Transitioning to low-pesticide agriculture: Practices, discourses, and policies

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Acronyms used

ADA: Argumentative discourse analysis
AEP: Agri-environmental policy
AES: Agri-environmental schemes
CP: Crop protection
EU: European Union
MLP: Multilevel perspective
SPT: Social practice theory
STR: Sustainability transitions research

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1 Introduction

Modern agriculture is the main driver of environmental degradation in Europe (Pe'er et al., 2020) and a significant driver worldwide (Campbell et al., 2017; Foley et al., 2011). Today's agricultural system is characterized by a strong dependency on pesticides, known as the "pesticide treadmill" (van den Bosch, 1978). The widespread use of pesticides provides for high crop productivity and food security (Oerke, 2006; Savary et al., 2019), but comes with numerous and well-documented adverse effects on the environment. These contribute to some of the grand societal challenges, such as biodiversity loss (e.g., Hallmann et al., 2017; Potts et al., 2010; van Swaay et al., 2006) and pollution of water bodies (Stehle and Schulz, 2015), drinking water sources (Kiefer et al., 2019) and agricultural soil (Riedo et al., 2021; Tang et al., 2021). Pesticides used to protect crops are also suspected to be carcinogenic, thus threatening human health (e.g., Alavanja and Bonner, 2012; Jones, 2020). In addition, increasing pathogen resistance to pesticides reduces their effectiveness. In turn, farmers may respond by increasing the dose and frequency of these less effective pesticides or switching to new pesticides available on the market (Popp et al., 2013). The latter option, however, has become less common, as fewer new active ingredients of pesticides are developed and approved (Kraehmer et al., 2014).

Against this backdrop, reducing the high dependency on pesticides and the risks associated with their use have reached the top of policy agendas in recent years in many European countries (EC, 2020; FOAG, 2021). However, the reduction targets mandated in National Action Plans are continuously missed (Möhring et al., 2020). Therefore, calls for a more fundamental transition of agricultural production to one with low or eventually no pesticide use have societal and scientific momentum (Jacquet et al., 2022). At the same time, the high complexity of this transition is increasingly being recognized.

1.1. The (lack of a) transition toward low-pesticide agriculture

Despite increased policy efforts, there is little evidence that the agricultural sector is on a trajectory toward significantly lower pesticide use. Pesticide sales in Europe have not decreased in the last decade (EEA, 2019), and farmers' usage has not declined either (see Hossard et al., 2017, for evidence from France). The contamination of surface water and groundwater is also frequently reported (e.g., in Switzerland, see Spycher et al., 2018; Stehle and Schulz, 2015). This suggests that the current policy pathway is largely ineffective in inducing or supporting a

transition to low-pesticide agriculture (Möhring et al., 2020). Incentive-based policies, such as agri-environmental schemes (AES), do not regulate (i.e., restrict or ban) pesticide use, but incentivize farmers to change their behavior concerning crop protection (CP). Voluntary AES are a central policy instrument on this pathway. AES, in particular, have been widely studied in terms of farmers' acceptance and their environmental effectiveness. Overall, this research pointed to the limited effectiveness and efficiency of these instruments (Hasler et al., 2022).

This dissertation takes as a starting point the fact that substantially reducing pesticide use is a complex issue, not only in terms of agronomic practices, but also with regard to the behavioral change required of farmers and the design and implementation of policies fostering this change (e.g., Jacquet et al., 2022). Furthermore, the emerging transition is highly controversial and subject to heated public debate (Finger, 2021). The complexity is reflected in multifaceted struggles and trade-offs associated with the transition that become apparent in farmers' routinized CP behavior (i.e., in their social practices), public discourses on pesticides, and agri-environmental policymaking. These three dimensions have become important areas of research.

1.2. Research gaps, research questions, and aims

Current calls for change in the wider agri-food system are increasingly framed in the context of sustainability transitions (Hebinck et al., 2021; Hinrichs, 2014). Because a sustainability transition such as the one to low-pesticide agriculture requires substantive change in farmer behavior, the literature on sustainability transitions in agriculture focuses on farmers and their behavior and on agri-environmental policymaking to steer that change (Waterfield and Zilberman, 2012; Weber et al., 2020). Another thread of literature has evolved on the role of discursive elements in sustainability transitions (e.g., Buschmann and Oels, 2019). The discursive elements of interest for agricultural transition scholars include the framing of technologies and farming practices (Rust et al., 2021) and the meaning of concepts such as sustainable agriculture (Janker et al., 2018). While all perspectives inform ideas around sustainable agricultural transitions and points of intervention, these perspectives are disparately featured in the literature, with few efforts to integrate them. Their integration represents an opportunity to forge more productive links and consider for example discourses and policies as part of farmers' practices, including their effects on these practices. This dissertation approaches the transition to low-pesticide agriculture by integrating analyses of the three dimensions: 1) routinized farmer behavior (i.e., practices), 2) public

discourses, and 3) agri-environmental policies. It thereby addresses several research gaps.

First, this dissertation helps to fill the gaps in the literature on farmer behavior, focusing on non-choice aspects. Research examining the lack of change among farmers tends to concentrate on farmer decision-making. Farmers' decisions to (not) adopt environmentally sustainable farming methods are viewed as driven by individual preferences (Barreiro-Hurle et al., 2018), environmental and risk attitudes (e.g., Bocquého et al., 2014; Meraner and Finger, 2019) and farming objectives (Kallas et al., 2010). These behavioral determinants have been widely studied along with other cognitive, normative, and dispositional factors (Dessart et al., 2019). In contrast, scholars have paid little attention to aspects of (un)sustainable farmer behavior that are not driven by (rational) choices, such as routines and habits. The utility of theorizing (un)sustainable behavior in terms of routine and habitual aspects is evident in research in other domains such as food consumption (O'Neill et al., 2019; Ulug et al., 2021), mobility (Meinherz and Binder, 2020), energy consumption (Sahakian et al., 2021), and investment (Lang et al., 2021). Despite this evidence, routines and habits have rarely been considered relevant for farmer behavior (with a few exceptions, e.g., Bakker et al., 2021; van Duinen et al., 2016; Wittstock et al., 2022). Moreover, the behavioral farming literature has been criticized for its focus on either structural or farmer-related issues, ignoring that change involves both (Anibaldi et al. 2021; Huttunen 2015; Ranjan et al. 2019).

Second, the dissertation addresses gaps in the literature on the role of discourse in agricultural transitions. Pesticides and their adverse effects on the environment and human health have become a source of major societal concern in recent years. Because these concerns were increasingly voiced, incumbent regimes countered with their framing of the issues, cumulating in discursive struggles over the legitimacy of agricultural pesticide use. The understanding of the role of these discursive elements in transition processes has been advanced using discourse analysis. Most research has focused on energy transitions (e.g., Isoaho and Markard, 2020; Markard et al., 2021; Rosenbloom, 2018). However, recent research on agricultural transitions has begun to analyze the construction of legitimacy for agri-technologies developed in response to environmental regulation in the Netherlands (van der Velden et al., 2022) and has compared different governance perspectives on pesticide regime destabilization along with related discursive shifts in Germany (Frank and Schanz, 2022). What remains underexplored is how current discursive struggles over pesticides and their

legitimacy unfold in detail. Closing this gap can help to better understand the role of discourse in policy outcomes and de- or re-stabilization processes of the incumbent pesticide regime.

Third, this dissertation contributes to closing the gaps in the literature on policies in the context of agricultural transitions. Switzerland is an example of a country with ambitious environmental objectives and is frequently ascribed a pioneering role in promoting multifunctional agriculture. However, it has so far failed even to come close to its environmental objectives related to farming (Meier et al., 2021; Wyss, 2020). Recently, the country encountered a series of failed attempts, using entirely different approaches, to create an agricultural policy with lower chemical inputs that would improve the sector's environmental performance. Although, in the context of a sustainability transition, it is crucial to understand why such attempts to reform policy continuously fail and how the presumed resistance to change is enacted, empirical evidence on these questions is scarce. Most prior studies analyzing agricultural policy consider normative aspects (DeBoe et al., 2020; Goral and Pilyavsky, 2018), promising governance models to achieve sustainability targets (Ehlers et al., 2021; Montanarella, 2015), and effective policy instruments (DeBoe, 2020; Lankoski and Thiem, 2020).

Based on the expectation to gain new knowledge by integrating analyses of the three dimensions, the dissertation poses the following main research question:

> ***RQ_main:*** *What elements and dynamics in practices, discourses, and policies hinder, enable, or shape a sustainability transition toward low-pesticide agriculture?*

The main research question is taken up in four papers that comprise this dissertation, each responding to specific sub-questions derived from the main question.

Paper 1 (Kaiser and Burger, 2022) focuses on sources of unsustainability in current local CP practices in Switzerland while also uncovering potentials for change. It does so by exploring the overlooked elements of routines in farmer behavior and by capturing differentiation in the routinized practices. The research questions it addresses are as follows:

> ***RQ1:*** *How is current crop protection practiced by local farmers?*
> ***RQ2:*** *How do farmers' crop protection practices differ?*

Paper 2 (Kaiser et al., 2024) investigates the neglected interplay of individual and structural aspects in routinized farmer behavior. It bridges social practice theory (SPT) and social-psychological concepts to gauge the relative roles of factors and mechanisms that (de)stabilize pesticide use practices. The research question it addresses is as follows:

> ***RQ3:*** *What is the interplay between individual and structural factors in routinized pesticide use?*

Paper 3 (Kaiser, 2023) explores the discursive dynamics surrounding pesticides in the transition process and links them to policy and regime changes. The research questions posed in this paper are as follows:

> ***RQ4:*** *How were pesticides discursively (de)legitimized?*
> ***RQ5:*** *How does the discursive (de)legitimation of pesticides link to policy change and regime (de)stabilization?*

Paper 4 (Mann and Kaiser, 2023) tackles the issue of better understanding why agri-environmental policy (AEP) is difficult to change, paying attention to resistance to such change in the Swiss context. The research question it addresses is as follows:

> ***RQ6:*** *What are common reasons for the failure of attempts to transform agricultural policy in Switzerland?*

One of the underlying presumptions for the lack of successful transition pathways in agriculture is that disciplinary perspectives too strongly dominate the analysis. Hence, analyzing these by bridging theoretical and methodological approaches rooted in different disciplines contributes to understanding the complexity of agricultural transition processes. In this way, I wish to enhance frameworks and tools for analyzing sustainability transitions in agriculture and create a knowledge base on the elements and dynamics at play using insights from a specific case of agricultural transition, the one toward low-pesticide agriculture in Switzerland.

The overarching aim of this research is to advance the knowledge on elements and dynamics that hinder, enable, or shape a sustainability transition toward low-pesticide agriculture. To this end, the thesis focuses on processes of stability and change in three key areas (practices, discourses, and policies, depicted in Figure 1) and seeks to:

- Contribute to a better understanding of farmers' current crop protection practices and of factors and mechanisms that (de)stabilize routines in pesticide use.
- Provide a nuanced understanding of pesticide discourses in Switzerland and examine how discourses link to policy and regime changes.
- Identify common reasons for the lack of change in (Swiss) agri-environmental policy.

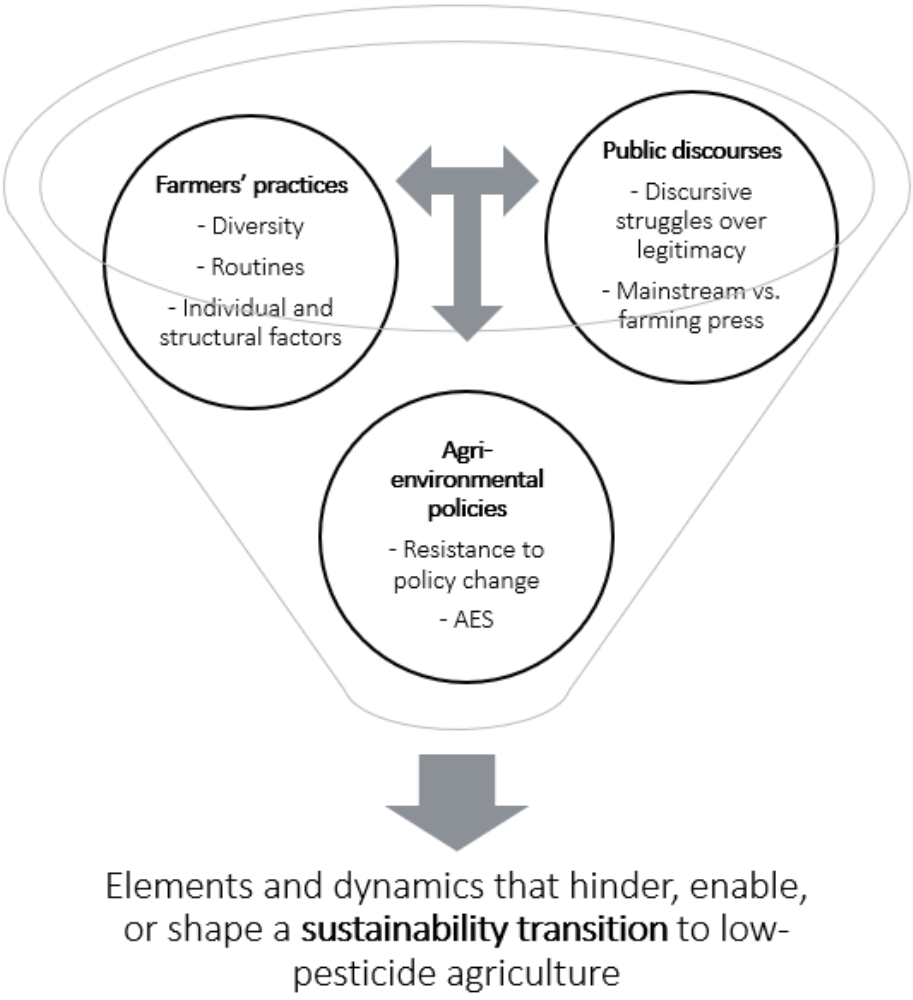


Figure 1. Schematic overview of key research dimensions.

2 Theoretical foundations, analytical approaches, and previous research

The following sections present the theoretical foundations of this dissertation. Their main function is to guide the empirical analyses. For this reason, the sections also introduce associated analytical approaches, and a brief review of existing research with respect to this dissertation's subject matter and each of the key research dimensions. I begin by describing what the socio-technical system of agriculture consists of in section 2.1. In that section, I also present the multilevel perspective (MLP) from the sustainability transitions literature as a heuristic framework because this dissertation draws on the different levels of the socio-technical system as laid out in the MLP. In section 2.2, I introduce social practice theory as a main theoretical lens of the dissertation. In section 2.3, I present a discursive lens on the transition process and the related literature on environmental discourse. Moreover, argumentative discourse analysis is introduced as a relevant analytical tool. In section 2.4, I lay out the governance understanding of (agri-environmental) policy and policy change that I adopted from the transition literature, including particularly politics. I then present a summary of the state of the art of policy and policy change research in the agricultural context because this serves as the basis for the empirical analysis carried out in the policy research dimension.

2.1. Agriculture as a socio-technical system

Building on sustainability transitions research (STR), this dissertation approaches agriculture as a socio-technical system. A socio-technical system is understood to represent the interactions and interlinkages between elements, such as technological artifacts, infrastructure, rules, norms, policies, social structures, and markets (Fünfschilling and Truffer, 2014; Rip and Kemp, 1998), each fulfilling a societal function (Fünfschilling and Truffer, 2016). It is common to analyze socio-technical systems within a sectoral context (e.g., agri-food, energy) to allow for the consideration of context-dependent factors (Turnheim et al., 2015) and the configurations (i.e., alignment) of the various socio-technical system elements.

The broader socio-technical system of agriculture reflects several peculiarities that need to be considered when studying transition processes. Features distinguishing the agricultural sector from industrial or service sectors include diversity in farming (Slee and Pinto-Correia, 2014), its spatial nature (Marsden, 2013), multifunctionality and, related to this, its public good character

(Renting et al., 2008). These features contribute to a high level of policy involvement in the sector. While policies initially aimed at food security, they later focused more broadly on farms' competitiveness and living standards, environmental sustainability, and rural development (Darnhofer et al., 2015).

A core issue in STR is the dialectic relationship between stability and change. On the one hand, there are many innovations and niche practices in farming (e.g., agroecology, direct marketing, alternative food networks, agri-tourism and recreation). On the other hand, there are deeply entrenched systems around intensive agricultural systems and retail chains with locked-in production and consumption patterns, creating stable, path-dependent trajectories (Köhler et al., 2019). By focusing on processes of stability and path dependence, as well as on processes of change, STR seeks to find ways to support the acceleration and governance of transitions.

To analyze transitions, many sustainability transition scholars use the seminal multilevel perspective (MLP) as a heuristic framework. The MLP posits that transitions occur through interactive processes within and among three analytical levels: 1) niches, 2) socio-technical regimes, and 3) a socio-technical landscape (Geels, 2002; 2011). Of particular interest here is the regime level, because this is where the use of pesticides is engrained in the socio-technical system of agricultural production. Regimes represent the so-called 'grammar' behind well-aligned and relatively stable configurations of socio-technical system elements (Frank and Schanz, 2022; Rip and Kemp, 1998). This reflects the idea that formal and informal rules are not just carried mentally and shared in social groups but are highly institutionalized and embedded in infrastructure and practices (Fünfschilling and Truffer, 2014; Geels, 2004). These rules mutually construct and are constructed by actors in a system. In these ways, the regime accounts for the stability of an existing socio-technical system (Geels, 2004; Geels, 2011). The pesticide-centered agricultural regime developed since the 1960s along with processes of agricultural intensification, internationalizing markets for CP products, industry consolidation, and a regulatory framework focusing on the benefits of pesticide use while acknowledging its risks (Frank and Schanz, 2022; Lamine et al., 2010; Maguire and Hardy, 2009; Shattuck, 2021). The regime is, however, neither homogeneous nor monolithic (Smith et al., 2005) but rather prone to internal tensions and conflicts of interest (Geels, 2011).

The grand societal challenges that many environmental problems associated with agriculture depict (Köhler et al., 2019) can only be solved by transitioning to more sustainable food production. Based on the literature, a

sustainability transition in agriculture is a long-term process in which the socio-technical system of agricultural production shifts to a new socio-technical system (Markard et al., 2012). It has been argued that radical regime-level changes are required for such shifts associated with sustainability targets because grand problems cannot be addressed by incremental improvements and technological fixes (Elzen et al., 2004; Grin et al., 2010). Therefore, in STR, conceptualizing and explaining how radical changes can occur in terms of how societal functions are fulfilled has prevailed over the analysis of incremental changes (Köhler et al., 2019).

However, the role of incremental changes in transition processes is contested. In recent research, some scholars have highlighted the problematics of incremental changes in transition politics (e.g., Simoens and Leipold, 2021). In contrast, others suggest that there is an interplay between incremental changes (e.g., in everyday practices) and disruptive changes (Huttunen and Oosterveer, 2017). Incremental change often occurs by developing protected niches (Lazarevic and Valve, 2020) which are juxtaposed against regimes. Cumulative incremental changes at the niche level can represent one phase of a gradual destabilization of the incumbent regime (Turnheim and Geels, 2013) or result in further stabilization, stabilizing the broader socio-technical system. A typical challenge with ongoing transitions is that the direction of change is unclear.

In summary, agriculture is a socio-technical system made up of interlinked elements including practices, discourses, and policies. This system can be described and analyzed in terms of the three levels landscape, regime and niche. The regime level is of particular relevance to this dissertation because the regime is where the use of pesticides is engrained in the socio-technical system. A (de)stabilization of the regime can occur through processes of stability and change in system elements. Yet, a debate in the literature revolves around the role of incremental versus radical change as elements enabling a sustainability transition.

2.2. Social practice theory

To comprehend and facilitate changes in the socio-technical system of agriculture, an in-depth understanding of how farmers perform and transform the practices in question is needed (Huttunen et al., 2015). SPT offers these deep and relevant insights into the emergence, stability, and changes in practices. It does so by drawing attention to the endogenous dynamics of practices (i.e., dynamics in cultural conventions, practitioner know-how, and technologies). The identified patterns can help explain inert, resource-intensive behavior and point to potential sites for intervention to facilitate transitions (Spurling et al., 2013).

For practice theorists, the nature of social structure is in routinization. In other words, social practices are routines: routines of "doing something" such as cooking, consuming, or working (Reckwitz, 2002). The core aspect of routinization originates from Bourdieu's (1977, 1990) observation that people are, for the most part, not acting rationally, that is, in response to incentives provided by policies or to norms and rules set by society. Instead, Bourdieu described the logic of practice as the basis of people's actions. This logic involves people following their daily flow of improvised activities and lacking conscious consideration of the reasons for their actions (Sutherland and Huttunen, 2018). Therefore, a common thread in the range of interpretations of SPTs is that they foreground practices, instead of individuals, as the central units of social scientific analysis (Köhler et al., 2019).

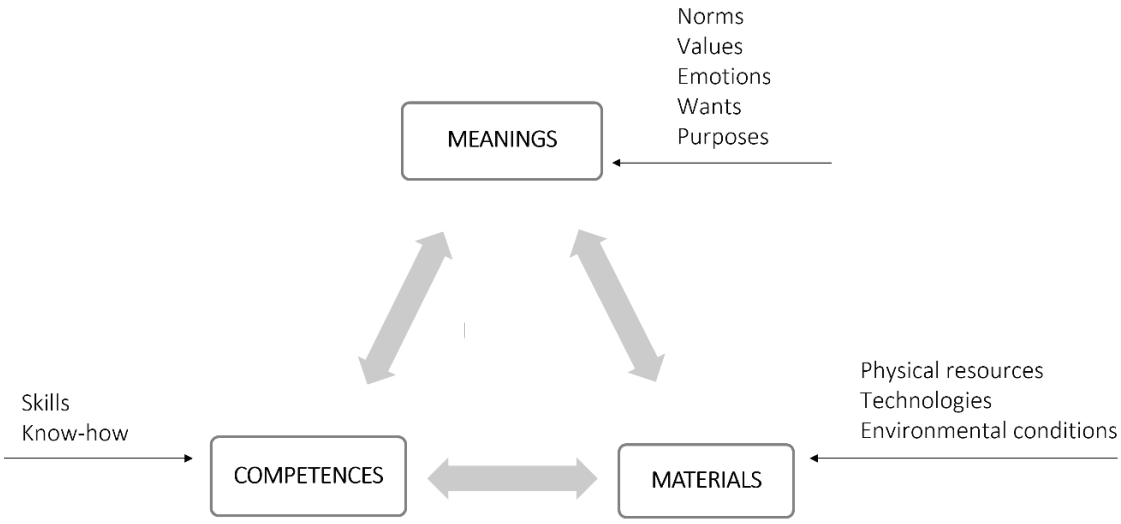


Figure 2. Three elements of the practice framework for empirically studying farmers' crop protection. Own illustration based on Hess et al. (2018), Kaiser and Burger (2022), and Shove et al. (2012).

