are observable when examining the actual practices. In addition, a possible implication for transition policies is that they need to be differentiated in order to engage all farmers in accomplishing the transition to low-pesticide farming. Specific designing and targeting is also discussed in the current literature with regards to encouraging farmers' engagement with extension activities (e.g., Hall et al., 2019).

Our research on routinized CP practices could be improved in at least four ways. First, our PT-informed study draws on a qualitative database. This research approach could be further developed by quantitatively investigating the relation between the elements of routinized CP and pesticide use. Second, we propose that there is much to be learned from studying incremental changes in CP practices, possibly by connecting PT with the concept of Boundaries to Change, which was beyond the scope of this article. Third, we point to the linkages of elements of CP practice with other farm-level practices such as fertilizing, crop production, soil conservation etc. as a direction for further research. Analyzing these linkages, in particular with a focus on the competence element, would help to situate CP within larger complexes of practices. Fourth, the typology developed may be used to determine the share of the different practice types in Swiss agriculture and further investigate the interaction between different practice types and AEP, including extension service. It would then be worthwhile to consider the assessment of possible practice-oriented AEP instruments through sensitivity analyses, which could be done using an experimental research design.

Credit author contribution statement

Antonia Kaiser: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. Paul Burger: Conceptualization, Methodology, Writing – review & editing, Supervision.

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Appendix A. Interview samples and topics

Table A.1
Description of the farm and farmer interview sample used for this study (n = *6)*

ID	Gender	Age	Canton	Farm size (ha)	Form of production	Farm type
Farmer 1	Male	43	Solothurn	17	Integrated production	Arable and livestock farming
Farmer 2	Male	42	Solothurn	40	Integrated production	Arable and dairy farming
Farmer 3	Male	46	Thurgau	105	Integrated production	Arable and livestock farming
Farmer 4	Male	46	Thurgau	86	Organic (recently converted from conventional)	Arable and livestock farming
Farmer 5	Male	36	Solothurn	34	Integrated production	Arable and livestock farming
Farmer 6	Female	48	Thurgau	24	Conventional (with *proof of ecological performance*)	Arable and dairy farming

Table A.2
Description of the expert interview sample used for this study (n = 5).

ID	Gender	Function	Canton
Expert 1	Female	Crop protection advisor, cantonal office	Zurich
Expert 2	Male	Head of department crop protection, cantonal office	Berne
Expert 3	Male	Advisor organic farming, cantonal office	Thurgau
Expert 4	Male	Head of department crop protection, cantonal office	Thurgau
Expert 5	Male	Scientific expert (plant pathology and innovative cropping systems)	Zurich/federal research institute

A.3 Interview topics

The main topics of the interviews with farmers were:

- The history of the farm
- The current crop protection (CP) practices at the farm
- The reasons for performing CP in a particular way and changes in CP practices over time
- What differentiates the farmer's practices from others
- The knowledge about and experience with different CP approaches
- The main problems in CP
- Where farmers source their information about CP issues from, with whom they exchange information and experiences
- What defines a good farmer according to their views

The interviews with CP experts dealt with:

- The different approaches for doing CP on Swiss farms
- The reasons for farmers to perform CP in a particular way
- Changes that had occurred over the last 10–20 years; drivers of these changes
- (Current) discourses around CP in the farming sector

Appendix B. Survey subsample and questions

Table B.1
Descriptive statistics for selected socio-demographic and farmographic indicators[1]

Indicator	Survey respondents (subsample) (n = 450)	Population characteristics[2] (N = 49,363)
Gender (%)		
Male	95.0	93.4
Female	3.0	6.6
Not specified	2.0	–
Age group (%)		
20–29 years	3.8	NA[3]
30–39 years	20.0	14.0
40–49 years	27.1	27.3
50–59 years	38.7	35.9
60–69 years	10.2	NA
70–79 years	0.2	NA
Canton (%)		
Berne	80.7	20.5
Geneva	0.7	0.8
Glarus	4.7	0.7
Solothurn	7.1	2.7
Thurgau	1.8	5.0
Vaud	4.0	7.3
Farm size (area under cultivation in ha) (mean)	31.1	21.15
Form of production (%)		
Non-organic/conventional (w or w/o PEP[a])	82.2	84.7
Organic	17.8	15.3

[a] PEP = proof of ecological performance.
[1] Comparison of the survey subsample used in our analysis with official statistics.
[2] For official figures (year 2020), refer to the Federal Statistics Office (2021a; 2021c).
[3] Only available for year 2016; some age classes were not available (NA) because they were composed differently (AGRISTAT, 2017).

B.2 Survey open-ended questions—responses to the following questions were included in the analysis

- Q 1.10) Do you occasionally find yourself in a dilemma when making decisions in crop protection? If yes, how would you describe the dilemma?
- Q 4.3) Please describe what you think the "farmer of tomorrow" should be like, and what the future holds for him/her.

- Q 8.4) Do you have any final remarks? Is there anything additional you would like to share with us?

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