Pesticide risk regulation in two distinct policy subsystems:

Investigating policy actors in Uganda and policy output in Costa Rica

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Die Fakultät hat diese Arbeit am 25. August 2022 auf Antrag der zwei Gutachterinnen Prof. Dr. Karin Ingold und Prof. Dr. Colette Vogeler als Dissertation angenommen, ohne damit zu den darin ausgesprochenen Auffassungen Stellung nehmen zu wollen.

You see, Momo,' he [Beppo Roadsweeper] told her one day, 'it's like this. Sometimes, when you've a very long street ahead of you, you think how terribly long it is and feel sure you'll never get it swept.' He gazed silently into space before continuing. 'And then you start to hurry,' he went on. 'You work faster and faster, and every time you look up there seems to be just as much left to sweep as before, and you try even harder, and you panic, and in the end you're out of breath and have to stop - and still the street stretches away in front of you. That's not the way to do it.' He pondered a while. Then he said, 'You must never think of the whole street at once, understand? You must only concentrate on the next step, the next breath, the next stroke of the broom, and the next, and the next. Nothing else.' Again he paused for thought before adding, 'That way you enjoy your work, which is important, because then you make a good job of it. And that's how it ought to be.' (Michael Ende)

Throughout my PhD journey, I had the privilege to be supervised by Karin Ingold who encouraged me to embrace a similar mindset as Beppo in Michael Ende's Momo. She has taught me to be patient and kind with myself – research takes time and nothing turns out as planned. Even more, she gave me the freedom to take one step at a time, find my own pace and path, and grow as a researcher. I am thankful for your guidance and trust. This journey has been full of rewards and rough patches, and I want to thank my co-supervisor Jennifer Inauen for her optimism, support and endurance in introducing me to social psychology. My PhD and the research I conducted would not be possible without the whole PESTROP Project, and particularly Philipp, my ginger partner in field work and a true friend. Along this journey, I was lucky to be part of PEGO, the Policy Analysis and Environmental Governance group at the University of Bern and Eawag. I am thankful for my colleagues Manuel, Lukas, Simon, Martin, Maiken, Jack, Mert, Mario, Lorenz and Laurence for providing a safe space, giving me feedback on so many occasions and making this experience much more fun. I also want to thank my colleagues from the Institute of Political Science at the University of Bern for making me feel at home and providing a inspiring work environment. Along my PhD journey, I was lucky to make friends in academia with whom I shared adventures, traveled together, danced the nights away, ran the 10 most beautiful miles of the world, had babies and was seriously sleep deprived for various reasons. Thank you Laura, Florence, Anik, Marlene and Liliane for your friendship.

Now, I want to thank the people who are very unlikely going to read this document and it is really their love and friendship that nurtured me throughout this journey. I thank my friends from far and near, who continue to be patient, loyal and caring. My parents who taught me endurance and passion – two fundamental skills to pursue this journey. My siblings, Andreas, Christoph, Markus, Jonas and Nina who are my most critical advisers, most loving shoulders to cry on and funniest individuals to spent time with. And finally, I dedicate this dissertation to Silviu and our beautiful son, Emil. While I am closing the chapter on my PhD journey, our story continues and I cannot wait to see what's next for us.

Contents

List of Figures

List of Tables

Introduction

Background and research question

Economic development and demographic growth fundamentally shape global environmental changes. As these changes are largely determined by human activity and behavior, geologists often refer to this epoch as the Anthropocene (Crutzen, 2006; Lewis & Maslin, 2015; Steffen et al., 2007). In this epoch, synthetic chemicals like pesticides are thought to contribute to global environmental changes such as chemical resistance (Palumbi, 2001) and widespread contamination (Hayes & Hansen, 2017). Although closely associated with economic development and demographic growth, the use of agricultural pesticides is a contentious issue, as the benefits for agricultural production are accompanied by negative effects for humans and the environment (Bourguet & Guillemaud, 2016; Damalas, 2009). These "plant protection products" are applied to protect crops from unwanted pests (Rathore & Nollet, 2012), but incorrect application or failure to take appropriate precautions – for example, by wearing personal protective equipment (e.g. wear personal protective equipment) (Damalas & Eleftherohorinos, 2011) – exposes humans, the environment, and agricultural goods to multiple risks. Given the widespread use of these chemicals, their environmental persistence, and the likelihood that they will spread beyond their target (Hayes & Hansen, 2017), the risks include pollution of water, soil, and air (Chopra et al., 2011; Gil & Sinfort, 2005), impairment of the aquatic and other ecosystems (Beketov et al., 2013; Malaj et al., 2014; Stehle & Schulz, 2015), and threats to birds, amphibians, and bees (Carson, 1982; Fairbrother et al., 2014). In humans, the effects of pesticide exposure include increased risk of cancer, chronic disease, and neurological impairment (Jørs et al., 2018; Mostafalou & Abdollahi, 2013); in vulnerable agricultural systems, pesticides can kill non-target organisms and may inhibit crop resistance (Hayes & Hansen, 2017).