Practices are generally considered to be a composition of several elements connected to one another and mediated by practitioners (Warde, 2005). According to Shove et al.'s (2012) widely established SPT framework, three overarching categories of elements make up a practice: 1) meanings, 2) materials, and 3) competences (Figure 2). Meanings refer to the ways in which a practice is understood including (social and personal) norms, values, emotions, wants, and purposes. Competences are the skills and know-how related to a particular practice, and materials refer to all tangible elements (e.g., technological and natural artifacts) related to performing the practice. Applied to the topic in question, the social practice of CP consists of the interplay of farmers connecting their

understanding of suitable CP to the properties of the field, the crops, the available tools and techniques, and their own as well as external skills and know-how (Kaiser and Burger, 2022). This framework comprised of three overarching elements has been usefully employed in several farming (sub)practice analyses, other than CP. For example, it has been applied in 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 framework has been used to study the role of routines in food system transitions (Hinrichs, 2014).

In addition to the SPT perspective, I linked routinization with a social-psychological perspective. The two are often presented as opposing perspectives. Social-psychological research examines habits and regards them as automatic behaviors driven by contextual cues (Verplanken, 2005). Therefore, the unit of analysis is the (mental constitution of the) individual, whereas it is the practice in SPT (Reckwitz, 2002; Shove et al., 2012). Similarly, the basis of action in social-psychological research is individual choice. In contrast, it is the socially shared conventions in SPT (Shove et al., 2012).

Underlying these diverging conceptualizations are epistemological differences. Without neglecting these differences, I do not intend to enter the vast theoretical debate following from them, such as the role of individual versus structural factors in behavior (e.g., Boldero and Binder, 2013). Instead, this dissertation is built upon three arguments previously made to emphasize the benefits of merging both perspectives.

First, each of the two perspectives reveals a weakness exactly where the other has its strength. In SPT, a practice is understood as a routinized "way of doing", inextricably bound to elements that are largely under-theorized as "context" in social-psychological approaches (Kurz et al., 2015; Steg et al., 2015).

Second, bridging the two perspectives is expected to serve an empirically oriented analysis of routinized behaviors. This has been demonstrated by other scholars (Hess et al., 2018; 2022 from an SPT perspective; Kurz et al., 2015 from a psychological perspective).

Third, on an empirical level, the literature on farming practices in particular displays a strong focus on either structural or farmer-related issues, whereas the interplay of both remains neglected (Anibaldi et al., 2021; Huttunen, 2015; Ranjan et al., 2019). This can be addressed by practice approaches as many of them aim to overcome the dichotomy between agency operating at two levels, at the level of

individuals and at a structural level (e.g., through culture). Hence, there are good reasons to merge SPT, which takes contextual factors not as exogenous but as endogenous, with social-psychological concepts.

To do so, this dissertation draws on an individual-practice framework suggested by Piscicelli et al. (2015) (Figure 3). This framework positions the individual (or "carrier of a practice" in PT) at the center of the practice. It thereby explicitly acknowledges the interaction between the individual and a specific configuration of material, competence, and meaning elements. The core underlying assumption is that the relationship between the elements is partly mediated by individual traits, preferences, and characteristics that social-psychological concepts capture. Adapting this framework to the investigation of CP practices lends itself well to examining the interplay between individual and structural factors in routinized pesticide use (see Kaiser et al., 2024).

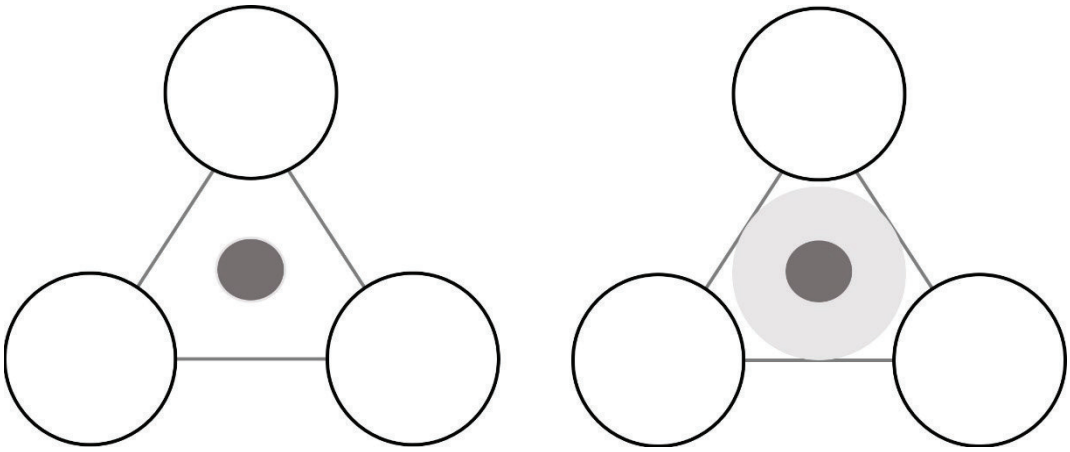


Figure 3. Illustration of an individual-practice framework depicting the individual/carrier of the practice (in dark gray) and the interaction (light gray) with elements of practice (adapted from Piscicelli et al., 2015).

With respect to this dissertation's focus on stability and change, SPT not only contributes to understanding persistence in patterns but also processes of change. Change in practices is understood as happening through the emergence, replacement, or disappearance of practice elements and inter-linked practices (Keller et al., 2022). A possible entry point for 'breaking routines' can thus be the deliberate reconfiguration of practice elements (Shove, 2014; Shove et al., 2012) in a way that renders less sustainable elements systematically less prominent and promotes alternative, more sustainable elements (Kurz et al., 2015). Another source of change is the naturally occurring variation in practices when they are being performed (Shove et al., 2012). The analytical distinction between practice-

as-entity and practice-as-performance (Reckwitz, 2002) is helpful here. Practice-as-entity is what people generally understand and recognize as the practice in question on a conceptual level without actually performing it. It provides a pattern to which people adhere and reproduce when performing 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, slight variations exist between performances of the same practice-as-entity. Therefore, individuals or groups of individuals can also be change agents and develop niches in otherwise dominant routines. These niches are, in turn, considered potential forces to reconfigure socio-technical regimes (e.g., Bui et al., 2016). Reckwitz's (2002) proposal that "[…] the 'breaking' and 'shifting' of structures […] must take place in everyday crises of routines" (p. 255) implies that the development of niches does not have to happen strategically but at times happens naturally, for instance, when people react to events that disrupt their everyday life. In the context of CP, an everyday crisis of routines may emerge when an active pesticide substance is phased-out, forcing farmers to look for alternative elements, such as other pesticides, non-chemical alternative measures, changes in crop rotation, or the like.

Overall, SPT helps to understand CP as a social practice, which means that, next to choice elements, it is comprised of routine elements. This theoretical lens has proven valuable in generating insights into the emergence, stability and change of practices. In addition, linking routinization with a social-psychological perspective offers an approach that considers both, individual and structural aspects in farmer behavior, and their interplay.

2.3. Discourse

Discourse has been recognized as a critical element in transition processes (Buschmann and Oels, 2019). I draw on Hajer's (1995, 2006) approach to environmental discourse, according to which discourse is "[…] an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices" (Hajer, 2006, p. 67). A discursive approach focusing on the use of language highlights how (political) problems and potential solutions are socially constructed. Thus, policy problems such as the legitimacy of pesticide use become the subject of discursive struggles. In these struggles, actors exchange views about topics, trying to make others see the issue according to their own

realities (Markard et al., 2021). They frame their arguments and mobilize storylines that summarize complex narratives (Hajer, 2006).

The influence of discourses on sustainability transitions has been demonstrated repeatedly across sectors. Prior research has, for instance, focused on the role that discourse plays in environmental policy development (Smith and Kern, 2009), on how incumbent actors frame the energy transition (Bosman et al., 2014), and on how discourse is used in directing change along transition pathways (Rosenbloom et al., 2016). For transition pathways in particular, it is relevant to note that a specific discourse can become so dominant that it leaves no opening to alternative pathways (Fairclough, 2003; Hajer, 2006). This may lead to incremental rather than fundamental changes and create a lock-in in the established socio-technical system (van den Bergh et al., 2011).

Recent contributions to STR have usefully employed the Argumentative discourse analysis (ADA) (Hajer, 1995, 2006) as an analytical approach to discourses (e.g., Ampe et al., 2020; Isoaho and Markard, 2020; Lowes et al., 2020; Markard et al., 2021; Rosenbloom et al., 2016; Rosenbloom, 2018). The two key concepts in ADA are storylines and discourse coalitions. Storyline is a condensed statement summarizing complex narratives that people use as "shorthand" in discussions where they tend to present facts as a story. Discourse coalition denotes a group of actors that commonly use a particular set of storylines over a certain period of time (Hajer, 2006). Drawing on these two concepts to study the storylines employed and the coalitions that form around them helps us to understand processes of stability and change in and through discourses. The crucial role of storylines in sustainability transitions has been highlighted in prior research, for example, as they are used to (de)legitimize the use of specific technologies and thereby contribute to shaping the development paths of socio-technical systems (Markard et al., 2021).

In summary, discourse is expected to be an important element in the transition to low-pesticide agriculture. Particularly relevant are the discursive struggles and dynamics evolving around pesticide use and its legitimacy because these contribute to opening or closing transition pathways. The dynamics can be traced by drawing on the analytical concepts of storylines and discourse coalitions.

2.4. Agri-environmental policy and policy change

Policies and politics are essential elements of the socio-technical regime. Policies here refer to the content or substance of policymaking and include objectives, programs, regulations, laws, and funding priorities. They are often formalized and

part of the institutional configuration of socio-technical systems. Therefore, a central element in sustainability transitions is policy change. Policy change is about implementing, adapting, and discontinuing public policies. Because this change affects a broad range of stakeholders, some typically win, and some lose, depending on how the transition unfolds (Markard et al., 2016).

An important role in transitions has been ascribed to policy reforms. Reforms are significant policy changes, such as altering policy instruments or substantially redesigning existing ones (Daugbjerg and Swinbank, 2016). Such re-design and implementation, however, happens in pre-existing policy contexts with their histories, policy paradigms, institutions, practices, and established actor networks. These pre-existing contexts render the adoption of agricultural policy reforms that would foster more sustainable agricultural practices (i.e., agri-environmental policies) difficult. This has been the case in many countries, despite the pressing need for policy reforms being acknowledged. The reasons ascribed to the difficulties in reforming agricultural policy are a general opposition to change and the exertion of political pressure to maintain the status quo (Jones et al., 2009; Metz et al., 2021). In addition, recent reforms have been found to focus on mitigating the negative environmental impacts of existing policies. In contrast, emphasis on increasing positive environmental effects through agriculture appears lacking (DeBoe et al., 2020).

Swiss agricultural policy, often attributed to a pioneering role in pursuing multifunctional agriculture (Metz et al., 2021, Pe'er et al., 2019), saw a major reform in 2014 (Mann and Lanz, 2013) and minor adaptations in 2018. In 2014, the country adopted policy changes that promoted greening[1] in agriculture. In the European Union (EU), the concept of greening was central to the reform of the Common Agricultural Policy in 2013 (e.g., Anania and Pupo D'Andrea, 2015) and continues to be a critical topic in policy debates (e.g., Metz et al., 2021).

Currently, green direct payments constitute a substantial part of many farms' incomes in Switzerland and the EU. The direct payment system consists of mandatory cross-compliance requirements and voluntary AES. AES have become a key policy instrument for environmental improvement. They offer financial incentives to farmers for adopting farming practices that reduce negative externalities (e.g., environmental pollution, soil erosion) and have positive environmental impacts (e.g., on biodiversity, landscape, and water management), thereby compensating them for additional costs or profits foregone (Espinosa-

[1] Greening is a metaphor for European policy measures that aim to enhance the positive impact of agricultural production on the environment and climate change (e.g., Pe'er et al., 2019).

Goded et al., 2010; Uthes and Matzdorf, 2013). At the farm level, the schemes lack the broad support necessary for a transition. Farmers are generally dissatisfied with, or even culturally resistant to AES (Burton et al., 2008). Those who participate may do so because they would comply with the scheme requirements either way, or are motivated by the payments (Lastra-Brava et al., 2015) and accept the often-only marginal or temporary changes to farming practices required under the scheme (Niskanen et al., 2021). The overall effectiveness of AES, especially in the longer term and once support payments are discontinued, has thus been evaluated negatively (Hasler et al., 2022).

Agri-environmental policies and their change can be viewed as a result of politics. Examples of politics in the agricultural sector include different groups of actors struggling to define sustainability in agriculture (Darnhofer, 2015) and may involve social struggles, such as contrasting aspirations for the spatial, temporal, and social distribution of benefits and costs (van der Ploeg, 2009). Organizations with vested interests in the current regime may coalesce to block policy reforms that change existing institutional and production patterns (Barbier, 2011). Frequently, agricultural policy has been described as exceptional, compartmentalized, and complex. Consequently, (environmental) policymaking in agriculture has been seen as particularly difficult, sometimes even as a 'wicked problem' (Vik, 2020).

Overall, policy change in agriculture is essential for a successful transition process but tends to be met with strong resistance. Among the factors that hinder policy changes are the pre-existing policy context along with its power relations and vested interests. While a greening of agricultural policy has taken place in the recent past, the current main instrument of voluntary AES does not appear effective in enabling a transition since the schemes lack sufficient support at farm-level.

To conclude section 2, practices, discourses, and policies are key dimensions of the socio-technical system of agriculture. To investigate these dimensions, research for this dissertation draws on the different disciplinary and analytical approaches laid out, which are SPT, a discursive perspective and an agricultural policy (change) perspective. The analyses on these dimensions are integrated by tying them to the overarching topic of a transition to low-pesticide agriculture under the umbrella of STR.

3 Presentation of the papers

This chapter provides a brief overview of the primary focus, the methods used and the results obtained in each of the four papers that form part of this cumulative dissertation. In addition, a short description of the research process and the author's contributions is provided. The original research papers are appended to the synopsis (see Appendix 2).

3.1. Paper 1: Understanding diversity in farmers' routinized crop protection practices (Kaiser and Burger, 2022)

Paper 1 is a peer-reviewed journal article published in the *Journal of Rural Studies*. The paper addresses the first two research questions (**RQ1:** How is current crop protection practiced by local farmers?; **RQ2:** How do farmers' crop protection practices differ?) and presents the results of a qualitative multimethod study applying an SPT framework to Swiss farmers' CP practices.

3.1.1. Summary

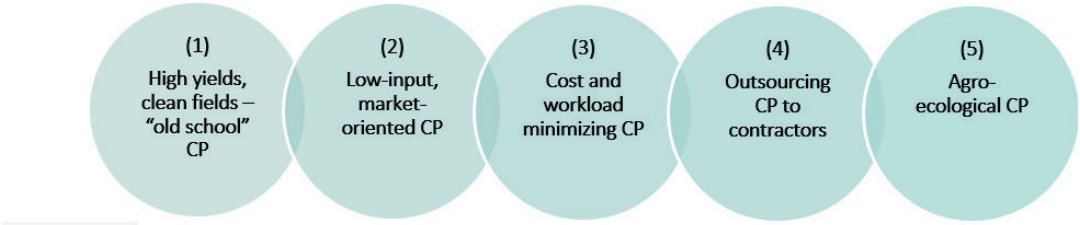
Paper 1 applied Shove et al.'s (2012) SPT framework of three elements (meanings, materials and competences) to the study of CP practices. Accordingly, this study aimed to better understand CP as a social practice and explore the diversity of routinized practices (i.e., how farmers' current local CP practices differ), using Switzerland as the empirical case.

The article employed a qualitative multimethod research design (Mik-Meyer, 2021), given our interest in revealing contextually bounded routines. It was based on data from semi-structured interviews with farmers (N = 6) and CP experts (N = 5), as well as on qualitative survey data (answers from farmers (N=450) to open-ended questions). Using SPT to analyze our data, we identified the meanings, materials and competences in farmers' practice narratives.

The analysis provided insights into the routinized nature of Swiss farmers' CP practices to answer **RQ1** (How is current crop protection practiced by local farmers?). The persistent patterns investigated helped explain the stability in how CP is practiced. Through the lens of SPT, the study focused on the level of farmers. Still, it could capture structural elements, such as policy instruments (e.g., incentive-based AES) and meanings (e.g., productivism discourse, see 'old school' CP type), that comprise routinized CP practices and emphasize these practices' embeddedness in the overall practice of farming.

Furthermore, the results showed that Swiss farmers' current CP practices differ systematically in the elements that make up the practices and in how these

elements become intertwined in farmers' CP performances. In addressing **RQ2** (How do farmers' crop protection practices differ?), we identified five distinct types of routinized CP practice as shown in the upper part of Figure 4. The typology created revealed that the practice types also vary in the degree to which one-size-fits-all policy interventions such as AES are embedded in practice elements. In other words, we identified the potential responses to today's mainly incentive-based AEP instruments. Currently, indications for a strong response to these instruments are only visible in two 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 the current AEP.



	(1) High yields, clean fields – "old school" CP	(2) Low-input, market-oriented CP	(3) Cost and workload minimizing CP	(4) Outsourcing CP to contractors	(5) Agro-ecological CP
Key meanings	A "good farmer" keeps fields clean and has high-yielding crops; autonomy	Strategic farm development, producing what market demands	Striving for cost-effectiveness and efficiency, no strong farmer identity	Focus on core business and interest such as livestock, dairy	Holistic approach: Aiming for healthy soils, healthy plants, healthy humans and animals
Key materials	Strong reliance on off-farm inputs, high outputs	Production for labels (organic, IP-Suisse etc.) with price premiums; direct payments to compensate higher risks and/or lower yields	Extensive production, often part-time, direct payments	Contractor for CP, keeps tight control over pests and diseases	Small scale production; mixed, resistant crops; often part-time plus off-farm employment
Key competences	Reliance on established methods	Learning, development high self-efficacy	Ability to optimize production costs, workload, direct payments, and revenues	Low skill levels in the area of CP, contracting to professionalize	Ability and willingness to use preventive measures, to observe and experiment

Figure 4. Five types of crop protection practices (own elaboration for this dissertation, based on Kaiser and Burger, 2022).

We concluded that the diversity of Swiss farmers' CP practices cannot be accommodated by a one-size-fits-all policy approach. This suggests that, in the Swiss case, the current main policy instruments are insufficiently aligned with three out of five CP practice types. Our study points to a need for further research on this practice–policy mismatch.

3.1.2. Research process and author contributions

Paper 1 was co-authored with Paul Burger. The interviews and the survey were conducted as part of Agroscope's accompanying research for the projects *3V, PestiRed,* and *Berne Plant Protection Project* and in collaboration with Maria Haller from Agroscope. I presented preliminary results at the Sustainability Research Colloquium in Basel in the autumn of 2020, the Swiss Geoscience Meeting in November 2020, the Agroscope PhD/PostDoc Symposium in March 2021, and the Network of Early Career Researchers in Sustainability Transitions (NEST) conference in April 2021. The final results were presented at the Platform Rural Sociology in May 2022. This paper's concept and methodology were developed together with Paul Burger. I conducted the data analysis and wrote the initial draft of the paper, which was reviewed and edited by Paul Burger and me.

3.2. Paper 2: Toward a low-pesticide agriculture: bridging practice theory and social-psychological concepts to analyze farmers' routines (Kaiser et al., 2024)

Paper 2 has been published in the peer-reviewed journal *Sustainability: Science, Practice and Policy*. This paper addresses the third research question (**RQ3**: What is the interplay between individual and structural factors in routinized pesticide use?) and is based on data from a survey among Swiss farmers.

3.2.1. Summary

The research for Paper 2 aimed to contribute to filling the gap in understanding CP practices as routines and individual variations within these routines. We bridged SPT and social-psychological concepts to investigate the relationship between individual and structural factors of CP practices on Swiss farms in a novel way. Elaborating on the individual-practice framework in Section 2.2, the factors were categorized into the three overarching analytical elements: meanings, competences, and materials. The individual factors were derived from four social-psychological concepts (personal norms, objectives, values, and perceived self-efficacy). Figure 5 illustrates the proposed structural model and the hypotheses developed (H1–H7) based on prior research.

The data for the study were collected from Swiss farmers (N = 652) with a survey. Covariance-based structural equation modeling allowed testing of the hypotheses, while simultaneously analyzing the relationships among several observed and latent variables with factor and path analysis (regression analysis).

The results supported hypotheses H2, H3, H5a, H6, and H7, whereas hypotheses H1, H4, and H5b were not supported. With regard to **RQ3**, this means

that structural factors are more strongly associated with pesticide use than individual factors. Although farmers' personal norms for limiting the use of pesticides were activated by values, self-efficacy, and social norms, they did not translate into behavior. Structural factors, such as local production conditions (material element) and knowledge sourced from private extension (competence element), appeared to inhibit the mediating role of personal norms concerning pesticide use.

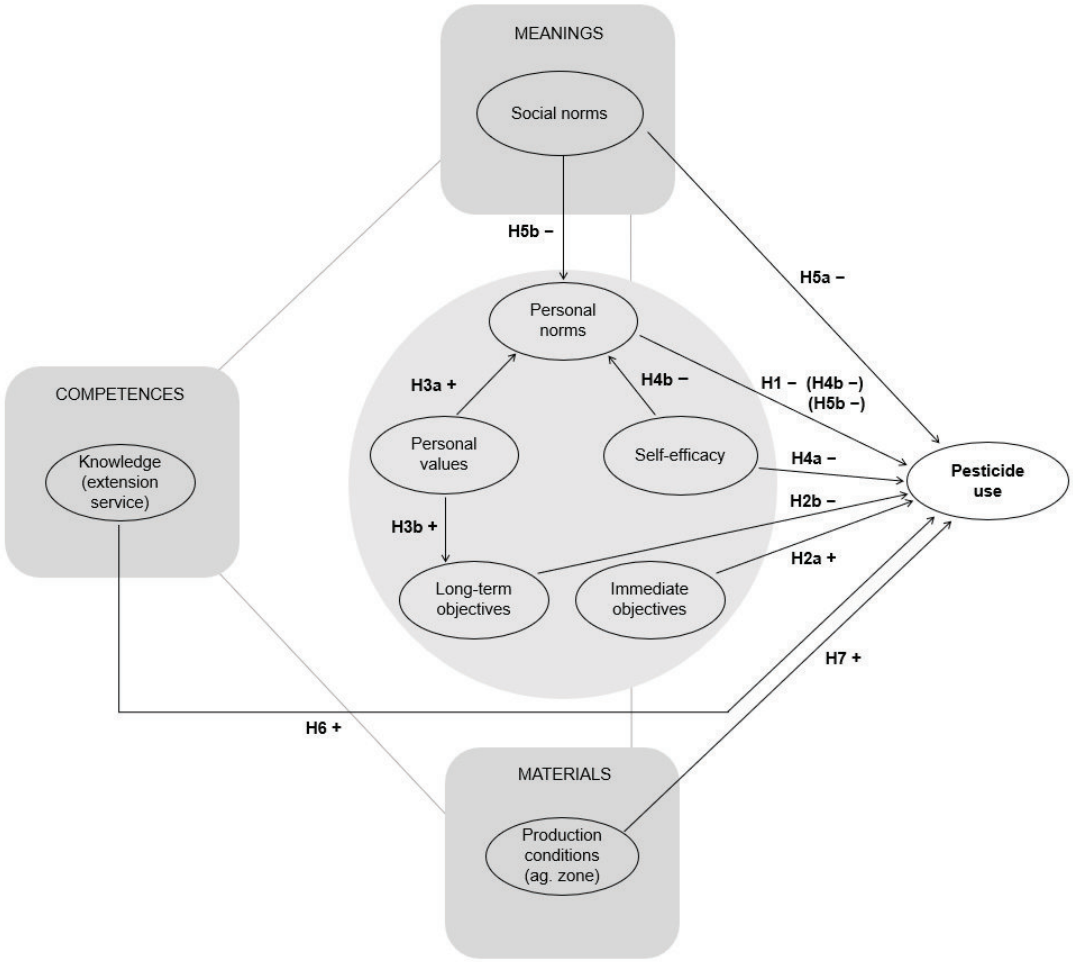


Figure 5. Proposed structural model and hypotheses (Kaiser et al., 2024).

Our findings thus suggest that farmers' individual agency is constrained by structural factors. We discussed reconfiguring structural factors, in particular material and competence elements of CP practices, as a first possible strategy for 'breaking routines'. A second strategy pointed out was to develop and empower niches to help change the incumbent pesticide regime. In addition to the empirical contributions, this paper highlights the benefits of integrating SPT and social-psychological concepts to advance our understanding of routines in farmers'

practices. This allows to gauge the relative roles of factors and mechanisms that (de)stabilize practices.

3.2.2. Research process and author contributions

Paper 2 resulted from a collaboration among three authors: myself, Robin Samuel (Department of Social Sciences, University of Luxembourg), and Paul Burger (Sustainability Research Group, University of Basel). The research was initiated by me, drawing on the in-depth exploration from interviews that were part of Paper 1 (Kaiser and Burger, 2022). Survey data were collected as part of Agroscope's accompanying research for the projects *PestiRed, 3V,* and *Berne Plant Protection Project*. The survey was developed and implemented in collaboration with Maria Haller (Agroscope). I was responsible for programming the online survey in Unipark/Tivian. The survey was also mailed to invited farmers who had not completed the online survey within the first two weeks.

Preliminary results of this research were presented by me at the International Conference on Environmental Psychology in October 2021, an earlier version of the paper at the annual conference of the Swiss Society for Agricultural Economics and Rural Sociology in April 2022, at the Platform Rural Sociology in May 2022, and at the Sustainability Research Colloquium in Basel.

I led the development of Paper 2, its concept and methodology. All authors helped to develop the paper's focus, shaped the research, reviewed and edited the initial draft, and approved the final manuscript after revision based on peer review recommendations.

3.3. Paper 3: Discursive struggles over pesticide legitimacy in Switzerland: A news media analysis (Kaiser, 2023)

Paper 3 has been published in the peer-reviewed journal *Environmental Innovation and Societal Transitions*. This paper addresses two of the research questions (**RQ4:** How were pesticides discursively (de)legitimized? and **RQ5:** How does the discursive (de)legitimation of pesticides link to policy change and regime (de)stabilization?). Paper 3 contributes to the exchange between different social science disciplines, which is crucial to enhancing the understanding and analysis of transformations toward sustainability. It connects critical concepts from the literature on sustainability transitions and environmental discourse, offering a discursive perspective on the transition to low-pesticide agriculture.

3.3.1. Summary

Paper 3 argues that the discursive struggles surrounding pesticide use in Switzerland led to a (preliminary) stabilization, rather than a destabilization, of the incumbent regime, which managed to adjust and integrate some of the societal criticism. The argument is built on the findings about the pesticide (de)legitimation process, which was examined using a discursive lens. Paper 3 systematically identified the topics associated with pesticides, key storylines, and discourse coalitions. It sought to untangle how certain storylines were used to delegitimize or (re-)legitimize pesticides and to support or oppose (radical versus incremental) pesticide reduction pathways. In addition, I further interpreted the findings on the discursive (de)legitimation of pesticides by linking them to policy changes and the (de)stabilization of the incumbent pesticide regime.

Paper 3 used a mixed-methods research design that innovatively integrated the strengths of inductive machine learning (more precisely, structural topic modeling) for a quantitative assessment of newspaper coverage and a discursive approach (argumentative discourse analysis) for an in-depth qualitative analysis. I applied these methods to a corpus of 2,523 newspaper articles. The corpus covered pesticide discourses in the mainstream press (NZZ, Tagesanzeiger, 20minuten, Blick) and the farming press (BauernZeitung, Schweizer Bauer, die Grüne) of the German language region of Switzerland from 2011 to early 2022.

The results showcased the different (and similar) topics that the mainstream and the farming press addressed in their coverage of pesticides over time. For example, topics concerning environmental and human health, such as pesticide toxicity and water pollution, were prominent in the mainstream press. In contrast, the farming press foregrounded topics related to the sector's remedies and pesticide reduction efforts, such as alternative CP techniques. Topics in both newspaper types included less controversial ones, such as vertical farming and viticulture.

This distinction in topic coverage was then reflected in the storylines that different actors employed in the discursive struggle over pesticides (Table 1). Addressing **RQ4** (How were pesticides discursively [de]legitimized?), the results of Paper 3 showed that disruptive storylines emerged from 2013 onwards and presumably led to the launch of two Swiss popular initiatives in 2018. The debate was also spurred by the initiatives' campaigning (2018–mid-2021). The findings indicated that two broad discourse coalitions (i.e., storylines and the actors using them) competed. Many non-regime actors coalesced around delegitimizing storylines that sought to induce rapid and radical changes in pesticide regulation,

as proposed by the two popular initiatives. Legitimizing storylines were employed by many regime actors, who used them to advocate for incremental and voluntary measures that would not change the overall logic of conventional, pesticide-intensive agriculture.

In response to **RQ5** (How does the discursive [de]legitimation of pesticides link to policy change and regime [de]stabilization?), first, it became evident in the Swiss voters' rejection of the two popular initiatives that the delegitimizing coalition had not been successful with its proposals. Nevertheless, the findings suggest that undermining pesticide legitimacy has likely contributed to opening up political spaces and striking a compromise. The compromise is a reduction path implemented through policy measures within the cross-compliance system. To achieve this compromise, the incumbent regime had to integrate some of the societal critique. This means that, although unsuccessful at first sight, the coalition undermining pesticide legitimacy has also reached an incomplete institutionalization of its discourses.

Second, however, from a sustainability transition perspective, the policy change represents an incremental improvement. By making this incremental change, the incumbent socio-technical regime could claim its efficiency and responsibility, thereby reinforcing regime credibility, resisting radical change, and likely stabilizing the regime. Consistent with prior studies, the findings thus suggest that no destabilization of the incumbent pesticide regime has been achieved. The overall functioning of conventional agriculture and the risk-reduction paradigm, instead of quantitative pesticide reduction, remained unaffected.

Table 1. Contending storylines surrounding pesticides. The table is shortened for this dissertation. Refer to Kaiser (2023) for the full table.

Sets of storylines	Storylines
Delegitimizing storylines:	(D1) Pesticides pollute water
Pesticide pollution	(D2) Pesticides threaten other species or biodiversity
Pesticides pollute the environment, harm human health, and threaten other species	(D3) Pesticides pose risks to human health
Legitimizing storylines:	(L1) Water protection compliance
Farming sector's remedies and reduction efforts	(L2) Alternative CP techniques in development or implementation
The farming sector exerts all kinds of efforts to reduce pesticide use (risks), but pesticides are still needed to produce and secure yields	(L3) Technology as a solution

3.3.2. Research process and author contributions

Paper 3 is a single-author paper. I was responsible for its conceptualization, analysis, writing, and finalization with feedback received from the thesis' supervisors, from colleagues and participants in the Sustainability Research Colloquium, and from two anonymous reviewers. Furthermore, the Research and Infrastructure Support at the University of Basel provided help with data acquisition and advised on the computational method used. The preliminary results of this research were presented at the International Association People-Environment Studies Conference in July 2022, the Conference of the Africa Network for Students and Alumni in October 2022, and the Swiss Agricultural Economics PhD Seminar in January 2023.

3.4. Paper 4: Why is agricultural policy not more environmentally ambitious? Comparing failed attempts in Switzerland (Mann and Kaiser, 2023)

Paper 4 is a peer-reviewed article published in the journal *Resources, Environment and Sustainability*. The paper addresses **RQ6:** What are common reasons for the failure of attempts to transform agricultural policy in Switzerland? This research was motivated by the fact that Switzerland has ambitious agri-environmental objectives, but continuously misses its targets. In our paper, we examine this contradiction by focusing on three recent attempts to transform and further "green" Swiss agricultural policies.

3.4.1. Summary

Paper 4's primary strength is in showing that the three reform attempts failed to meet their objectives because of the significant disadvantages that their realization would have generated. These included, above all, a reduction in the national self-sufficiency rate. The failures described were thus attributed to public preferences and regime resistance, since policies that would have lowered the degree of national self-sufficiency were fought unanimously by the politically powerful agricultural lobbyists. These insights address **RQ6.**

Paper 4 compared three cases in a qualitative multimethod research design using a rich database collected through participant observation, semi-structured interviews, and document search. The comparison along dimensions potentially relevant for explaining reform failures came close to Mill's Method of Agreement (Savolainen, 1994; Skocpol, 1991), where everything between the cases differed except for the explanation and the outcome. Since all other potentially relevant dimensions varied, only the similarities between cases on the explanation were expected to cause agreement between their outcomes.

While the analyzed reform attempts showed many distinctive features, such as their governance approaches, project contexts, and key actors, we identified a target conflict with food production to secure self-sufficiency and the related opposition to reforms through the Swiss Farmers' Union as a central common point (see Table 2). This finding also suggests that the strategy of providing incentives for mere agricultural extensification within the sectoral policy regime has reached a dead end.

Table 2. Comparison of the three cases along key dimensions (adapted from Mann and Kaiser, 2023).

	Case study 1 (3V project)	Case study 2 (IDZ project)	Case study 3 (AP 22+)
Stage of the policy process	Pilot project/pre-conceptualization	Pre-operationalization	Pre-approval by parliament
Governance approach	Bottom-up/interactive	Science-driven	Top-down plus stakeholder involvement
Objectives	Utilize knowledge by farmers and simplify policy	Use targeted indicators that improve environmental efficiency	Define stricter environmental rules
Context	Network of 31 farmers, consultants, and administrators	Interdisciplinary research project	Reform package in parliament
Key actors	Federal Office for the Environment	Agroscope federal research station	Federal Office for Agriculture
Opposition/target conflict	Food production to secure self-sufficiency (reflected in Swiss Farmers Union's voice)	Food production to secure self-sufficiency (reflected in Swiss Farmers Union's voice)	Food production to secure self-sufficiency (reflected in Swiss Farmers Union's voice)
Outcome/goal achievement	Improvement of the environmental performance of farming policies failed	Improvement of the environmental performance of farming policies failed	Improvement of the environmental performance of farming policies failed

Our findings supported the conclusion that broader food policy measures are needed to achieve the sector's ambitious environmental objectives. Promising avenues for extensifying agricultural production without reducing the desired degree of self-sufficiency include, first and foremost, changing food consumption (and thereby land use) patterns. Tackling the reduction of food waste and the share of calories from animal products are suggested measures.

3.4.2. Research process and author contributions

Paper 4 was co-authored with Stefan Mann and was based on a three-year collaboration at Agroscope in the accompanying research for the project *3V*. Stefan Mann initiated this paper by drafting a first idea. The further concept and methodology of the research were then developed jointly. Both authors contributed equally to the data analysis, the writing of the original draft, and its review and editing.

4 Discussion

This section discusses and synthesizes insights in response to the main research question using findings from the supporting research questions.

> ***RQ_main:*** *What elements and dynamics in practices, discourses, and policies hinder, enable, or shape a sustainability transition toward low-pesticide agriculture?*

Overall, the four research papers summarized in this dissertation have provided many insights into the main research question. These are discussed along two main lines, as follows:

(1) Processes of stability and change in practices, discourses, and policies.
(2) Stability and change in the socio-technical pesticide system through practices, discourses, and policies.

These two lines address different levels of analysis, the micro-level (1) and the macro-level (2), which are discussed in the following subsections. Section 4.1 discusses the micro-level processes into which I 'zoomed in' by focusing on practices, discourses, and policies as units of analysis. These micro-level processes are seen to underpin the transition, i.e., systemic change, so that the insights gained inform the 'bigger picture', i.e., the macro-level of the transition as discussed in section 4.2. In that sense, section 4.2 builds upon section 4.1 and distills three main points and associated implications for the transition to low-pesticide agriculture.

4.1. Processes of stability and change in practices, discourses, and policies

By focusing on stability and change in and across the three dimensions investigated, I address the first part of the main research question and discuss several elements and dynamics identified in this dissertation.

The results obtained from the analysis by Kaiser et al. (2024) provided insights into the interplay of individual and structural agency in practices. They indicated that farmers' individual agency is constrained by structural factors, particularly the material and competence elements of CP practice. Farmers' personal and social norms for reducing pesticide use were found to be "active" but overridden by structural factors. These structural factors thus seem to contribute to the stability of routinized pesticide use. Two potential entry points for 'breaking routines' in pesticide use could be identified. These are reconfiguring structural elements (e.g., use of public instead of private extension services) and strengthening farmers' capacity to act as change agents (e.g., by enabling them to identify and present alternative CP systems as promising) and develop pesticide-free niches.

The typology developed by Kaiser and Burger (2022) showcases the diversity and possibilities for change in local CP practices. The literature argues that change occurs through dynamics in practices (Shove et al., 2012); these dynamics are visible in the diversity of practice types uncovered. The heterogeneity found within one region and institutional setting can be explained by a fragmentation of good farming ideals, as described by Sutherland and Darnhofer (2012). This is reflected in fragmented practice types or "diverging trajectories," as found in the farming styles literature (van der Ploeg, 1986), which offers farmers the opportunity for social differentiation (Warde, 2005). For example, farmers practicing mainly market-oriented, lower-input CP were found to seek differentiation from those practicing 'old school' CP. Social differentiation must also be read as a response to societal demands and an outcome of farmers' attempts to break with the conventional CP system, which involves continuous development, bifurcation, and fragmentation of CP practices (Schatzki, 2002). In addition, the typology I developed allowed for an interpretation of the different practice types' sensitivities to the incentive-based policy instruments. Because they were only well aligned with two of the five practice types, the central policy implication is that policy instruments—as one element to enable and shape the transition—need to account better for the diversity in practices.

Linking pesticide use practices and discourses illustrates how discourses are expressed, produced, and reproduced through practices. The different meanings

ascribed to pesticides through discourse are evident in aspects that form part of the meaning element of CP practice. For example, the discourse acknowledging pesticides' risks and potential harmfulness is a feature of the market-oriented CP type. This practice type (implicitly or explicitly) conforms to the sustainability paradigm under which the farming sector seeks to reduce pesticide use, thus responding to societal demands while maintaining a relatively high level of production, which is in line with the productivism paradigm (cf. Watson, 2018). As expressed through storylines that delegitimize pesticide use, the integration of societal critiques is visible in farmers' personal and social norms to reduce pesticide use found by Kaiser et al. (2024). On the contrary, the (formerly dominant) discourse implying that pesticides are essential for food production and security is visible in the conventional type of CP (labelled as 'old school' in the typology developed by Kaiser and Burger, 2022). There, it is entangled with practitioners' corresponding education, skills, and material path dependencies (e.g., crop production geared toward high yields to serve established distribution channels, on-farm machinery and investments, and soil conditions limiting the spectrum of possible crop cultivation).

The evidence provided by Mann and Kaiser (2023) supports the claim that regime resistance and status quo preferences are common reasons for the lack of change in Swiss AEP. These factors are consistent with known barriers to change in the literature on governance in sustainability transitions (Geels, 2014; Köhler et al., 2019). In addition, the identified target conflict between greening agricultural policy and maintaining a specific national self-sufficiency rate suggests that agricultural policy goals are not coherent. Significant trade-offs have come to the fore due to the increased attention paid to long-term goals such as sustainability by the reform projects analyzed by Mann and Kaiser (2023). As these long-term goals clash with the shorter-term goal of national self-sufficiency, this points to tensions within the dominant agricultural regime (cf. Darnhofer et al., 2015), which may present possibilities for change in the longer run.

Regime resistance has likely averted major policy changes, as attempted by governmental reforms concerning broader agricultural policy (Mann and Kaiser, 2023) and bottom-up reforms targeting pesticides (proposed by popular initiatives) (Kaiser, 2023). In the latter case, the change appeared to be averted by the incumbent regime through its public mobilization with respect to the referenda held. Hence, a political compromise appeared to be a promising solution to the struggle over pesticides. Nevertheless, undermining pesticide legitimacy by what may be labeled an "environmental protection regime" created pressures on the

agricultural pesticide regime (cf. Diaz et al., 2013). This interaction and tension between the two regimes has likely contributed to opening up political spaces and striking a compromise because the pesticide regime was pressured to integrate some of the critique.

4.2. Stability and change in the socio-technical pesticide system through practices, discourses, and policies

Based on the elements of stability and change in practices, discourses, and policies discussed in the previous sub-section, three main points and associated implications can be distilled. These address the second part of the main research question by linking the elements and dynamics explored to their (potential of) hindering, enabling, and shaping a sustainability transition toward low-pesticide agriculture.

(1) The agricultural regime resists fundamental change and fosters a regime-stabilizing pathway of incremental change and risk reduction.

The incumbent regime in Swiss agriculture resisted the radical policy changes proposed by reform initiatives. The strategies included instrumental and broader institutional forms of power (cf. Geels, 2014), such as lobbying, since policies that were considered to lower the degree of national self-sufficiency were fought unanimously by politically powerful agricultural lobbyists. Concerning pesticide transition pathways, the discourse on the farming sector's remedies and reduction efforts left little opening for alternative pathways. The policy changes in the form of a pesticide reduction path were made under the dominant risk-reduction paradigm and had to be evaluated as incremental changes. Moreover, the regime re-stabilized after disruption by using discursive strategies. Considering that the regime accounts for the stability of the wider socio-technical system, this means that discursive and other strategies of regime resistance hinder a systemic shift that would qualify as a transition. If, however, the tensions hinted at within and between regimes (e.g., environmental protection versus the agricultural regime) were to intensify in the future, the incumbent regime could lose its dominant role, opening up space for acceleration and more radical changes to be enacted.

(2) Crop protection practices are the locus of continuous incremental change, but it remains unclear whether this can enable fundamental change.

Incremental changes in CP became visible in the multiplication into distinct parallel practice types. Sustainability transitions research differentiates between such incremental changes (which do not question fundamental values, paradigms, institutional arrangements, etc.) and radical changes (i.e., fundamental shifts in system logic), with only the latter qualifying as a transition (Darnhofer, 2015; Köhler et al., 2019). In the context of the emerging transition process to low-pesticide agriculture in Switzerland, it is unclear whether the observed incremental changes may accumulate and enable radical change. A clear cause–effect relationship will remain difficult to discern. However, incremental changes in practices may well point to promising niche developments such as agroecology and pesticide-free cultivated crops in farmers' crop rotation. Such niches have the potential to effect changes in the socio-technical pesticide system at large. This potential results from features of niches (e.g., the breeding and cultivation of pest resistant crops) that become institutionalized in new routines or transform dominant routines (cf. Darnhofer et al., 2015).

(3) Shifts in the socio-technical pesticide system will likely be characterized by diversity. Transition policies must account for this diversity.

There cannot be a uniform transition to low-pesticide agriculture. This is because the CP practices found are diverse, farmers' agency is limited, and farming is constrained by the natural and cultural environment. Hence, a transition is likely to be shaped by shifts in segments, each with its own developmental pathway. This requires policy measures that are well targeted toward the different practice types and enable a 'breaking of routines'. Since structural factors seem to hinder farmers' individual agency in doing so, policies to enable and shape the transition should target the structural elements that comprise pesticide use practices and better align them with farmers' norms.