It follows that pesticide risks pose challenges for policymakers seeking to transform the agri-food sector (Feindt et al., 2021). Traditionally, agri-food policy has been considered a "closed" and stable policy subsystem shaped mainly by a few privileged actors with access to the policy process (Feindt et al., 2021; Skogstad, 1998). For that reason, policy making in this subsystem has been characterized as "compartmentalized and 'exceptionalist"' (Daugbjerg & Feindt, 2017, p. 1566) leading to sectoral gatekeeping. In recent decades, this subsystem has been politicized, as challenges within the subsystem have attracted increased public attention (Tosun, 2017). In light of these dynamics, the subsystem has opened to new ideas about sustainability and environmentally friendly production driven by new policy actors[1] that include environmental non-governmental organizations (NGOs). This in turn has prompted new state-led efforts beyond self-regulation or new policy instruments that target multiple stakeholders other than farmers (Daugbjerg & Feindt, 2017; Daugbjerg & Swinbank, 2012; Tosun & Leininger, 2017). However, despite this growing interest in the agri-food subsystem (Feindt et al., 2021; Möhring et al., 2020; Vogeler, 2021), there has been relatively little research

[1]The term *policy actors* refers to collective actors from the private and public sectors, including government agencies, academia, and environmental, health, and agricultural organizations; NGOs; and interest groups representing the target population. The terms *policy actor* and *stakeholder* are used interchangeably throughout.

interest in decision-making related to pesticide regulation. To date, studies have typically focused on agricultural policy implementation (Loha et al., 2018; Mengistie et al., 2015), private sector-led regulation (Mengistie et al., 2016, 2017), and regional (Hunka et al., 2015; Lee et al., 2019; Skevas et al., 2013) or global (Handford et al., 2015) efforts to address pesticide-related risks.

In general, existing studies suggest that pesticides should be regulated at different points in the life cycle (e.g., manufacturing, importation, disposal) to achieve meaningful change and move toward sustainable agricultural production (Finger et al., 2017; Lee et al., 2019; Lefebvre et al., 2015; Skevas et al., 2013). At international level, for example, the United Nations Food and Agricultural Organization (FAO) Code of Conduct on the Distribution and Use of Pesticides includes guidelines for the application and effective and efficient use of pesticides (FAO and WHO, 2014). Other initiatives include the Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Stockholm Convention on Persistent Organic Pollutants (for a comprehensive overview, see Handford et al., 2015). Additionally, several harmonization efforts have addressed pesticide registration procedures (OECD, 2011), standards for pesticide residues (WTO, 2011) and the classification and labeling of chemicals (UN, 2011).

Pesticide regulation varies widely across regions and countries (Handford et al., 2015). In the European Union, Directive 2009/128/EC establishes a framework for action on the sustainable use of pesticides. In seeking to reduce the risks and impacts of pesticide use on human health and on the environment, it targets the promotion and use of integrated pest management and alternatives to chemical pesticides. By November 2012, EU member states were required to adopt national action plans to implement the requirements of the Directive. Non-member states like Switzerland have also developed national action plans (Mohring et al., 2019), and other major users of pesticides like the US, Brazil, India, South Africa, and China have developed comprehensive policies to protect the environment from pesticide pollution (see Handford et al., 2015; Osteen and Fernandez-Cornejo, 2013; Zhang and Wen, 2008). However, as many countries in Africa and South and Central America still lag behind (Handford et al., 2015; Loha et al., 2018), *how can we explain these differences in pesticide regulation?*