5 Scientific and societal relevance, limitations, and scope for further research

This section describes the scientific and social relevance of the research, along with limitations and avenues for future research.

5.1. Scientific relevance

This section discusses the scientific relevance of this dissertation with respect to contributions to two different strains of literature.

First, the dissertation contributes to filling the gaps in understanding farmer behavior and farming practices. It highlights the benefits of considering routines and diversity in CP practices. Specifically, Paper 1 contributes an empirically grounded typology of routinized practices to the current knowledge on farmer behavior in CP. The significance of this approach can also be illustrated by the paper's number of citations. In the short time since its publication in January 2022, Paper 1 has been cited 17 times (excluding self-citations) and is thus already having some scientific impact. Paper 2 contributes to understanding individual variations within CP routines and the relative roles of factors and mechanisms that (de)stabilize pesticide use. This may guide further research on how to "break routines" in CP. In addition, the paper contributed to the further advancement of a framework bridging SPT and social-psychological concepts for analyzing routinized farmer behavior.

Second, this dissertation contributes to the literature on the STR subfield of agricultural sustainability transitions. Using insights from the specific case of a low-pesticide transition in Switzerland, it helps closing empirical gaps regarding an emerging transition process in three ways. First, in connecting the advancements made in understanding farmers' CP practices to the knowledge on the socio-technical pesticide system, it adds a practice-based perspective on stability and change in the pesticide system. Second, using a discursive perspective, this dissertation strengthens the understanding of the role of discursive elements in pesticide policy and regime change. Third, from a policy perspective, it contributes to understanding agricultural policy reform failures that are linked to regime resistance.

In addition, this dissertation makes two methodological contributions. First, Paper 3 enriches the methodological repertoire in transition studies by illustrating the combined application of text mining for analyzing a large dataset and ADA to zoom into a subset of this data. Second, Paper 2 illustrates the

usefulness of studying CP practices within a quantitative survey-based research design, whereas most prior research on practices used a qualitative research design.

5.2. Relevance to society

The analytical perspectives employed in this dissertation bring new knowledge that can support the design and targeting of public policies when they seek to enable and shape transformative change. Given the role that policy must play in the transition of the agricultural sector with its high policy involvement, the findings from this dissertation may be used as a basis to inform policymaking. Its policy relevance can also be illustrated by a policy brief on Paper 1 published in *Agrarforschung Schweiz* and an article summarizing the dissertation in the *Agrarbericht 2023* published by the Federal Office for Agriculture (see *Weitere Veröffentlichungen während des Doktorats*). Selected results from Papers 1 and 2 were presented at workshops with extension and training officers who showed great interest in using research outputs such as the CP practice typology in their teaching at farmer (vocational) training centers.

5.3. Limitations of the dissertation and prospects for further research

This section discusses the limitations of this dissertation. Moreover, as the dissertation advances the knowledge on elements and dynamics that hinder, enable, or shape a sustainability transition toward low-pesticide agriculture, it opens several avenues for future research endeavors which are pointed out.

The dissertation includes research integrated into three of Agroscope's accompanying research projects. Along with the advantages of field access to farmers, the interviews and survey conducted for parts of this dissertation covered only the regions in Switzerland where the projects were conducted. Thus, for example, the Italian-speaking part of Switzerland was excluded, reducing the generalizability of the findings for Switzerland as a whole. These limitations affect Kaiser and Burger (2022), Kaiser et al. (2024), and Mann and Kaiser (2023). In addition, while the results and implications for reducing pesticide use are significant for many European countries, they may not be generalizable to Europe due to the diverse nature of the farming sector within large and even smaller geographical locations.

Another limitation is the ongoing nature of the transition process in question. Empirically, this process could not be covered from beginning to end; therefore, the analysis is neither exhaustive nor conclusive. This limitation especially affects Kaiser (2023).

Four primary avenues for future research can be pointed out based on this research. First, there is a need for further research on the practice–policy mismatch pointed to by Kaiser and Burger (2022). Second, based on the typology developed in Paper 1 (Kaiser and Burger, 2022), it would be helpful to quantify the shares of practitioners in each of the identified practice types. This can be done using survey research. Third, this dissertation analyzes processes of regime change. Further research should include the links and interactions between niches and the regime in the transition process. Fourth, drawing on transition theory, a better understanding of changes that do not occur within the regimes themselves but in a shift in the dominant role of one regime over another (e.g., the nature conservation regime may at some point become more relevant than the agricultural regime) is required.

6 Conclusions

This dissertation sought to advance the knowledge on elements and dynamics that hinder, enable, or shape a sustainability transition toward low-pesticide agriculture. The research focused on three key dimensions (practices, discourses, and policies) in which transition struggles and trade-offs are particularly pronounced. Integrating analyses of these three dimensions provides various insights and explanations for stability and change in CP. It also allowed to capture processes of stability and change in the broader socio-technical system.

Based on these findings, the dissertation derives three main implications for the emerging transition to low-pesticide agriculture. First, the agricultural regime currently resists and hinders fundamental change, fostering a regime-stabilizing pathway of incremental change and risk reduction. This dissertation has also shown how pesticide discourses in Switzerland link to policy and regime changes. The findings point to a preliminary further stabilization rather than destabilization of the regime. Second, CP practices are subject to continuous, incremental changes including niche developments. It remains unclear whether these incremental changes accumulate and enable more fundamental change in the longer run. Third, a transition toward low-pesticide agriculture is likely to be shaped by diversity due to the heterogenous practice types identified. Moreover, CP consists of routinized components and transition policies must account for both, routines and diversity in CP. The typology developed in this dissertation may serve as a basis for informing policymakers in this regard.

Overall, the research conducted for this dissertation highlights the context-dependence and unpredictability of many change processes in agriculture. It cannot be known whether the current incremental changes, combined with disruptive events such as popular initiatives on agricultural issues, will indeed contribute to a fundamental transition process. Nevertheless, the ongoing change processes in the crop production and pesticide system feature a number of characteristics that are necessary preconditions for a transition. By advancing frameworks and tools and employing them for analyzing these processes, this dissertation sheds light on such preconditions and contributes to strengthening the field of agricultural sustainability transitions research more broadly.

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Appendix 1. Conference presentations and posters

Throughout my doctorate, I gave several oral and poster presentations to distribute the findings of my papers, both in person and online.

- "Discursive struggles over pesticide legitimacy in Switzerland: A news media analysis using topic modelling and discourse analysis", SCP23: SCORAI-ERSCP-WUR Conference Transforming consumption-production systems toward just and sustainable futures, Wageningen (NL), July 2023.
- "Discursive struggles over pesticide legitimacy: A news media analysis", 4th Swiss Agricultural Economics PhD Seminar, Agroscope, January 2023.
- "Text mining for 'non-geeks'—what is it and what can it do for you?", Conference of the Africa Network for Students and Alumni (ANSA), Stuttgart (D), October 2022.
- "Sustainable agricultural development through the lens of rural-urban divide: A computational text analysis of the media coverage of Swiss popular initiatives on pesticide policies", Symposium Bottom-up engagement of citizens and stakeholders in sustainability transitions, International Association People-Environment Studies, Conference 2022, online, July 2022.
- "Vielfalt und Routinen im Schweizer Pflanzenschutz verstehen: eine Anwendung der Theorie sozialer Praktiken", Platform Rural Sociology, HAFL Bern, May 2022.
- "How do factors of routinization in farmers' crop protection relate to pesticide use? Evidence from Switzerland," Annual Conference of the Swiss Society for Agric. Economics and Rural Sociology, FIBL Frick, April 2022.
- "Factors of routinization in farmers' crop protection and pesticide use" (Poster presentation), International Conference on Environmental Psychology, Siracusa (IT), October 2021.
- "Uncovering routines and diversity in farmers' crop protection: A social practices approach", Network of Early Career Researchers in Sustainability Transitions (NEST) Conference, online, April 2021.
- "Uncovering routines and diversity in farmers' crop protection: A social practices approach" (Poster presentation), Agroscope PhD/PostDoc Symposium, online, March 2021.
- "A social practice theory approach to farmers' crop protection", Swiss Geoscience Meeting, online, November 2020.

Appendix 2. Articles included in the cumulative dissertation

The articles that make up the cumulative dissertation can be found on the following pages and appear in the following order:

1. Kaiser, A., Burger, P., 2022. Understanding diversity in farmers' routinized crop protection practices. *Journal of Rural Studies,* 89, 149-160. https://doi.org/10.1016/j.jrurstud.2021.12.002.
2. Kaiser, A., Samuel, R., Burger, P., 2024. Toward a low-pesticide agriculture: bridging practice theory and social-psychological concepts to analyze farmers' routines. *Sustainability: Science, Practice and Policy,* 20, 2306731. https://doi.org/10.1080/15487733.2024.2306731.
3. Kaiser, A., 2023. Discursive struggles over pesticide legitimacy in Switzerland: A news media analysis. *Environmental Innovation and Societal Transitions,* 49, 100777. https://doi.org/10.1016/j.eist.2023.100777.
4. Mann, S., Kaiser, A., 2023. Why is agricultural policy not more environmentally ambitious? Comparing failed attempts in Switzerland. *Resources, Environment and Sustainability,* 11, 100096. https://doi.org/10.1016/j.resenv.2022.100096.

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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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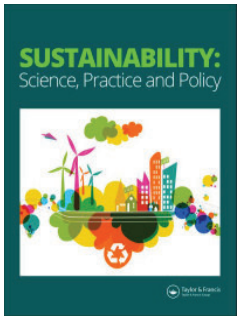

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Toward a low-pesticide agriculture: bridging practice theory and social-psychological concepts to analyze farmers' routines

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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

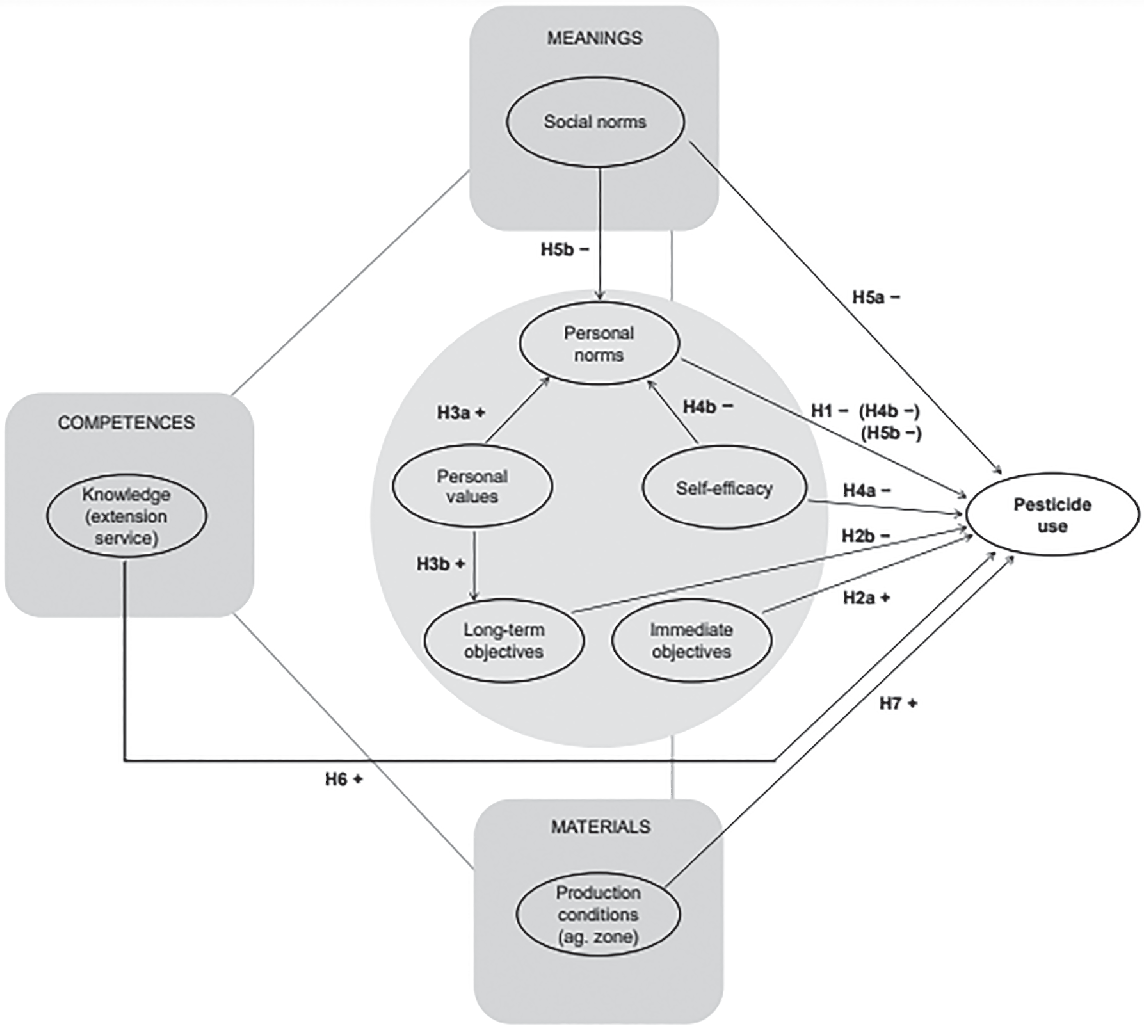

Figure 1. Proposed structural model and hypotheses. No causal interpretation is implied by the structural pathways in the model.

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 chi²/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.

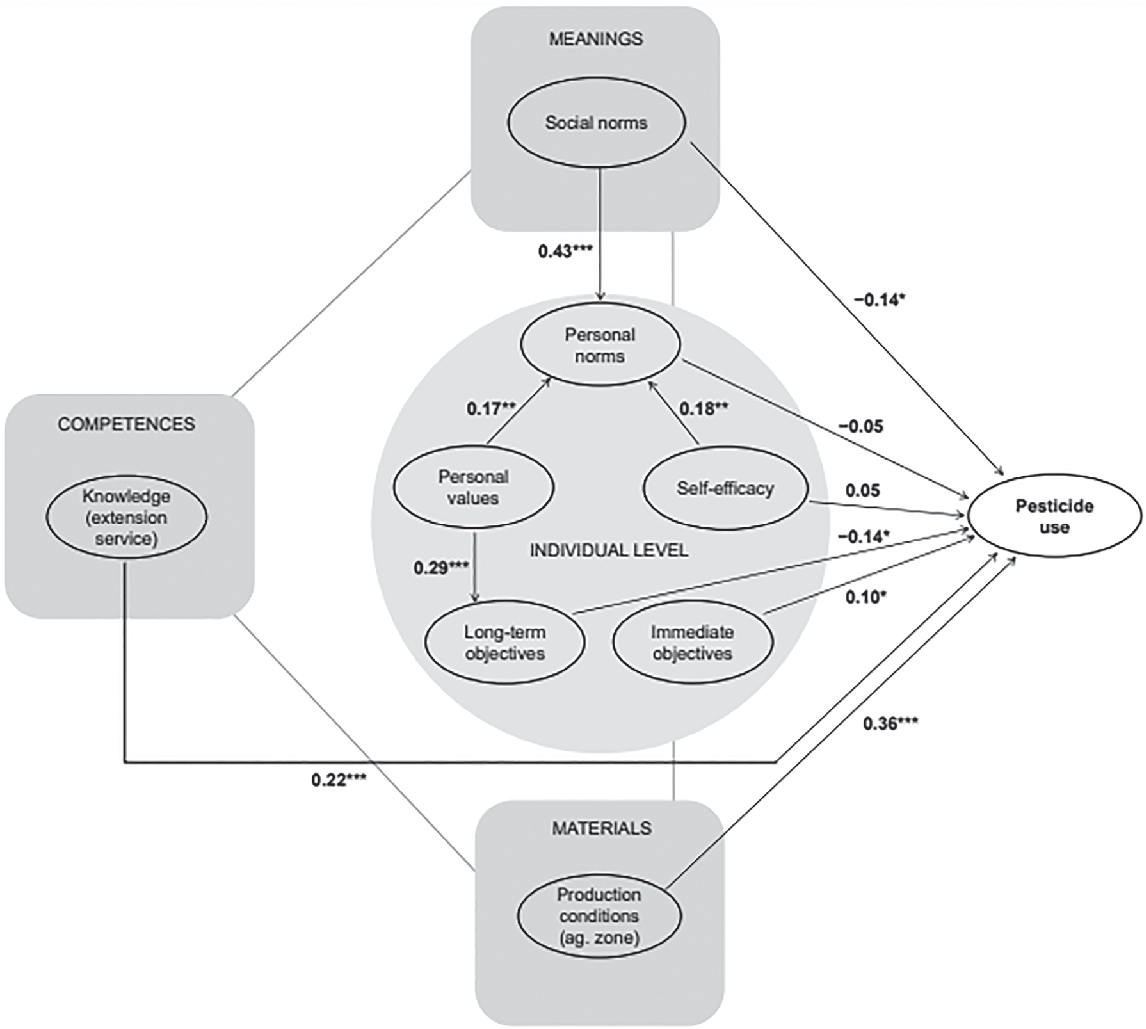

Figure 2. Results of the structural equation modeling with respect to the tested hypotheses. Displayed values are standardized parameter estimates for direct effects. Significance levels in the structural model: ***$p < .001$, **$p < .01$, *$p < .05$. No causal interpretation is implied by the structural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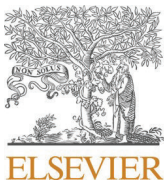

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Discursive struggles over pesticide legitimacy in Switzerland: A news media analysis

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ABSTRACT

Societal concerns about pesticides and their negative effects have increased significantly in recent years. These concerns cumulated into discursive struggles over pesticide legitimacy. Although the emerging transition towards low-pesticide agriculture has become an important area of research, our understanding of those pesticide discourses and their function in (de)stabilizing the pesticide regime is still limited. This study reveals the discursive elements by investigating topics, storylines and discourse coalitions and links them to policy and regime changes. The paper's argument is being built on the case of pesticide discourses in Switzerland. A corpus of 2,523 articles from the mainstream and farming press covering the period from 2011 to 2022 is analyzed by combining topic modeling and discourse analysis. The results show how two broad, distinct discourse coalitions competed by employing de- versus relegitimizing storylines. They also indicate that the external contestation rather led to a (preliminary) regime stabilization than to its destabilization.

1. Introduction

Agricultural pesticide use and its reduction pathways are highly contested. Driven by societal concerns about the adverse effects of pesticides on the environment and human health, discursive struggles over the legitimacy of pesticides have strongly increased (Young et al., 2022). Legitimacy here refers to the perceived consonance of pesticides with their institutional environment, i.e. a socially constructed set of beliefs, norms, values, and practices in the pesticide context (Scott, 2008; Suchman, 1995). In discursive struggles, some actors mobilize narratives to problematize and delegitimize the established use of pesticides, whereas others seek to (re)legitimize it (Binz et al., 2016; Markard et al., 2016; Rosenbloom et al., 2016). The struggles become visible in contrasting topics (e.g., *food security, water pollution*) and storylines (e.g., *pesticides are needed to produce food, pesticides pollute water*) that different actor groups coalesce around. They thereby seek to influence public policies, which in turn can determine the pace and direction of agricultural change (Markard et al., 2021). These discursive elements and their relations to changes in pesticide policy and in the socio-technical system of agriculture have received relatively little attention from scholars although they could be part of lock-in mechanisms and important factors in explaining change (Buschmann and Oels, 2019).

Drawing on the prominent analytical dimensions of transition research (landscape, regime, and niche), this paper is interested in how discourse links to changes in policy and at the regime level. The regime represents the so-called "grammar" behind well-aligned

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and fairly stable configurations of socio-technical system elements (Frank and Schanz, 2022; Rip and Kemp, 1998). Such elements include infrastructures, markets, norms, policies, rules, social structures and technological artefacts (Fuenfschilling and Truffer, 2014; Rip and Kemp, 1998). In other words, the regime is where the use of pesticides is engrained in the socio-technical system of agricultural production.

Through its reliance on pesticides, modern agriculture provides for high productivity and food security. However, on the downside of massive pesticide use there are numerous and well-documented negative effects on the environment. These contribute most notably to biodiversity loss (e.g., Hallmann et al., 2017; Potts et al., 2010; van Swaay et al., 2006) and pollution of water bodies (Stehle and Schulz, 2015), drinking water sources (Kiefer et al., 2019) and agricultural soil (Riedo et al., 2021; Tang et al., 2021). Moreover, pesticides used to protect crops are suspected to be carcinogenic, thus threatening human health (e.g., Alavanja and Bonner, 2012; Jones, 2020). Although the reduction of pesticide use and risks has made it to the top of European policy agendas in recent years, the reduction targets are continuously missed (Möhring et al., 2020). Against this backdrop, calls have been made for a fundamental sustainability transition of agricultural production with low- or eventually no-pesticide use (Jacquet et al., 2022) .

Overall, there are signs that the pesticide regime is coming under increasing pressure in many European countries (European Commission, 2020; Lamine et al., 2010; Pe'er et al., 2020). This pressure is largely driven by societal concerns, which have grown in the study period (2011–2022) (e.g., Schaub et al., 2020). A typical response to growing concerns voiced by social movements or interest groups that question the legitimacy of single technologies, such as a specific pesticide, is phase-out (Turnheim and Geels, 2012). The ban of the agrochemical DDT in many countries throughout the 1970s and 1980s is a prominent case that was retrospectively described as having played a key role in regime changes, for example through destabilization processes (Levain et al., 2015).

In the sustainability transitions literature, struggles over technology legitimacy and associated regime changes were understudied but are now receiving more attention (e.g., Mattioni et al., 2022; Novalia et al., 2021; Runhaar et al., 2020). Whereas most studies focus on the energy transition (e.g., Isoaho and Markard, 2020; Markard et al., 2021; Rosenbloom, 2018), recent research on agricultural transitions has begun to analyze the construction of legitimacy for agri-technologies developed in response to environmental regulation in the Netherlands (van der Velden et al., 2022) and compared different governance perspectives on pesticide regime destabilization along with related discursive shifts in Germany (Frank and Schanz, 2022). However, it remains underexplored how current discursive struggles over pesticides and their legitimacy unfold in detail, and how these discourses link to policy changes and a (de)stabilization of the incumbent pesticide regime. Deepening our understanding of the discourses helps to take an important source of pesticide regime (de)stabilization into account.

This paper thus explores the (de)legitimation of pesticides through a discursive lens. Focusing on the discursive dynamics surrounding pesticides, it untangles which topics were discussed and how certain storylines were used to delegitimize or (re-)legitimize pesticides and to support or oppose (radical versus incremental) reduction pathways. In addition, I discuss how the discursive struggles link to regime (de)stabilization. Two research questions orient the study: (1) How were pesticides discursively (de)legitimized; and (2) how does the discursive (de)legitimation of pesticides link to policy change and regime (de)stabilization?

Empirically, these questions are investigated with a study on the discourses surrounding pesticides in Switzerland. Public concerns about pesticides have provoked a highly controversial debate in the country, which led to and was reinforced by the launch of two popular initiatives.[1] The initiatives proposed the strict regulation of pesticides but were ultimately rejected at the voting poll.[2] Nevertheless, they have left a strong imprint on current pesticide policies (Finger, 2021), which makes the Swiss case an interesting one to study the links between discourses and policy change.

Because news media is a central arena of discourses (Markard et al., 2021), tracing the discourses in the news media allows capturing a broad array of actors participating in a political debate (Leifeld, 2013). However, this approach entails the key challenge of dealing with potentially large amounts of data. Utilizing such data becomes possible by building on advances in computational text analysis (e.g., Repo et al., 2021). In transition research, computational methods can be expected to be particularly useful when employed in combination with traditional methods such as discourse analysis (Savin and van den Bergh, 2021). The study at hand thus employs a mixed-methods approach consisting of structural topic modeling (Roberts et al., 2019) and argumentative discourse analysis (Hajer, 1995, 2006). Based on a large corpus of 2523 newspaper articles covering the mainstream and farming press, the paper tracks the public discourses about issues arising from the prevalent use of pesticides over roughly 11 years (from 2011 to early 2022) in the German language region of Switzerland.

The article makes three contributions to the literature. First, by systematically identifying the topics associated with pesticides, the key storylines and the discourse coalitions, the study offers a nuanced understanding of pesticide discourses in Switzerland. Second, examining the interplay between discourse, policy and regime changes yields insights into the role and the effects of discourse in low-pesticide transitions. These insights are relevant beyond the Swiss case for other countries in Europe as they strive to reduce pesticide use and transition to a more sustainable agricultural production. Third, the article enriches the methodological repertoire in transition

[1] Popular initiatives are a special feature of Switzerland's direct democratic system that allows citizens to develop and articulate a proposal to revise the federal constitution. Both popular initiatives proposed stricter pesticide policies. Whereas the first initiative, "For a Switzerland without artificial pesticides," aimed at banning all synthetic pesticides from agricultural and non-agricultural uses and banning all import of food produced with synthetic pesticides, the second initiative, "For clean drinking water and healthy food," wanted to strongly tighten the entry criteria for direct payments to farmers (i.e., the cross-compliance requirements) (Federal Chancellery, 2023). Signature collections started in 2016 and 2017, respectively, and easily reached the 100,000 required signatories, so that the initiatives were put to the vote of the Swiss people on June 13, 2021.

[2] See https://www.admin.ch/gov/en/start/documentation/votes/20210613/popular-initiative-for-clean-drinking-water-and-healthy-food.html and https://www.admin.ch/gov/en/start/documentation/votes/20210613/popula-initiative-for-a-switzerland-without-artificial-pesticides.html.

studies by illustrating the combined application of text mining techniques for analyzing a large dataset and argumentative discourse analysis to zoom into a subset of the data.

The following section presents the theoretical background to the study. Section 3 describes the mixed-methods approach adopted to identify topics, storylines and discourse coalitions. In Section 4, I present and discuss the results of the analyses. The conclusions in Section 5 highlight the interplay of discourse, policy changes and regime stabilization.

2. Theoretical background

This article builds on the literature on sustainability transitions. Sustainability transitions are long-term processes in which socio-technical systems such as agricultural production go through fundamental changes that are associated with sustainability targets (Markard et al., 2012). Typically, these targets are formulated by public policies and depend on the creation of legitimacy for focal technologies such as, in this case, pesticides. An important share of the process of creating or undermining legitimacy happens in the discursive space where struggles over technologies unfold. The (de)legitimation that may result from the discursive struggles is a source of (de)stabilizing change (Turnheim, 2022). Therefore, the paper examines two processes. First, it examines the process of pesticide (de)legitimation through a discursive lens. Second, it establishes a link between the discursive (de)legitimation and regime (de)stabilization processes.

2.1. Discursive struggles over pesticide legitimacy

Struggles over technology legitimacy can be intense and evolve around both novel and established technologies (Markard et al., 2021). Pesticides as an established agrochemical technology have become the target of fierce criticism in a wider debate around the unsustainability of modern agricultural production. Different actors join forces by building networks, alliances (Kishna et al., 2017; Musiolik et al., 2012) and discourse coalitions (Duygan et al., 2018). These coalitions mobilize a variety of strategies in order to create or undermine the legitimacy of the focal technology (Binz et al., 2016; Isoaho and Markard, 2020; Kishna et al., 2017). On the one side, there are calls for a more sustainable agriculture including the phasing-out of pesticides, ranging from single hazardous substances to the ban of all pesticides. To mobilize support for any kind of phase-out, an established technology such as pesticides first has to lose its legitimacy. Only if many actors question or reject the viability of the technology, there is a chance for phase-out to be passed and implemented (Markard et al., 2021). On the other side, to (re)gain legitimacy, pesticides need an integration with existing institutions (Geels and Verhees, 2011) and the acceptance or even active support by a broad range of societal actors (Rosenbloom, 2018).

A central arena in which these struggles over legitimacy and policy change unfold is public discourse. Discourse is broadly defined as "[…] particular ways of talking and thinking about an issue" (Geels and Verhees, 2011, p. 913). Central features of discourse, and its analysis, are narratives or storylines because facts often get told in a story (Hajer, 2006). Public discourse is widely accessible, unlike other arenas such as parliamentary debates (Leipprand et al., 2017). It is mediated through competitive public arenas such as the media. Media discourse represents a specific type of public discourse. Many different actors can share their views, for instance on a technology and the broader policy issue. At the same time, however, it is prone to bias as access to and dependance on media to achieve goals are not distributed equally among actors (Entman, 2007). In sum, these characteristics make public discourse in the media interesting for studying processes of (de-)legitimation (Markard et al., 2021).

In addition, different media types such as mainstream and alternative media function as discursive arenas for different audiences. Whereas the mainstream media audience includes virtually everyone, the audience of media such as farming newspapers is domain specific and, in this case, includes farmers and other farm actors who regularly use them to collect information on relevant agricultural topics (Defra 2019; Shimoda et al., 1992). The mainstream media present discourse from other media too but often in a highly selective and simplified way (Ferree, 2010). To better understand the details of the struggle around an agricultural issue such as pesticide use, it is therefore useful to study not only its coverage in the mainstream but also in the farming media.

In relation to policymaking, exchanges in the media happen in all stages, i.e., before, during and after formal policymaking processes. Studying struggles over legitimacy in public discourse is also crucial because policy and discourse are viewed as being mutually constitutive. Through discourse, where actors constantly position themselves toward policy issues, they contribute to the opening and closure of political space in which policies are debated and formulated (Yearley, 2005). In terms of policymaking, there are two aspects of interest here. First, the policy outcome, i.e., whether a policy change such as technology phase-out happens or not. Second, the policy processes and pathways for a phase-out, i.e., the details of the policy decision such as the pace and potential actor compensation. For policy processes, storylines are particularly relevant because those used by the seemingly unsuccessful coalition may become institutionalized as well, for example through their integration as part of a political compromise (Markard et al., 2021).

2.2. Regime (de)stabilization

Analyzing discursive struggles over legitimacy lends itself to exploring the link between the discourses, policy changes and regime (de)stabilization processes because these broader and external factors affect regime de(stabilization) (Johnstone and Stirling, 2015).

Regimes being the "grammar" behind certain configurations of socio-technical system elements (Frank and Schanz, 2022; Rip and Kemp, 1998) reflects the idea that formal and informal rules are not just carried mentally and shared in social groups but are highly institutionalized and embedded in infrastructures and practices (Fuenfschilling and Truffer, 2014; Geels, 2004). These rules mutually construct and are constructed by actors in a system. In these ways, the regime accounts for the stability of an existing socio-technical system (Geels, 2004; 2011).

The stability of an incumbent regime itself is often ascribed to phenomena such as lock-in and inertia (Turnheim, 2022). According to a slightly different conceptualization, it should rather be seen as the outcome of active resistance to fundamental change by incumbent actors. To actively resist change, incumbents utilize various forms of power (Geels, 2014). These include instrumental (e.g., a position of authority, access to media), material (e.g., technical capabilities, financial resources), institutional (e.g., political cultures, governance structures) and discursive forms. Discursive strategies used by regime actors include identifying and defining problems, promoting solutions to problems, and providing a rationale for action. These discursive strategies unfold their power when they culminate in dominant discourses that shape what and how issues are being discussed.

Destabilization of an incumbent regime can best be understood in relation to its role in a transition process. Building on the seminal multilevel perspective, a transition denotes the phase between two states of stabilized regimes. The weakening or destabilization of a regime has been conceptualized as a process where landscape pressures (e.g., eroding legitimacy) create problems for actors or businesses (e.g., decreasing support), which undermine their commitment to the existing regime (Turnheim and Geels, 2013). The actors may thus discontinue to reproduce core elements of the regime (Turnheim and Geels, 2013) such as developing active substances for pesticides in the case of the pesticide regime. As a response to external pressure, the incumbent regime may also adapt by integrating some of the critique (Levain et al., 2015), which leads to incremental changes in the socio-technical system.

The role of incremental change in processes of regime destabilization and transition is contested. In the sustainability transitions literature, a transition by definition implies a radical shift (Darnhofer, 2015). Some scholars highlight the problematics of incremental changes in transition politics (e.g., Simoens and Leipold, 2021), whereas others suggest that there is an interplay of incremental changes, e.g. in everyday practices, and disruptive changes (Huttunen and Oosterveer, 2017). Incremental change often takes place via the development of protected niches (Lazarevic and Valve, 2020), which are juxtaposed against regimes. It has been argued that cumulative incremental changes at niche level can represent one phase of a gradual destabilization of the incumbent regime (Turnheim and Geels, 2013) or instead result in its further stabilization, which in turn stabilizes the broader socio-technical system.

3. Materials and methods

This article uses a mixed-methods research design that integrates the strengths of inductive machine learning for a quantitative assessment of newspaper coverage (distant-reading) and a discursive approach for an in-depth qualitative analysis (close-reading). I apply this mixed-methods approach to a corpus of Swiss newspaper articles on pesticides.

3.1. Research case

Switzerland serves as the empirical case for investigating pesticide discourses. It is a highly relevant and instructional case for three main reasons. First, the country has early on invested in the promotion of a multifunctional, sustainable agriculture (Mann, 2018) and currently has one of the highest levels of agricultural subsidies in Europe[3] (Federal Office for Agriculture [FOAG], 2021). Second, nevertheless, the agricultural sector's pesticide use alone produces external costs that are estimated to range from 100 to 500 million Swiss francs per year (Guntern et al., 2021), which appear high in relation to the sector's gross value added of 4.1 billion Swiss francs (FOAG, 2021). Third, an increasing awareness of such imbalances may be one of the reasons for the extremely controversial societal debate about pesticides that the country has recently seen. This debate has led to the launch of two popular initiatives. Despite the Swiss idiosyncrasies, the case has many similarities with and implications for other countries. Pesticide pollution is a severe problem globally and has given rise to similar societal concerns and pressures in other countries as well.

3.2. Data sources and corpus creation

This study draws on newspaper data to examine the media coverage of pesticides. I chose two categories of newspapers as data sources. The first category entails the most-read daily mainstream newspapers including two tabloids (see Table 1) and is expected to cover the public discourses in the wider Swiss population. The second category comprises the most important farming newspapers to capture the discourses within the farming sector. This selection allowed tracking similarities and differences in the presumably audience-biased discourses of these media landscapes.

I collected a total of 3203 articles published over roughly 11 years (from January 2011 to mid-April 2022). This temporal scope was chosen because during those 11 years, pesticide issues became a major concern for the wider population and consequently gained political trajectory. Moreover, a number of changes to (inter)national pesticide policies were made (see Supplementary Data). Geographically, the collected data covers the German language region of Switzerland.[4] The articles were downloaded from the media database Swissdox Essentials[5] using the search terms "Pestizid* OR Pflanzenschutzmittel* OR Agrarinitiativ* OR Agrar-Initiativ* OR

[3] Agricultural subsidies amounted to 2.9 billion Swiss francs in 2021 (Federal Statistical Office, 2022).
[4] German was the main language spoken for 62% of Swiss inhabitants in 2021 (Federal Statistical Office, 2023).
[5] See https://essentials.swissdox.ch/.

Table 1
Descriptive statistics of newspaper data per source.

Newspaper type	Newspaper	Number of articles	Share [%]
Mainstream	Tagesanzeiger (print and online)	328	13.00
	Neue Zürcher Zeitung (print and online)	340	13.48
	20 minuten (print and online)	184	7.29
	Blick (print and online)	228	9.04
All mainstream		*1080*	*42.81*
Farming	Schweizer Bauer (print and online)	846	33.55
	BauernZeitung (only print available)	550	21.80
	Die Grüne (only print available)	47	1.86
All farming		*1443*	*57.21*
All		**2523**	**100**

Trinkwasserinitiativ* OR Trinkwasser-Initiativ* OR TWI OR 19.475″.[6] The search string yielded also duplicate and irrelevant articles. Applying the procedure described in the Supplementary Data, articles identified as duplicates or irrelevant were excluded from the dataset. After these preparatory steps, 2523 articles entered the analysis[7] (see Table 1 for descriptive statistics).

3.3. Analytical strategy and procedures

The analysis proceeded in two methodological steps. First, given the large amount of data available, I identified structural topic modeling (STM; Roberts et al., 2019) as a suitable tool for quantitatively assessing the entire corpus of 2523 collected newspaper articles. Second, I chose argumentative discourse analysis (ADA; Hajer, 1995, 2006) to zoom into a subset representative of the identified topics (10–15 articles per topic, i.e., approximately 10 % of the full dataset). The schema in Fig. 1 illustrates the interplay of the two methodological steps and additional analyses performed such as topic correlations. The two steps were used complementary and in approximately equal parts in the analysis. However, in the presentation of the results, those generated from ADA make up a larger part of the section owing to their qualitative nature.

3.3.1. Structural topic modeling

Topic modeling is an automated approach to assess the content of large datasets. It uses natural language processing techniques to make human language machine-readable. For text classification, topic models such as STM can use unsupervised machine learning where no pre-existing categories of text are fed into the model; instead, the algorithm defines categories for the underlying text (e.g., Blei and Lafferty, 2007). STM is an innovative probabilistic mixed membership model in the tradition of the latent Dirichlet allocation (Blei et al., 2003). It has become a popular method for example for modeling the framing of newspapers (e.g., Dehler-Holland et al., 2022). The key innovation of STM is "[…] that it permits users to incorporate arbitrary metadata, defined as information about each document, into the topic model" (Roberts et al., 2019, p. 1), such as, in this case, publication date and document source. In doing so, information from these covariates were leveraged to trace the dynamics of the topics discussed over time, the differences in topic coverage between the mainstream and farming newspapers, and the association of the topics' prevalence with the mainstream versus the farming newspapers. The automated content analysis performed required various steps to clean and pre-process the data, select an optimal number of topics, choose a final model and validate this model. A detailed description of these steps is provided in the Supplementary Data.

3.3.2. Argumentative discourse analysis

ADA lends itself well to analyzing the use of language in political processes through an argumentative lens (Markard et al., 2021) and has been usefully employed by a number of recent contributions to sustainability transitions (e.g., Ampe et al., 2020; Isoaho and Markard, 2020; Lowes et al., 2020; Markard et al., 2021; Rosenbloom et al., 2016; Rosenbloom, 2018). Two key concepts in ADA are storylines and discourse coalitions. First, because statements often have the form of a narrative, storyline refers to a condensed statement that summarizes complex narratives and is used by people as "shorthand" in discussions. Second, discourse coalition refers to "[…] the ensemble of a set of story lines, the actors that utter these story lines, and the practices through which these story lines get expressed" (Hajer, 2006, p. 70). In the second methodological step of this study, I systematically examine the narrative patterns, i.e.,

[6] This translates to "Pesticid* OR Plant protection product* OR Agriculture initiativ* OR Agriculture-Initiativ* OR Drinking water initiativ* OR Drinking water-Initiativ* OR TWI OR 19.475". Note that TWI refers to "Trinkwasserinitiave" (Drinking water initiative) and 19.475 refers to the parliamentary initiative 19.475 "Das Risiko beim Einsatz von Pestiziden reduzieren" (Reducing the risk of pesticide use), which was the unofficial counterproposal to the two pesticide initiatives.

[7] Note: The dataset consists of unequal numbers of articles from the two landscapes (1,080 from mainstream, 1,443 from farming press). Thus, a direct comparison of the frequency of coverage in the mainstream versus the farming press will yield limited insight. In addition, articles from BauernZeitung and Die Grüne were only available in the database from 2019 onwards, so that the only farming media included in the corpus prior to 2019 is Schweizer Bauer. This influences the reversal of the ratio between mainstream and farming press coverage from 2019 on as depicted in Fig. 2. The potential influence on the results that the sudden appearance of articles from BauernZeitung and Die Grüne in the dataset in 2019 has was assessed; this is reported as robustness check in section 4.1 and in the Supplementary Data.

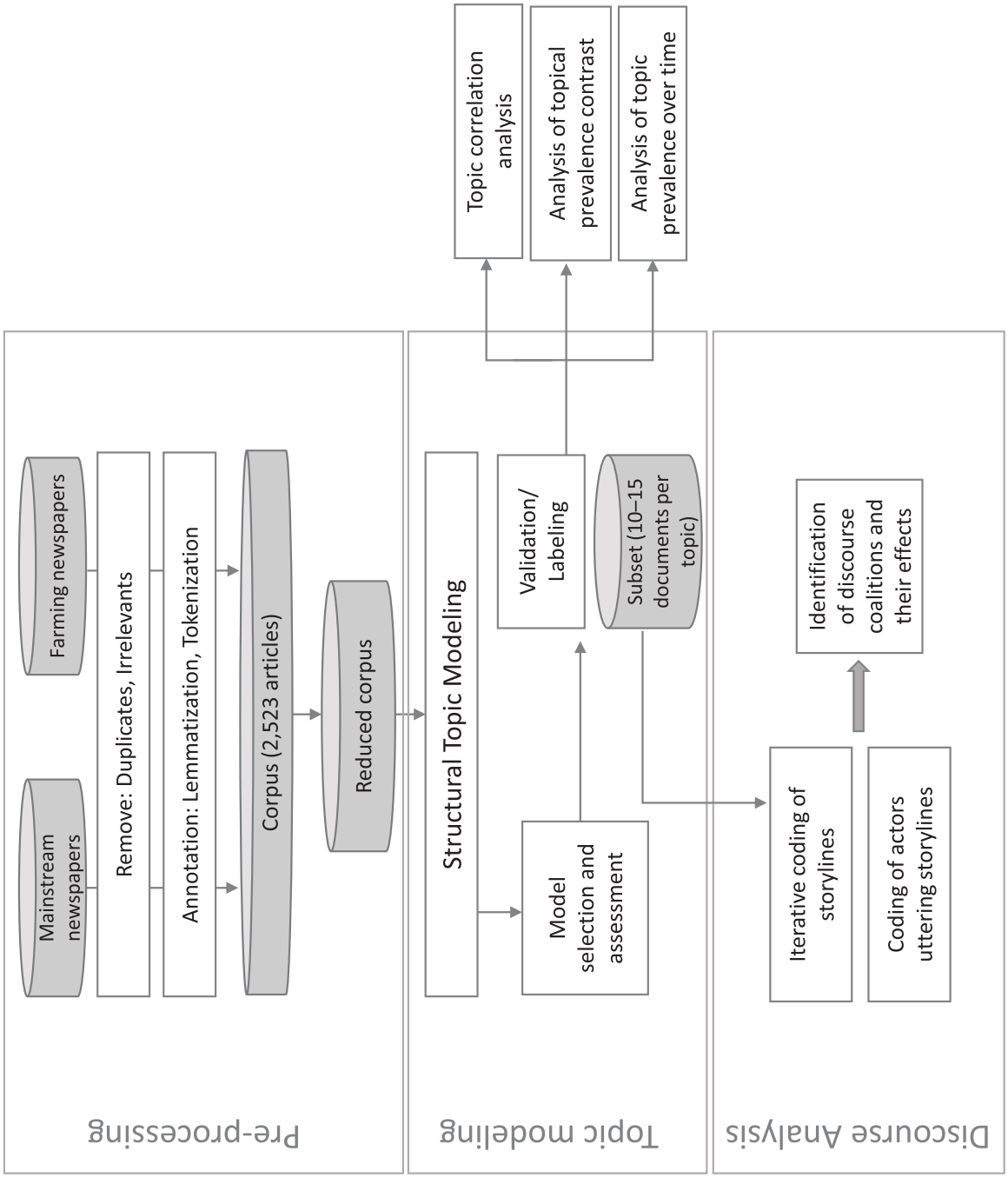

Fig. 1. Schematic representation of pre-processing, modeling, text and discourse analysis steps. Own illustration based on Dehler-Holland et al. (2022).

which storylines were used and by whom. To do so, I use the subsample of the most representative 10–15 articles per topic that has been used to validate the model from STM and to label the topics in the previous step. Details on the qualitative coding procedure are provided in the Supplementary Data.

4. Results and discussion

Starting with the descriptive presentation of the frequency of media articles in the mainstream and the farming press, I also discuss key events and identify different phases of the pesticide debate. Next, I present and briefly discuss the results from topic modeling in Section 4.1 and the identified main storylines and discourse coalitions in Section 4.2. Section 4.3 further interprets the findings on the discursive (de)legitimation of pesticides by linking them to policy changes and the (de)stabilization of the incumbent pesticide regime. In Section 4.4, I outline limitations and directions for further research.

The period of analysis can be divided into three phases, 2011/2013 to 2017, 2018 to mid-2021, and post-2021. I used major political and other real-world events to distinguish these phases, which I explain in more detail below. Fig. 2 provides an overview of the three phases, the key events (see also Supplementary Data) and the frequency of articles published in the two newspaper landscapes.

In phase 1 (2011/2013 to 2017), the societal debate about pesticides slowly emerged. During this time, a few external events such as the publication of international reports (International Agency for Research on Cancer, 2015a; 2015b; World Health Organization and Food and Agriculture Organization of the United Nations, 2016a; 2016b) stimulated the media coverage of pesticides. In Switzerland, the emerging societal concerns are likely to have contributed to the launch of the two popular initiatives aiming to restrict pesticide use (cf. Schaub et al., 2020), for which signatures were collected in 2016 and 2017.

Phase 2 (2018 to mid-2021) was marked by the submission of the two Swiss popular initiatives in the first half of the year 2018. The societal debate thus gained trajectory and was increased by the campaigning around the initiatives (Finger, 2021). Accordingly, a strong increase in coverage of pesticides in both media landscapes can be observed. This observation is in line with the societal concerns tracked by Schaub et al. (2020) using Google Trends data but is likely also influenced by the keywords used which included the names of the initiatives. In 2021, when the referenda were held, the coverage in both media landscapes reached a peak.

In phase 3, the post-vote phase from mid-2021 onwards, the data collected for this analysis does not allow identifying a clear pattern. Nevertheless, it hints towards a strong decrease of coverage in the mainstream press, whereas the farming press seems to have kept reporting on it rather much. This seems plausible because the consequences of the policy outcome (i.e., a pesticide reduction path) are heavily discussed within the farming sector, whereas for the broader population, this is no longer a topic of high relevance or the issue is deemed settled.

4.1. Topics

The estimation of a model with 21 topics resulted in 19 interpretable and hence labeled topics, ranging from agricultural subsectors (e.g., viticulture, fruit and vegetable cultivation), political aspects (e.g., federal politics and parliament, referendum campaigns, rural–urban gap in voting behavior) and actors (e.g., agrochemical industry, farmers' associations) to environmental aspects (e.g., biodiversity, groundwater pollution), the farming sector's remedies (e.g., water protection compliance, precision farming) and social aspects (e.g., farmers and society) (Table 2).

The topic correlation graph (Fig. 3) yields insights about the relationships between the identified topics. Positive correlations between topics indicate that these topics are likely to be discussed within the same document (Roberts et al., 2019). Four thematic clusters are particularly noticeable in the newspaper coverage of pesticides. The associated topics address *environmental aspects, water issues*, the *farming sector's remedies (practices to reduce pesticide use and risks)*, and *political issues.*

Next, by examining the contrast between topical prevalence for the two groups (mainstream and farming press), it becomes evident that certain topics were much more discussed in one newspaper type versus the other (Fig. 4). Topics #1, 2 and 3 (cluster *farming sector's remedies*) as well as topics #4 (farmers and society), #17 (farmers' associations) and #19 (fruit and vegetable cultivation) were strongly covered by farming newspapers compared with mainstream newspapers. On the contrary, the topics #9, 12 and 15, which concern environmental aspects and more precisely the toxicity and risks associated with pesticides, and #6 and 21 (cluster *water issues*) were more strongly discussed in the mainstream than in the farming newspapers. Similarly, the mainstream press covered political aspects (topics #5, 10, 14) more heavily. Topics #13 (vertical farming) and #18 (bee mortality) are close to the middle but still mainstream press–leaning, whereas the inverse is the case for topics #7 and 16, which concern agricultural subsectors, and for topic #20 (agricultural policy). The latter are relatively close to the middle but still farming press–leaning.

Overall, a rather clear pattern of how differently pesticides were discussed in the mainstream and in the farming press became visible. It appears that the mainstream press focused more on topics related to pollution through and harmfulness of pesticides, whereas the farming press strongly covered remedies and solutions by the farming sector. These results remained largely stable when checking for bias stemming from the construction of the dataset (i.e. availability of articles from BauernZeitung and Die Grüne only from 2019 on; see details in the Supplementary Data). However, it can be assumed that the two media landscapes analyzed use different vocabulary when discussing highly domain specific topics. Using the topic *Alternative crop protection* as an example, I therefore examined the influence of a topical content covariate. This allows for the vocabulary used to talk about a particular topic to vary (Roberts et al., 2019). Indeed, this showed that the farming press used vocabulary associated with agronomical (non-technical) alternatives to pesticides, whereas in the fewer reports on the topic by the mainstream press, reference was made to technological solutions such as gene technology and drones. The word lists and additional details are provided in the Supplementary Data.

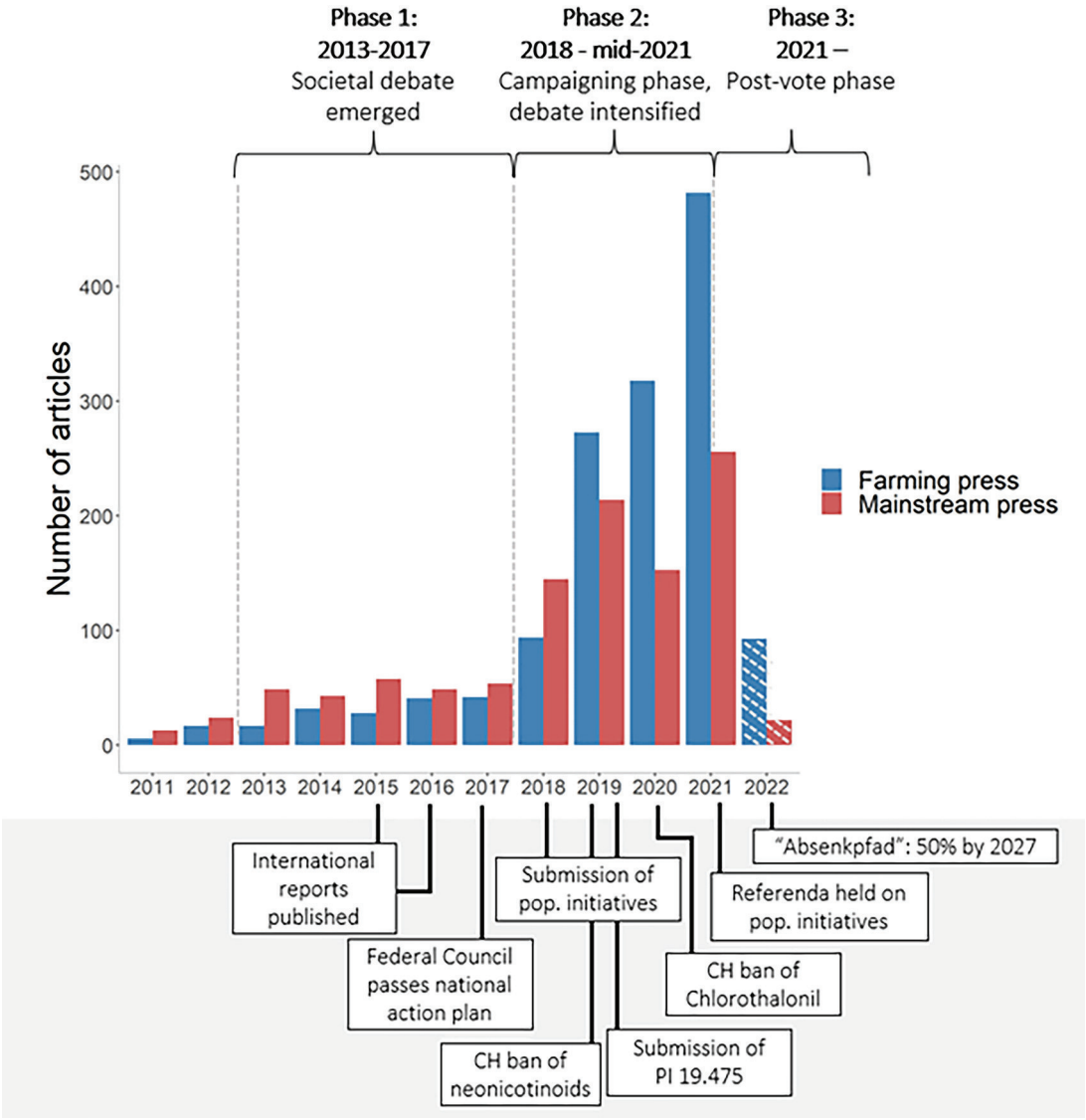

Fig. 2. Phases, key events and frequency of media articles in mainstream and farming press. The bar for 2022 is shaded because it only covers articles until mid-April 2022.

4.2. Storylines and discourse coalitions

Using ADA, the discourses were categorized in terms of six main contending storylines, which framed pesticides and their use in agriculture either as polluting water (D1), threatening other species or biodiversity (D2), posing risks to human health (D3), complying with water protection regulations (L1), being reduced by farmers' alternative crop protection techniques that are in development or implementation (L2), or technology as a solution (for reducing pesticide use) (L3). These storylines relate to the topics identified through STM and form two sets, a delegitimizing (D) and a (re)legitimizing (L) set of storylines (following Rosenbloom, 2018) (see Table 3).

The dynamics of the storylines over time can be traced approximatively by looking at the prevalence over time of the topics that are associated with each storyline (Fig. 5). Discourse coalitions are analyzed by furthermore including the actors that utter these storylines (Hajer, 2006). Overall, the topics associated with delegitimizing storylines were more prevalent in the mainstream press, whereas topics associated with (re)legitimizing storylines were predominant in the farming press. In the following, I integrate results from STM and ADA to present the discursive patterns evident in the newspaper coverage.

4.2.1. Delegitimizing storylines and discourse coalitions

The delegitimizing storyline *(D1) Pesticides pollute water* was used as a shorthand to refer to issues with surface water quality and

Table 2
Topic labels and prevalence.

#	Topic label	Prevalence [%]
7	Viticulture	3.09
19	Fruit and vegetable cultivation	5.01
16	Arboriculture and forest management	3.97
5	Referendum campaigns	7.39
14	Rural–urban gap in voting behavior	4.32
17	Farmers' associations	7.55
20	Federal agricultural policy(making)	4.64
10	Federal politics and parliament	4.69
15	Human health risks of pesticides	4.19
18	Bee mortality	2.66
9	Agrochemical industry	4.60
12	Biodiversity	4.15
6	Groundwater pollution through pesticide residues	4.38
21	Surface water quality	3.75
1	Alternative cultivation techniques and weed management in arable farming	5.81
2	Precision farming	4.96
3	Water protection compliance in agriculture	5.11
4	Farmers and (the non-farming) society	6.63
13	Vertical farming	4.93
8	*Not interpretable*	4.27
11	*Not interpretable*	3.40

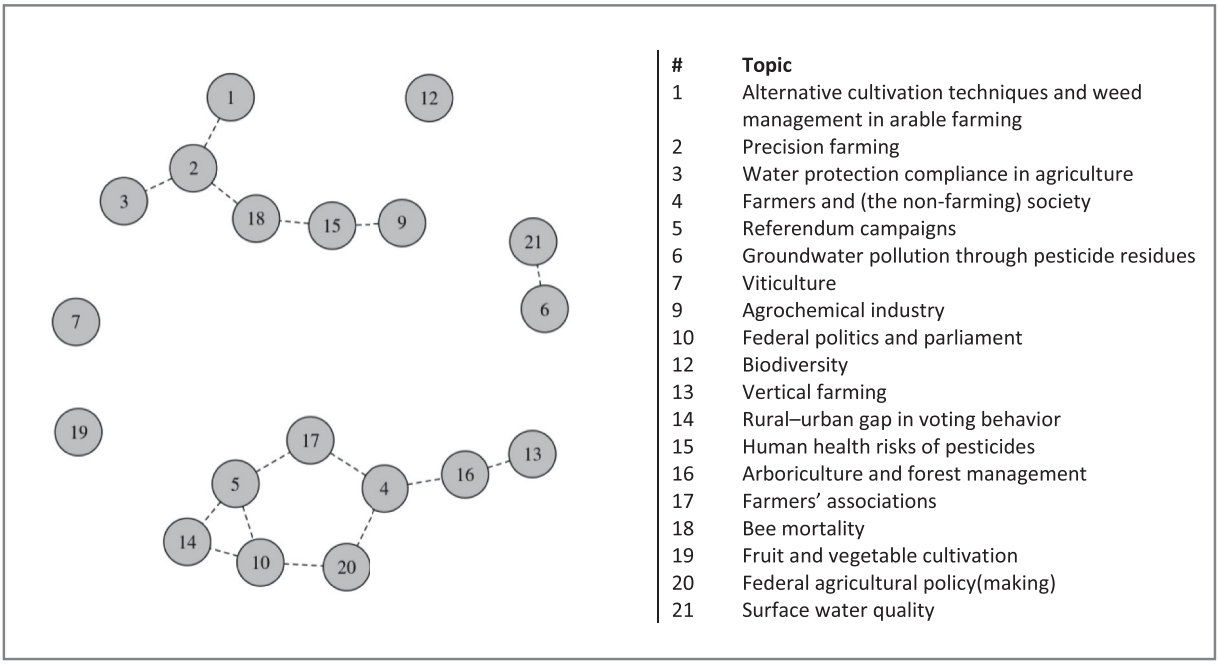

Fig. 3. Topic correlation graph.

groundwater pollution. Surface water quality issues were more prevalent in the first years of the period covered by this study, i.e., until 2017/2018, and then declined. Immediately before the vote on the pesticide initiatives in 2021, the topic of groundwater pollution clearly dominated, with a peak in 2020, but only in the mainstream press; in the farming press the topic achieved only a slight increase at that time and otherwise was never covered much. The main actors that uttered the *Pesticides pollute water* storyline were the federal and cantonal offices for the environment as well as for food safety, municipalities, water suppliers and non-governmental organizations (NGOs), who reported on cases of detected pesticide metabolites that exceeded the legal thresholds in ground- and surface waters. These threshold exceedings were predominantly caused by residues of chlorothalonil, a fungicide that was banned first in the EU in 2020 and slightly thereafter also in Switzerland. One narrative invoked by this storyline was also that certain municipalities and environmental offices of the cantons downplayed or concealed measurement results; another emphasized that measurements were taken at the level of groundwater which did not mean that the drinking water was affected as well.

Related to storyline *(D2) Pesticides threaten other species or biodiversity* were the topics of bee mortality and biodiversity. Bee

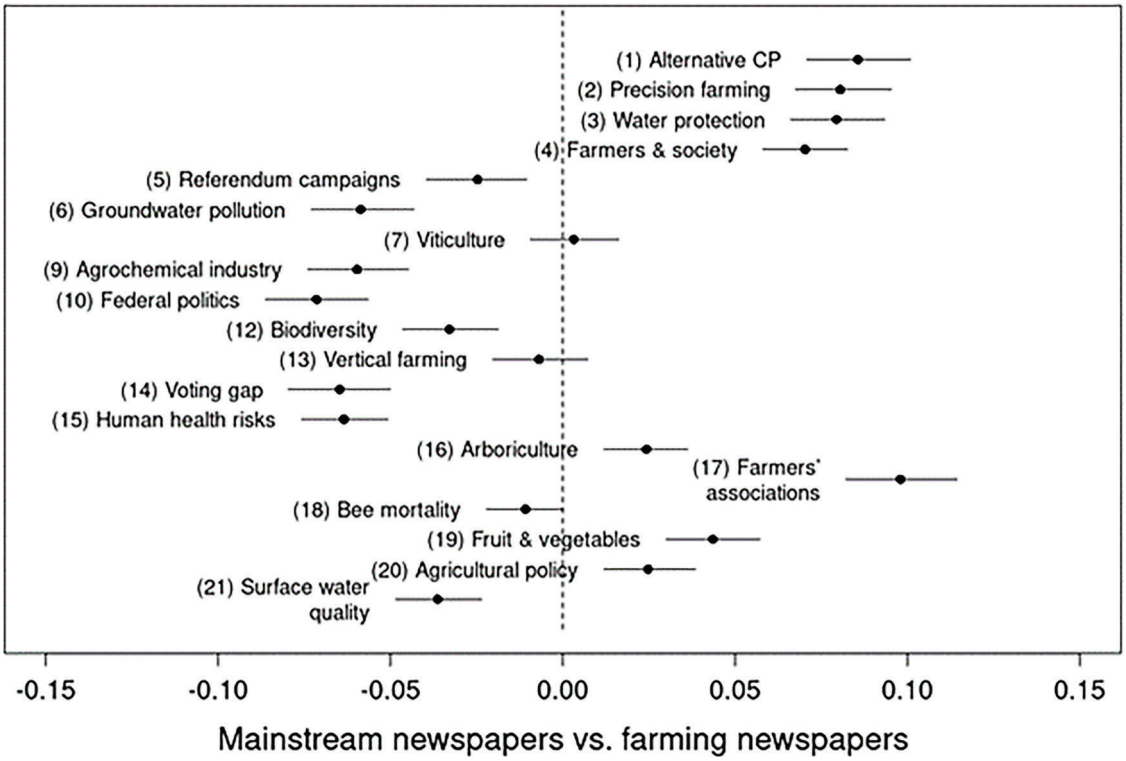

Fig. 4. Topical prevalence contrast, i.e., association of topic prevalence with mainstream versus farming press. The variable newspaper type has been used to calculate the association.[8] The x-axis indicates the change in topic proportion shifting from one newspaper type to the other.

mortality was a relatively prevalent topic in the mainstream press in 2013–2014, after which its coverage declined. Biodiversity was strongly covered by the mainstream press in 2017–2018, then its coverage declined a bit and saw two smaller spikes in mid-2020 and mid-2021 (the latter coincided with the time when the referenda were held). Biodiversity was heavily covered in early 2022 when its prevalence reached up to 40 %. In the farming press, both topics never seemed important. The actor groups that employed this storyline were scientists, environmental NGOs and the federal and cantonal offices for the environment.

The storyline *(D3) Pesticides pose risks to human health* and the associated topic gained prominence in the mainstream press in 2019. Interestingly, the topic coverage declined sharply in 2021, right at the time of the referenda, to then spike again end of 2021. The broader narratives addressed with this storyline relate to pesticide residues found in urine samples, increased cancer risk, and effects on human sperm quality. Scientists, EU authorities and certain Swiss authorities (i.e., the Federal Food Safety and Veterinary Office and the Cantonal Department of Health) were the main actor groups that appeared together with this storyline, to a lower degree also the World Health Organization, NGOs and consumer protection organizations.

In summary, the analysis of the discursive dynamics of the set of delegitimizing storylines reveals that the storylines served as devices to argue for rapid and radical change, implemented top-down. These storylines created a sense of urgency, and they positioned the general public and the environment as victims of pesticide pollution while mainly blaming farmers and the insufficient pesticide regulation. The coalition that formed around this argumentation was made up of many non-regime actors such as (environmental) NGOs, water suppliers, municipalities, federal and cantonal offices for the environment as well as those for health and food safety, environmental and medical scientists, and the World Health Organization.

4.2.2. (Re)Legitimizing storylines and discourse coalitions

The (re)legitimizing storylines found, respectively the topics associated with these, appeared to be more prevalent in the farming press (Fig. 5) than in the mainstream press. An additional close-reading of a randomly selected sample of articles (as opposed to the prior used most representative articles per topic) from the mainstream press revealed, however, that (re)legitimizing storylines were also prevalent here. In particular, the storylines of *Technology as a solution* and *Alternative crop protection* were taken up by some articles in the mainstream press.

The first legitimizing storyline *(L1) Water protection compliance* invoked the narrative of farmers who are being sensitized to water protection and a control and monitoring system as well as water protection programs that are in place. The associated topic gained

[8] For this, I re-estimated the model to allow topic prevalence to be a function of newspaper type, instead of newspaper, and a spline of the publication date (the latter is held at sample median for the effect estimation).

Table 3
Contending storylines surrounding pesticides.

Set of storylines	Storyline	Illustrative example	Related to topic	
Delegitimizing storylines: **Pesticide pollution** *Pesticides pollute the environment, harm human health, and threaten other species*	**(D1) Pesticides pollute water** *Thresholds for pesticide residues in ground- and surface water are regularly exceeded*	"The uproar was immense when the Federal Office for the Environment published its report on the quality of groundwater in Switzerland: Chemical substances from agriculture were causing 'widespread and lasting' damage to the water, especially in the Central Plateau, it said a fortnight ago."	#6 #21	Groundwater pollution through pesticide residues Surface water quality
	(D2) Pesticides threaten other species or biodiversity *Insect and bird populations are in sharp decline, and the intensive agricultural production including pesticide use is a main driver of this decline*	"The scientists' conclusion is clear: 'If we do not change the way we produce food, insects will have gone down the path of extinction in a few decades,' says the article that will appear in the forthcoming issue of the journal Biological Conservation."	#12 #18	Biodiversity Bee mortality
	(D3) Pesticides pose risks to human health *Pesticides are suspected of being carcinogenic and damaging to fertility; there is no clear evidence of the harmfulness or harmlessness of pesticide residues found in the human body*	"Pesticides as possible trigger: Children in the Seeland Region are exposed to increased brain tumor risk. Bernese researchers found that the risk of brain tumors among children in the Seeland Region is higher than in other parts of Switzerland. However, the reasons for this have not yet been proven."	#15	Human health risks of pesticides
Legitimizing storylines: **Farming sector's remedies and reduction efforts** *The farming sector exerts all kinds of efforts to reduce pesticide use (risks), but pesticides are still needed to produce and secure yields*	**(L1) Water protection compliance** *Control and monitoring system, and programs or projects are in place, farmers are being sensitized for water protection*	"After the polluters at the Äächeli had been made aware of this, further measurements were performed, which showed that the values were improving. This shows that the sensitization is working as a measure, explains the expert." "In order to make reliable statements about the effect of a reduced use of plant protection products on water quality, further years of measurements are necessary, the Office for Agriculture and Nature (Lanat) informs. An important part of the Berne plant protection project is water monitoring."	#3	Water protection compliance in agriculture
	(L2) Alternative crop protection techniques in development or implementation *Farmers already develop and implement alternative crop protection techniques, but pesticides need to be part of the toolbox; reduction targets have to be moderate*	"The LBBZ Schluechthof estate will invest in the mechanization of weed control. This is done to meet society's demand for the reduction of plant protection products, writes the LBBZ." "Protect without harming." "I have nothing against plant protection products. They help to secure our yields. That's why I'm glad we can resort to them."	#1	Alternative cultivation techniques and weed management in arable farming
	(L3) Technology as a solution *Technology can optimize crop protection and reduce (excess) pesticide use; this needs training and advisory services*	"Digital technologies have great potential to reduce the use of crop protection products." "Around 60 […] farms are participating in the five-year resource project of the Federal Office for Agriculture. With resource-saving and very precise technologies, at least 25 percent of plant protection products are to be saved."	#2	Precision farming

prominence from 2014 on and spiked in mid-2021. Actors using this storyline included the federal and the cantonal offices for agriculture, the cantonal offices for the environment, and to a lower extent also farmers.

The narrative of farmers who already develop and implement alternative crop protection techniques but need pesticides to be part of the crop protection toolbox was invoked by storyline *(L2) Alternative crop protection techniques in development or implementation*. The topic that is contained in this storyline has been moderately covered by the farming press over the complete time span analyzed. Two peaks are visible in mid-2020 and mid-2021. The storyline has mainly been employed by farmers and agricultural advisors, extension and training centers, and by the federal and cantonal offices for agriculture. They stressed that they "are already on the way," searching and developing alternatives to chemical pesticides, also because they feel obliged owing to the societal pressure and future phase-outs of certain pesticides or active ingredients. Moreover, they emphasized that damage thresholds are respected and that only necessary

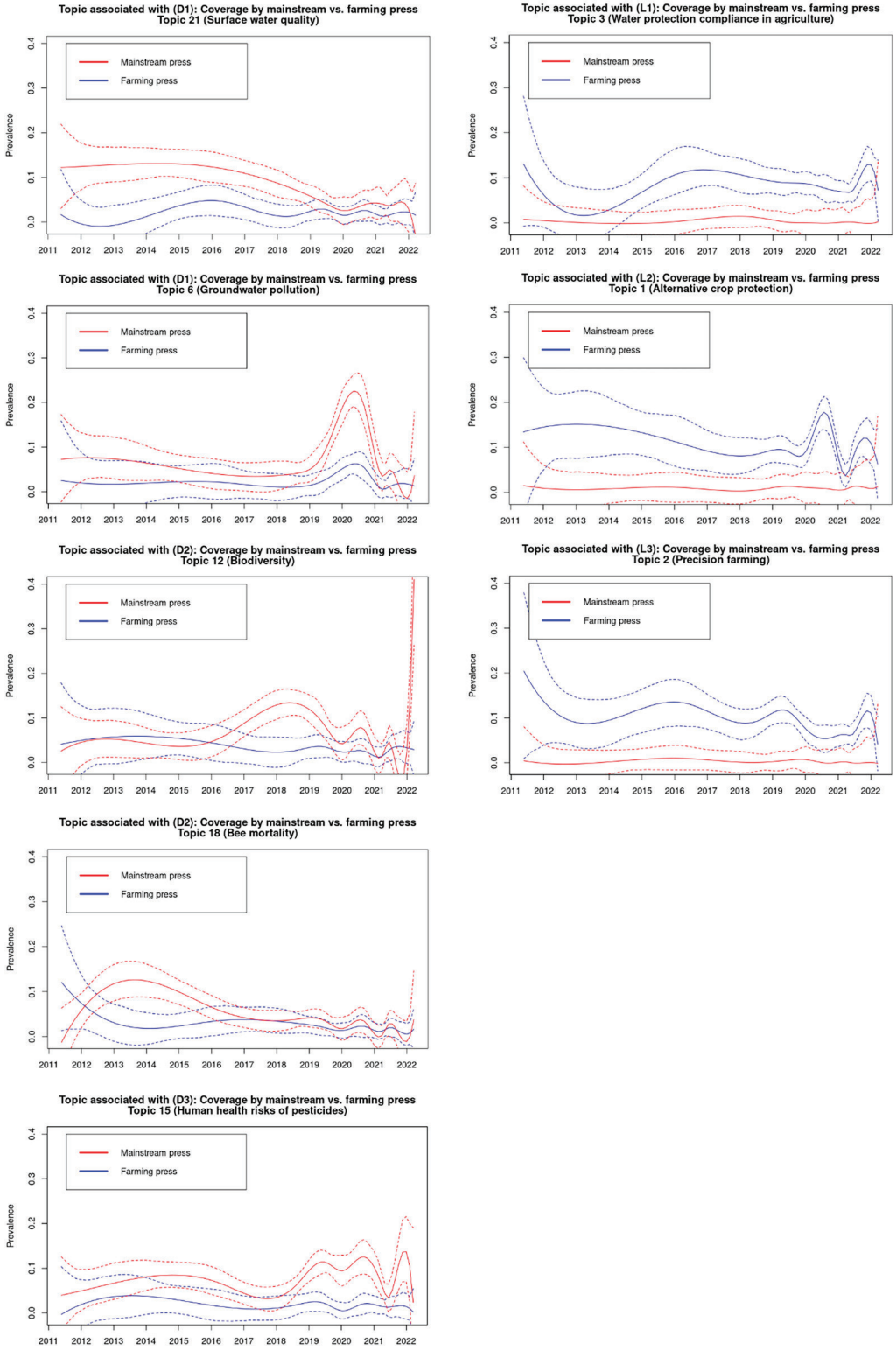

Fig. 5. Coverage of key pesticide topics associated with storylines, comparison of mainstream versus farming press, 2011–2022. The plots are based on a model that allows for an interaction between time (publication date of newspaper article) and newspaper type (mainstream versus farming press). Here, newspaper type moderates the effect of topical prevalence at a given time. The prevalence of the topic(s) associated with each identified storyline is plotted as smooth function (using a spline) of time. The dotted lines depict model uncertainty (95 % confidence intervals).

crop protection treatments are performed. Frequently, it was also pointed out that the effects of alternative crop protection on yields must be taken into account.

The third storyline with which a (re)legitimation of pesticides was attempted is *(L3) Technology as a solution.* The topic of precision farming has always been moderately covered in the faming press. Periodically, it showed slight ups and downs with spikes in 2016, 2019 and end of 2021/early 2022. Agricultural advisors, extension and training centers, agri-businesses as well as the federal and the cantonal offices for agriculture were the main actors that relied on this storyline to promote the optimization of crop protection through technology. The two core statements were, first, that technology helps to reduce (excess) pesticide use and, second, that farmers need access to technology training and advisory services in order to be able to adopt new technologies.

Overall, the findings concerning these storylines point to their use as devices to (re)legitimize a large share of pesticide use. They were thus also used to argue against rapid change and stricter pesticide regulation, proposing instead incremental (and voluntary) changes that would not put too much of farmers' yields at risk. The farmers and other farm actors were positioned as problem solvers that can best take care of the externalities of pesticide use and should alone be in charge to steer the change. This became for example evident in narratives about them (striving towards) displaying responsible behavior, despite being scapegoated by the public, vowing improvements and referring to the improvements already made (i.e., risk prevention and pesticide use reduction). It has been argued in the literature that through this kind of integration of critique into the pesticide regime, the regime seeks to restabilize (Levain et al., 2015). The actors that coalesced around this set of storylines included many pesticide regime actors, i.e., farmers, farmers' associations, agricultural advisors and extension services, agri-business/industry, the federal and the cantonal offices for agriculture, and (engineering) scientists. The next section therefore moves on to discuss the links between the discursively (de)constructed pesticide legitimacy, policy changes and regime (de)stabilization.

4.3. Discursive pesticide (de)legitimation, policy change and regime (de)stabilization

In addition to the results obtained through the analyses, this section adds a discussion of the changes made in pesticide policy. It then links the findings on the discursive (de)legitimation of pesticides to these policy changes and further interprets them in relation to a (de)stabilization of the incumbent pesticide regime.

The mutually constitutive nature of policy and discourse is observable in the empirical case of this article. Stricter pesticide regulation as proposed by the Swiss popular initiatives was rejected, but the discourses that presumably led to the launch of the initiatives and that spurred the debate, particularly during the campaign phase, contributed to the opening of a political space in which policies were debated and formulated.

The main policy change that occurred during the study period is the formulation of policy targets and their implementation through a package of ordinances (FOAG, 2023). A reduction path has been engrained in the federal legislation (through an amendment of the agricultural act), aiming to reduce the risks associated with the use of pesticides by 50 % by 2027.[9] This aim represents a quantified risk reduction target, but not a use reduction target. Use reduction is only being implemented for pesticides with increased risk potential. These may, after an amendment of the direct payment regulation, no longer be used by farmers fulfilling the cross-compliance requirements. In addition, measures against pesticide run-off and drift are made mandatory for farmers qualifying for direct payments.

A reduction path like the one adopted was the unofficial counterproposal (in the form of a parliamentary initiative, PI 19.475 "Reducing the risk of pesticide use"[10]) to the pesticide initiatives. The seemingly unsuccessful delegitimizing discourse coalition has been successful in institutionalizing their pollution storylines to a certain degree. The political compromise struck is an outcome of the legitimizing coalition's reaction to the delegitimizing storylines. For example, the (D1) *water pollution* storyline was countered by the (L1) storyline of *water protection compliance,* which integrated the critique by proposing or highlighting measures against pesticide run-off and drift.

Further examples for how storylines became integrated in the policy outcomes can be observed. One measure put in place is investment support for farmers to adopt new technologies (Finger, 2021). This measure aligns very well with storyline (L3), which promoted *technology as a solution.* The development of public and private pilot projects, which also heavily focus on technology adoption, and new direct payment programs align with storyline *(L2) Alternative crop protection techniques in development or implementation*, which was in addition used to advocate for moderate reduction targets.

In summary, the formulated targets are a compromise and a step forward. However, they mainly concern the reduction of pesticide risks and not of absolute pesticide use. Moreover, no binding policy instruments have been introduced, apart from the tightening of cross-compliance requirements that farmers must fulfill to be eligible for receiving direct payments. Just like the ban of single substances, this strategy lacks the ambition to change the overall functioning of conventional agriculture, which has frequently been observed by other scholars (Levain et al., 2015; Maguire and Hardy, 2009). It must thus be evaluated as incremental and not fundamental change.

The current Swiss pesticide policy is similar to the EU's policy. However, in the EU's Farm to Fork Strategy (European Commission, 2020), the targets are more ambitious in the sense that they include the reduction of quantitative pesticide use as well.[11] Thus, in EU policy strategies, there are signs of a paradigm shift, from a risk reduction approach to a generic quantitative reduction approach. This

[9] The reference period is 2012–2015.

[10] See https://www.parlament.ch/de/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20190475.

[11] The targets under the EU's Farm to Fork Strategy are "to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030" (European Commission, 2020, p. 9).

has been interpreted as a shift towards systemic change and as a case of destabilization governance (Frank and Schanz, 2022). However, because there are also no binding policy instruments, as observed by Frank and Schanz (2022), "[…] pesticide use is reined in through a gradual tightening of regulations within the risk reduction paradigm, such as selective local application bans" (p. 253).

Concerning the Swiss pesticide regime, the discourses identified and the incremental policy change described point to an opening-up of the regime, although without amounting to a serious destabilization at any point of the discursive and political struggle. The key components of the regime, for example food production based on supplies by the agri-industry and food distribution through retail, remained unaffected. This finding corroborates the conclusion by Frank and Schanz (2022) that policy change does not necessarily amount to successful socio-technical regime change. Through the integration of some of the critique, as evident in the storylines mainly employed by the coalition around the incumbent actors and in the compromise struck in the form of a reduction path, the socio-technical regime likely managed to further stabilize.

There are two further mechanisms that probably aided the regime in stabilizing. First, the singularization process of phasing-out a few "dirty ones" in order to protect the whole (Levain et al., 2015), which in this case were the bans of neonicotinoids in 2019 and chlorothalonil in 2020. The problematization of certain aspects of pesticide use, such as water pollution through chlorothalonil residues, offered a possibility to un-tie this element from the regime. Second, a substitution effect (Levain et al., 2015) for agri-businesses that were able to open a substitution line of precision farming technologies and biocontrol products (Klerkx and Rose, 2020). The strong policy focus on such innovations may serve to protect existing regimes by detracting attention from the actual pesticide use problem (Geels, 2014).

The discourse coalition of policymakers and administration (here, federal and cantonal offices for agriculture with their associated agricultural extension centers) and incumbent firms (here, the agri-tech industry) is particularly powerful in dominating the public discourse (Lindblom, 2008) and in discursively resisting fundamental change because of the actors' positions and media access (Geels, 2014). A key consequence of these mechanisms is that by the management of incremental change, the incumbent socio-technical regime can claim its efficiency and responsibility, thereby reinforcing regime credibility and likely achieving a stabilization in the long term (Levain et al., 2015).

4.4. Limitations and directions for further research

A first limitation of the discursive analysis performed in this study is that it relied on a single data source, newspaper articles. Thus, other arenas (e.g., social media, street protests) and more covert arenas (e.g., town halls) where discursive struggles unfold may not be adequately represented. However, a focus on the media is warranted as it plays a central role in how people perceive and discuss technologies and policy (Delshad and Raymond, 2013). Further research might include other discursive arenas and for example compare insights from traditional and new media channels (Stutzer et al., 2021) .

Second, only articles in German are included in this study's database because analyzing a multilingual corpus poses several challenges that can only be addressed with sophisticated corpus linguistics. Because this study pursues a substantive rather than a linguistic interest, applying advanced corpus linguistics was beyond the scope of this research.

Third, the rather distinct categorization of newspapers into mainstream and farming newspapers inevitably lead to a disregard of internal differences in the two categories. The analysis could thus be expanded upon by a more finetuned analysis at the level of the individual newspapers instead of the two broad categories. A similar limitation applies to the use of topics as a reflection of storylines when analyzing their development over time (cf. Fig. 5). Here, the model does not seem to capture the (re)legitimizing voices in the mainstream press appropriately, nor does the linking of topics with storylines allow this. Only close-reading of a randomly selected sample of mainstream articles elucidated how (re)legitimizing storylines were also prevalent in the mainstream press.

Fourth, this paper deviates somewhat from traditional ADA that includes other steps (e.g., conducting interviews with key actors) and that places discourse coalitions more in the center of the analysis. Hence, future research could focus more on pesticide discourse coalitions, e.g., by using discourse network analysis to study how discourse coalitions, and the storylines they mobilize, change over time (Markard et al., 2021).

Fifth, because the (de)stabilization process of the pesticide regime is an ongoing one, the present empirical study cannot cover this process from beginning to end, and thus the link between discourses and regime changes is expected to remain somewhat tenuous (cf. Frank and Schanz, 2022).

Finally, an important topic for future research is to better understand not just regime resistance and stabilization but also instances of past destabilization and decline of incumbent agricultural regimes.

5. Conclusion

Through the combined application of computational text analysis and argumentative discourse analysis on a large corpus of 2523 newspaper articles ranging from 2011 to 2022, this study provides a nuanced understanding of current pesticide discourses in Switzerland. The analysis revealed that two broad, distinct discourse coalitions competed over pesticide legitimacy. Many non-regime actors coalesced around delegitimizing storylines that sought to induce rapid and radical change in pesticide regulation, as proposed by two popular initiatives. Legitimizing storylines were employed by actors of the pesticide regime and were used to advocate for incremental and voluntary measures that would not change the overall logic of conventional agriculture in any way.

This paper contributes to the literature on the role and the effects of discourse in agricultural transition processes. It has shown that although the delegitimizing coalition has not been successful with its proposals, its undermining of pesticide legitimacy has likely contributed to opening up political spaces and contributed to the striking of a compromise. The storylines employed have thus been

institutionalized as well, albeit incompletely. The political compromise struck is a reduction path, implemented through policy measures within the cross-compliance system. From a sustainability transitions perspective, this policy change represents an incremental improvement including technological fixes. Generally, this kind of incremental change can represent one phase of a gradual destabilization of the regime or result in its further stabilization instead.

In this paper, I argued that the discursive struggles surrounding pesticide use in Switzerland have rather resulted in a further stabilization than a destabilization of the pesticide regime. In line with prior studies, the findings suggest that the regime managed to restabilize following the emergence of disruptive discourses by adjusting and integrating some of the societal critique. Thus, the overall functioning of conventional agriculture and the paradigm of risk reduction, instead of quantitative pesticide reduction, remain unaffected. Attention to pesticide issues in the mainstream press strongly decreased after the rejection of the popular initiatives and approval of the reduction path and the package of ordinances. An exception is the biodiversity topic to which attention increased, stimulated by the United Nations biodiversity conference in 2022.[12] Nevertheless, the discursive struggles are likely to continue, in line with the trend of more frequent popular initiatives on agriculture such as the upcoming referenda on stricter biodiversity and landscape conservation.[13]

Declaration of Competing Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The code is available from the author upon reasonable request.

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Supplementary materials

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[12] See https://www.unep.org/un-biodiversity-conference-cop-15.

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Why is agricultural policy not more environmentally ambitious? Comparing failed attempts in Switzerland

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ABSTRACT

Switzerland is a country that has ambitious agri-environmental objectives, but its targets are continuously missed. The paper at hand examines this contradiction by describing and analysing three recent attempts to transform agricultural policies and change the unfortunate situation. The three cases were compared in a qualitative multimethod research design and along dimensions that are potentially relevant for explaining reform failures. While the attempts depicted involved distinctive governance pathways, they all failed to meet their objectives because of the large disadvantages their realisation would have generated. These included, above all, a reduction of the national self-sufficiency rate. It is concluded that the strategy of providing incentives for mere extensification has reached a dead end. New strategies to tackle food consumption patterns appear to be more promising.

1. Introduction

Farming is held responsible for a vast amount of environmental problems. These include unsustainably high greenhouse gas and other emissions (Blandford and Hassapoyanes, 2018) and the continuing decline of biodiversity (Pilling et al., 2020). Although a major number of agri-environmental schemes (AES) in Europe have made farming look more environmental, they have not solved any of these environmental problems. For example, the limited number of existing monitoring programmes have shown that AES often do not deliver what they promised (Calvi et al., 2018; MacDonald et al., 2019), and so agricultural economists continue to call for a further greening of the Common Agricultural Policy (Dobbs et al., 2021).

A country that set clear targets for the environmental performance of the farming sector at a relatively early stage is Switzerland (BAFU, 2008). Switzerland has seen the last major reform of its agriculture policy in 2014. This reform's core element was the adaptation of direct payments so that in principle, societal objectives would be assigned to each kind of payment (Mann and Lanz, 2013). Swiss agricultural policy has thus often been attributed a pioneering role in pursuing multifunctional agriculture (Metz et al., 2021; Pe'er et al., 2019).

There is certainly no lack of environmental awareness in Switzerland (OECD, 2017). Nevertheless, the country has so far failed to even come close to its environmental objectives related to farming (Wyss, 2020; Meier et al., 2021). Switzerland's data availability in terms of environmental performance is good (Repar et al., 2018), but it has recently encountered several failed attempts to create an agricultural policy with lower chemical inputs that would improve its environmental performance.

There is no shortage of normative papers suggesting that agricultural policy should devote more attention to the environment (DeBoe et al., 2020; Goral and Pilyavsky, 2019; Karttunen et al., 2021) and what governance models would be needed for this (Ehlers et al., 2021; Montanarella, 2015). There are also multiple descriptions of which policy instruments can be effective in doing so (DeBoe, 2020; Lankoski and Thiem, 2020). However, to our knowledge, no attempts have yet been made to describe the continued failure to transform agricultural policies in such a way that they would reach environmental objectives.

The paper addresses this research gap by incorporating three different, failed initiatives to answer the question: What are common reasons for the failure of attempts to transform agricultural policy in Switzerland? After outlining the methodological approach in Section 2, Section 3 is devoted to describing and analysing the three attempts and reasons for their failure. The three case studies of failed agricultural policy reforms provide empirical support for our attempt to contribute to explaining why we are unable to make farming more environmentally friendly through mere extensification, as shown in Section 4. Section 5 concludes.

2. Materials and methods

Given our interest in identifying common reasons for failure in the three reform projects, we opted for a comparative research design

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using multiple qualitative methods for data collection and analysis. The cases compared are three of Switzerland's failed attempts at implementing environmental measures, namely the 3V project (case study 1), the IDZ project (case study 2) and the *Agrarpolitik ab 2022* (AP 22+) (case study 3). All three initiatives had the objective of making Swiss agricultural policies more environmentally friendly, but their governance approaches were extremely different, as will be shown in Section 3. The paper draws on empirical material mainly gathered through accompanying research for the three analysed reform projects, as well as through long-term research on Swiss agricultural policy.

2.1. Study context

Switzerland is a convenient case study to engage in a deeper analysis of the continuing contradiction between environmental measures and ongoing environmental problems, as laid out in Section 1. The Swiss government has invested much effort to promote multifunctional, sustainable farming (Mann, 2018). This resulted in one of the highest levels of agricultural subsidies in Europe, amounting to 2.9 billion Swiss francs in 2021 while the sectors' gross value added is estimated at 4.1 billion Swiss francs. The 48,864 Swiss farms supply 57% of all energy consumed from food as expressed in the national self-sufficiency rate. With an average size of 21 ha farmland, the mainly family farms are small in international comparison (Federal Office for Agriculture, 2021; Federal Statistical Office, 2021a,b,c). The sector's ecological footprint, on the contrary, is not small. A recent study by Schläpfer (2020) has estimated the total external costs of Swiss farming at 3.7 billion Swiss francs (3494 Swiss francs per hectare).[1] Reducing the high ecological footprint has been the aim of several recent initiatives that attempted to transform agricultural policies towards this end.

2.2. Data collection

Data on the three initiatives examined in this study were collected between 2019 and 2022 using several qualitative and ethnographic techniques. They include participant observation, document analysis and five semi-structured interviews (see Table 1). The interviews were conducted as part of the accompanying research for case study 1. We interviewed three farmers, one farm adviser and the project management team, consisting of three persons (see Appendix A.1 for the sample description and Appendix A.2 for the interview topics).

2.3. Data analysis

The analysis proceeded in two steps. In the first step, the data for each project were analysed using document analysis (Bowen, 2009) and content analysis (Krippendorf, 2004) on the interview transcripts and on the field notes from participant observation. We coded the data along the three overarching categories 'context and design', 'experiences' and 'outcomes', which we used to arrange the materials in Section 3.

In a second step, the three cases were compared along dimensions that are potentially relevant for explaining reform failures. As potentially relevant dimensions we identified the stage of the policy process, the governance approach, the overall goal, the objectives, the project context, key actors, and any opposition or target conflict. The approach comes close to the description of comparative analysis by Hancke (2009), where 'everything between the [. . .] cases is different, except for the explanation and the outcome. Since all other potentially relevant dimensions vary, but [the] outcomes are the same, only the similarities between cases on the explanation can cause the agreement between the cases in terms of outcomes' (pp.74–75).

[1] Estimates of external costs are derived for emissions of greenhouse gases, ammonia, nitrate and pesticides, soil erosion, habitat deficits, and animal suffering. The calculations are based on the agri-environment measures' average avoidance costs (for further details, see Schläpfer, 2020).

3. Case descriptions and results

This section subsequently presents the three cases and the results of their analysis in detail. We first describe the context and design of each project. We then explore the main stakeholders' experiences regarding the implementation of the reform project in the sub-sections entitled 'experiences'. Finally, we conclude each project's section with presenting the outcomes of the project. The results from the cases are compared and discussed in Section 4.

3.1. Case study 1: Bottom-up

3.1.1. Context and design

The first case is the 3V project, which was a pilot project of the Swiss Federal Office for the Environment, implemented within the framework of the Biodiversity Action Plan. It was launched in 2019 and has run for three years. Initially proposed by farmers from the Thurgau Farmers' Association, the project was designed to interactively develop and test a bottom-up approach to agricultural policy implementation on 30 to 45 farms.

Experimentation characterised the pilot project, which is also regarded as a distinct 'approach to governing' (Huitema et al., 2018, p.144). In relation to the policy process, the project can be situated before the stage of policy conceptualisation. As a pilot project, its expected function was to 'enable evidence gathering to inform policy or validate assumptions' (Nair, 2021, p.5). In addition, 'piloting does implement something, albeit limited in spatial and temporal scope' (Nair, 2021, p.5). Therefore, by design, the project involved both data gathering and small-scale implementation of a project.

The mode of governance employed by the 3V project was a combination of bottom-up and interactive governance (using the classification of governance modes by Lange et al. (2019)). The project was initiated by farmers, who then decided to include public authorities to leverage the project. In this way, the structures became more formalised. The lead was handed over to a project management team. Intending to assign equal roles to all actors involved, the project guidance stated that the farmers, advisers, researchers and authorities 'should meet at eye level and contribute all their expert knowledge' (Projekt 3V, 2021). As a result, the project's policy–science–practice interface was transdisciplinary, integrating (place-specific) expert and practitioner knowledge.

Core components of the 3V approach were the environmental performance targets of the agricultural sector (*Umweltziele Landwirtschaft*, BAFU, 2008), which had been formulated at a sectoral level but lacked any farm-level indicators. Thus, the project aimed to collaboratively develop such indicators with farmers, cantonal farm advisers, researchers and public authorities, as well as to generate a tool that would allow for two things. First, the tool had to enable farm managers to identify the farm-specific optimisation potential in each of the 13 environmental target areas while considering presumed synergies with improving the economic (income) and social (quality of life) farm situation. According to the project's objectives, it needed to provide 'scientific proof of the extent to which 3V farms can provide better ecological services and achieve good economic results while maintaining or improving the quality of life' (Projekt 3V, 2021). Second, this tool had to demonstrate the feasibility and acceptability of a radical change in the way the farms' environmental performance and direct payments were assessed. The approach that the project proposed for this was based on its eponymous three 'Vs', which stand for the German words *Vertrauen* (trust), *Verantwortung* (responsibility) and *Vereinfachung* (simplification). According to the project's vision of a better agricultural policy, trust should replace the inflated control system by giving responsibility back to farmers and strengthening their awareness of the responsibility they bear for the environment. In this way, the control system could be drastically simplified, reducing farmers' administrative burden (Projekt 3V, 2021). Working towards simplification appears to have been the main motivation for farmers to participate in the pilot.

Table 1
Overview of data collection, data sources and data analysis (first step).

Data collection	Data sources	Total data sources	Data analysis
Participant observation	Project meetings (case study 1 and 2) Project workshops (case study 1 and 2) On-farm demonstration events (case study 1)	$N = 26$	Content analysis (field notes)
Semi-structured interviews	Farmers (n = 3, case study 1) Farm adviser (n = 1, case study 1) Project management team (n = 1, case study 1)	$N = 5$	Content analysis (interview transcripts)
Document search	Minutes from project meetings and workshops Project reports Media reports Websites Newsletters Emails Additional documents	$N \approx 60$	Document analysis

3.1.2. Experiences

In addition to the 15 initial farms from the Canton of Thurgau, 16 more farms were recruited via cantonal extension officers (the cantons of Glarus and Zurich; in the latter case, only one farm ultimately participated). When asked what differentiates the participating farms from other farms, one farm manager from Thurgau explained that as board members of the farmers' association, they are not different but simply more open.

There were three central instruments to facilitate the implementation at the farm level in the 3V project; these were as follows: (1) free advice for the whole farm, (2) compensation of additional expenditures on the farms according to standard market rates, and (3) authorised exemptions for project-specific requirements that differed from those of the current federal and cantonal programmes (Projekt 3V, 2021). The project was supposed to rest on the inputs given by the farmers. Therefore, the project leaders initially provided relatively vague information in terms of the specific ways in which (in particular, the last of) these instruments would be applied. This led to ongoing discussions and confusion among the participating advisers, farmers and researchers, which became evident in project workshops. Further, the insecurity about what would happen to on-farm changes made under the project's umbrella once the pilot ended prevented advisers and farmers alike from focusing on concrete steps. A rather extreme but illustrative example brought up by one farmer was agroforestry; this farmer feared that areas he would forest today could become protected in the near future, which would cancel out his financial investments.

For the involved stakeholders, the project sometimes came across as what McFadgen and Huitema (2017) called an 'advocacy experiment'. Such an experiment is one that seeks to generate evidence to support predetermined policy positions. The following statement from a participating farmer provides support for this observation:

> When we started... uhh, the goals were already defined, so not to use pesticides anymore. [...] But you don't have to do a pilot for that if you say, 'in the end, this has to be gone'. [With a] pilot, in my understanding, we have to look at what happens and then conclude... And if we don't do that, then we don't have to do a pilot. (F1C1)

Nair (2021) described piloting as 'an opportunity [for bureaucrats] to initiate policy change, demonstrate implementation of specific policy strategies, and gain accolades' (p. 8). The asymmetry between the actors of the project was pointed out by farmer F3C1, who spoke about how the project had been 'bureaucratised' so that farmers would benefit the least from it. Farmers 1 and 3 also thought that the project served as an arena where the bureaucrats that led the project would demonstrate their power towards a rival federal office.

The project's three pillars were *trust, responsibility* and *simplification*. While the aspect of simplification was the one that pulled most farmers into the pilot project, the farmers came to doubt the realisation of this, even on a conceptual basis. One reason for this is that for organic producers, many inspections are carried out either way by the label organisations and these would not be affected by simplifying changes made through the project. The trust among stakeholders reached its limit—at least for some of the farmers—when they were required to share sensitive data, such as full accounting records.

3.1.3. Outcomes

While the project is ongoing, it seems unlikely that the pilot will be replicated, expanded or integrated into existing policy, or alternatively, whether it will transform this policy. The project's vision for diffusion appears unclear, as providing comprehensive farm assessment and extension services like the pilot attempted to do does not seem feasible for upscaling.

The first expectation of a pilot—to gather evidence—has been partially met. Farm-level indicators for the sectoral environmental performance targets were specified and used for the (ongoing) completion of a 'light' version of the 3V tool. This tool has been used on some of the farms to (again, partially) assess the status quo and build scenarios for the improvement of environmental performance. It is currently envisaged that the tool could be made available to public extension and farmer education and training centres. However, little evidence could be produced that would support 3V's central assumption that ecological, economic and social improvements could be realised in a synergistic way.

Regarding the second expectation of a pilot—to implement something—one success has been reported so far: some of the farms started introducing biodiversity measures, which the advisers and researchers suggested based on the identified farm-specific potential in this area. While not negligible, this appears to be a minor outcome compared with the initial project's ambition, which was to conclude a target agreement with each farmer for holistic sustainability optimisation of farms. Given that 3V cost several million Swiss Francs, an overall evaluation of 3V has to come to a critical result.

3.2. Case study 2: Targeted measures

3.2.1. Context and design

Swiss agricultural researchers have been active in developing and applying sustainability assessment tools for farms (Grenz et al., 2009; Schader et al., 2016). The indicators used in these tools are strongly linked to farms' environmental performance, often attempting to measure environmental outputs directly. Some of the key actors in sustainability assessment in the farming sector were able to convince Switzerland's federal administration to explore the potential of these tools for agricultural policy. The resulting feasibility study by Schader et al. (2018) concluded that linking a strong consultative process on farms with a point-based reward system could allow sustainability assessment tools to be used to support a more performance-related agricultural policy.

Researchers' conclusions encouraged the Swiss Federal Office for Agriculture (FOAG) to commission a follow-up study in which a system was to be designed that would be based on sustainability assessment tools to make Swiss farming more environmentally efficient. A consortium was formed that focused on the creation of an indicator-based system, intending to use the indicators from sustainability assessment tools with the best feasibility for agricultural policy. The consortium was finally given two years to draw up such a system to be potentially followed by a pilot phase in which the system could be tested.

3.2.2. Experiences

In their final report for the project called IDZ, Gilgen et al. (2022) delineated three different direct payment systems that differed in their degree of complexity. A surprising point that united them is that none of the three systems used many indicators from sustainability assessment tools. During the design process, it became increasingly clear that the indicators in the common sustainability assessment frameworks had a strong need to be adapted to make them suitable for a direct payment system. Neither very complex indicators nor indicators that rested either on claims by the farmer or subjective evaluations by the person in charge could be transferred to agricultural policy. These reservations also excluded most of the actual performance-oriented measures, prioritising measures at the driver level. The resulting system included policy instruments on emissions, biodiversity, erosion and soil quality and left untouched current policy instruments in the realms of animal welfare and landscape, which are often outside of sustainability assessment tools. For the environmental issues included, the chosen instruments focused on penalising animal density and nitrogen fertiliser; in particular, the instruments in the more detailed systems also sought to provide incentives for technical measures like phase-feeding for pigs or intertillage on the arable land.

An agent-based simulation model (Möhring et al., 2016) was used to explore the likely impacts of the simplest of the three concepts on the environment, farm incomes and the production portfolio of Swiss agriculture. The model predicted that the effects would be small: Reductions of animal numbers between 3 and 5 per cent and arable production between 2 and 3 per cent would result in a reduction by 5 to 6 per cent of the degree of self-sufficiency and slightly lower surpluses of nitrogen (−2 to −4 per cent). Income was expected to rise, but this would be solely due to direct payments, which the model estimated would become higher than it was for the current system.

3.2.3. Outcomes

After the final report on the three indicator-based scenarios had been submitted alongside a proposal to enter into a pilot phase of the policy concept, FOAG's board decided to terminate the project. The official reason for this was that the project had not advanced in using output-related agri-environmental indicators. However, background talks indicated that the model results eroded all enthusiasm for the project. Whereas the Swiss population voted to maintain food security by emphasising national production in 2017, representing what Blattner and Ammann (2021) characterise as a largely symbolic election, the new policy would result in a notable decrease in domestic food production while contributing little to decreasing the sector's emission problems in Switzerland.

Because of its projected shortcomings, the IDZ remained a largely academic exercise. It has been used for scientific publications (in progress) but is very unlikely to ever be implemented.

3.3. Case study 3: Small steps

3.3.1. Context and design

Switzerland is among the countries with the highest shares of subsidies for its farmers; the Swiss administration develops budgets and policy packages for parliamentary approval every four years to secure ongoing funding for the sector. In recent decades, there has been a consensus that the main justification for support is the delivery of public goods. However, the Swiss farming sector's continuous failure to meet official environmental objectives, in conjunction with two radical public initiatives to engage in environmentally ambitious farming (Finger, 2021), has recently created pressure for the government to advance this dimension of agricultural policy. After a major reform in 2014 (Mann and Lanz, 2013) and minor adaptations in 2018, FOAG invited stakeholders to attend numerous workshops to develop a new policy package that would take effect from 2022 onwards. As an outcome of external and internal consulting, it has been suggested to basically continue with the same system but to implement a few changes to improve the environmental situation of the sector.

The many modifications to the complex system of Swiss agricultural policy were labelled AP 22+ and took the administration 258 pages to describe and defend (Schweizerische Eidgenossenschaft, 2020). While this report contained many measures that were unrelated to environmental issues, such as additional leeway for family enterprises to register as legal persons, the core environmental step was a reduction of the amount of nitrogen fertiliser one could apply and some other measures to reduce the nutrient load. In particular, there is currently a 10 per cent tolerance to add only as much nitrogen to the farm system as is used for production, and the elimination of this tolerance would have had the greatest impact. In addition, the amount of organic fertiliser to be distributed on farmland would have been reduced from 3 livestock units/ha to 2.5.

Also outside the nitrogen problem, environmental restrictions would be slightly tightened as delineated in the policy draft. A proportion of 3.5 per cent of the arable land would have to be used for ecological compensation measures. It was proposed to ban additional pesticides and recommended that pesticide-free production should be incentivised more strongly than before.

3.3.2. Experiences

The impact of the proposed policy package was estimated using the same agent-based model as the IDZ concept, and the simulation results were similarly sobering. Both the acreage of arable land (−5%) and the number of livestock units (−4%) would decrease, as would the degree of self-sufficiency (−4%) and aggregated farm incomes (−8%).

For past reforms of Swiss agricultural policy, the two parliamentary chambers at the national level usually made a few changes to the propositions by the administration and then approved the adapted bill. This was not the case in 2021, when both chambers decided to flatly reject the administration's proposal and to ask the administration to work on a programmatic strategy to develop Swiss agricultural policy further. The conservative majority argued that there were no strengths, only weaknesses in the administration's proposal. Some parliamentarians cited food imports in times of the coronavirus crisis, when even butter and cheese—strongholds of the many Swiss dairy farms—would have to be imported, and emphasised the reduced production that the proposed agricultural policy would entail. Others mentioned that there was no need to further reduce the options of farming families and restrict their incomes. There were also liberal parliamentarians who demanded a more basic approach to readjusting agricultural policy to the needs of the market.

3.3.3. Outcomes

Although the bill was rejected in parliament, parliamentary members still approved the necessary budget to continue the current agricultural policy. While the conceptual work in the administration has gained momentum in terms of the task assigned by parliament, there is some perception that there has been a standstill after the parliamentary vote, particularly among Switzerland's environmentalists (WWF, 2021).

4. Discussion

We first focus on an overarching comparison of the three cases and then discuss the identified common reasons for their failure. Finally, we discuss the study's limitations and provide directions for further research.

Table 2
Comparison of the three cases along key dimensions.

	Case study 1 (3V project)	Case study 2 (IDZ project)	Case study 2 (AP 22+)
Stage of policy process	Pilot project/pre-conceptualisation	Pre-operationalisation	Pre-approval by parliament
Governance approach	Bottom-up/interactive	Science-driven	Top-down plus stakeholder involvement
Overall goal	Improve environmental performance of Swiss agricultural policies	Improve environmental performance of Swiss agricultural policies	Improve environmental performance of Swiss agricultural policies
Objectives	Utilise knowledge by farmers and simplify policy	Use targeted indicators that improve environmental efficiency	Define stricter environmental rules
Context	Network of 31 farmers, consultants and administrators	Interdisciplinary research project	Reform package in parliament
Key actors	Federal Office for the Environment	Agroscope federal research station	Federal Office for Agriculture
Opposition/target conflict	Food production to secure self-sufficiency (reflected in Swiss Farmers Union's voice)	Food production to secure self-sufficiency (reflected in Swiss Farmers Union's voice)	Food production to secure self-sufficiency (reflected in Swiss Farmers Union's voice)
Outcome/goal achievement	Improvement of environmental performance of farming policies failed	Improvement of environmental performance of farming policies failed	Improvement of environmental performance of farming policies failed

4.1. Case comparison

As depicted in Table 2, the three reform attempts described in this article pursued different governance strategies. Case 1 was a conscious attempt to actively include the competence of farmers in agricultural policies. In contrast to this bottom-up approach, case 2 attempted to steer environmental science knowledge into improving agricultural policy tools. Finally, FOAG pursued a pathway in between the two approaches for case 3, when they combined stakeholder workshops with top-down planning. Other attempts could have been added to this, such as the two public initiatives for a radical greening of Switzerland's agricultural policy, which easily collected more than 100 000 signatures but then failed to obtain a majority at the polling box (Finger, 2021).

These initiatives did not aim to increase the economic output while liberalising environmental restrictions, nor have any other in the country aimed to do this. To the contrary, all initiatives focused on the environmental performance of the farming sector, attempting to decrease the adverse effects of farming on the ecology. However, why did none of them succeed?

4.2. Common reasons for failure

Public choice theorists would look in the realm of political markets to explain the failure of the Swiss initiatives. If agricultural policy is considered, for instance, as a process of rent-seeking (Schmitz, 2010), then the failure of the different initiatives could be attributed to the political power of the Swiss Farmers Union, which aim to protect their farming members from undue restrictions. Indeed, the Swiss Farmers Union fought unanimously against the AP 22+ policy concept presented in case study 3 (Schweizer Bauernverband, 2020). However, this standoff between environmental lobbyists and agricultural lobbyists could have ended a different way. A public vote on a new hunting law in Switzerland in 2021 has shown that environmental groups have also been able to organise victories against the Swiss Farmers Union (Triaca, 2020).

That could mean that the failures described can plainly be attributed to public preferences. Improving environmental performance comes with costs. A lower self-sufficiency rate (which might decrease Switzerland's food security status) and lower value generation in the primary sector incur costs to secure more species, cleaner resources and a slightly slower process of global warming that Swiss citizens may find too high. It may help agricultural economists if they can account for the possibility that it is not the low environmental performance of agricultural policy that is the problem but that the ambitious environmental objectives can only be met via broader food policy measures. Studies on a global scale (Mora et al., 2020; Müller et al., 2017) have indicated that reducing food waste and the share of calories coming from animal products are levers that can allow for an extensification of agricultural production. Such pathways may be a more fruitful option to solve the environmental problems of farming than the focus on national production intensities, which appear to have reached a dead end.

4.3. Limitations and directions for further research

Our research on common reasons for the failure of agricultural policy reform attempts could be improved in at least two ways. First, our study draws on a small number of case studies and qualitative methods for data collection and analysis. This research approach could be complemented by a larger-scale study that focuses on capturing causal complexity, using a method such as Qualitative Comparative Analysis. Second, while we were able to attain our objective of identifying common ground between the failed attempts, there were also other failed initiatives of making Swiss farming more environmentally friendly which we largely ceased to analyse.

5. Conclusions

This study aimed to identify common reasons for the failure of attempts to transform agricultural policy in Switzerland so that the sector's environmental performance would be improved. The comparison across the three cases on potentially relevant dimensions suggests that the failures described can mainly be attributed to public preferences. The focus on mere extensification of agricultural production would have also involved a reduction of the national self-sufficiency rate. This was fought unanimously against by agricultural lobbyists. Our findings thus support the conclusion that broader food policy measures are needed to achieve the sector's ambitious environmental objectives. Promising avenues for extensifying agricultural production without reducing the desired degree of self-sufficiency include the reduction of food waste and of the share of calories coming from animal products. Even though we have focused on agricultural policy reform attempts in Switzerland, it is likely that such attempts in other advanced economies are subject to similar target conflicts and sectoral policy limitations. The insights drawn from our study may thus be of interest to researchers and policymakers in other countries as well.

CRediT authorship contribution statement

Stefan Mann: Conceptualisation, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition. **Antonia Kaiser:** Conceptualisation, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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Appendix

A.1. Interview sample

See Table A.1.

Table A.1
Interview sample description (n = 5).

ID	Gender	Canton	Case study
F1C1	Male	Thurgau	Case study 1
F2C1	Male	Thurgau	Case study 1
F3C1	Female	Thurgau	Case study 1
FAC1	Male	Thurgau	Case study 1
PTC1	3x Male	–	Case study 1

A.2. Interview topics

The main topics of the interviews with farmers (F1C1-F1C3) were:

- The history of the farm
- What differentiates the farmer's practices from others
- Reasons for participation in the project
- Experiences as participating farmers in the 3V project
- The main sustainability related challenges on the farm
- Agricultural policies from the farmer perspective

The interview with the farm adviser (FAC1) dealt with:

- Their role as farm adviser
- Development and changes in agriculture over the last 10/20 years
- Current sustainability issues and approaches to solutions in the canton
- Experiences as adviser in the 3V project

The interview and project management team (PTC1) dealt with:

- Governance of the project
- Experiences with the project so far
- Central challenges as perceived by the project team

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