In public policy research, decision-making processes and regulatory output are typically captured by investigating the policy process itself (Cairney & Heikkila, 2014). According to the Advocacy Coalition Framework (ACF), which is one theory of the policy process, these processes occur in so-called *policy subsystems* (Sabatier & Jenkins-Smith, 1999; Sabatier, 1988; Sabatier & Weible, 2007). The ACF conceptualizes a policy subsystem as an arena in which stakeholders and decision-makers negotiate public policies based on their values, beliefs, and preferences regarding a specific policy issue (Jenkins-Smith et al., 2014b; Sabatier & Jenkins-Smith, 1993; Weible & Nohrstedt, 2012). Weible and Ingold (2018, p. 329) define a policy subsystem as "the area or space within a country where policy issues are governed, such as the processes of formulating and adopting public policies and implementing and enforcing them". Given the complexity of policy issues, specialized and knowledgeable stakeholders in the relevant domain tend to form a policy subsystem (Sabatier & Jenkins-Smith, 1993). These include policy actors from private and public organizations (e.g., government

agencies, media, interest groups, NGOs, political parties) that interact in attempting to influence public policy on the issue in question (Sabatier, 1998). Within the policy subsystem, stakeholders with shared values, beliefs, and preferences form coalitions that compete to gain influence, and regulatory outputs can be understood in terms of the winning coalition's objectives (Weible & Sabatier, 2005). This subsystem perspective, focusing on policy actors, beliefs, and coalitions, has informed policy studies for a long time, especially in domains like environment and energy (Bukowski, 2007; Cairney et al., 2018; Kammermann & Angst, 2021) public health (Bandelow et al., 2019; Breton et al., 2008; Poulsen, 2014) and education (Beverwijk et al., 2008; DeBray et al., 2014; Shakespeare, 2008; for a comprehensive overview, see Pierce et al., 2017). To clarify how policy subsystems differ and how policy issues are regulated, Sabatier and Jenkins-Smith (1993) distinguish between *mature and nascent subsystems*. Although this distinction strongly influences the focus of policy subsystem studies, most ACF-based studies have neglected nascent subsystems – that is, emergent policy subsystems that are still evolving around new issues on the political agenda that have attracted little public attention, are not a priority for decision-makers, and have produced little or no policy output (Ingold et al., 2017; Jenkins-Smith & Sabatier, 1999). In contrast, mature subsystems have existed for more than a decade (Pierce et al., 2017), key actors are easily identified, and there is some policy output (McGee & Jones, 2019). According to ACF, decision-making in nascent subsystems is fundamentally shaped by *policy actors* who interact and form coalitions around their positions on emergent policy issues; in mature subsystems, *policy output* reflects the shared objectives of such coalitions. This temporal aspect of subsystem formation is a useful way of identifying the relevant units of analysis when investigating a subsystem's potential to address a given policy issue. Using this distinctive feature of policy subsystems as a point of departure, the present dissertation examines decision-making related to pesticide regulation in a nascent subsystem (Uganda) and a mature subsystem (Costa Rica). This maturation-based approach promises to enhance our understanding of decision-making and of problem-solving drivers and barriers. To that end, the dissertation addresses the following overarching research question: *How can we enhance pesticide regulation in nascent and mature subsystems?*

Goal and analytical framework

To answer the research question and to develop practical insights for policy makers, the dissertation investigates **policy actors in a nascent subsystem** and **policy output in a mature subsystem**. In a nascent subsystem, where the issue has only recently entered the political agenda, decision making is shaped by the conflicts and uncertainties associated with pesticide risks as a policy issue. In the first place, decision-making is challenged by goal conflicts (e.g., agricultural productivity versus environmental protection). Along the food value chain, stakeholders from national government authorities, industry, civil society organizations, farmers' associations, and consumer interest groups interact and influence decision-making (Hunka et al., 2015). These stakeholders represent different interests and values and encounter high levels of uncertainty in assessing pesticide risks (Skevas et al., 2013), as scientific evidence of a causal link between pesticide exposure and health impairment is often inconclusive (Bonner & Alavanja, 2017). Because pesticides enter the environment in diffuse ways, it can be difficult to confirm the source of pollution (Önneby et al., 2010), and unpredictable events contribute further to this uncertainty. In particular, pesticide management is strongly influenced by

climatic, socio-economic, and socio-demographic changes. Climate change can increase vulnerability to pests and so encourages the use of pesticides (Le Goff et al., 2022; Zinyemba et al., 2021). Increased use of pesticides may also relate to population growth (Galt, 2008) and the need to ensure food security (Stein & Luna, 2021). Different interest groups exploit these uncertainties as well as the public health benefits of pesticides (e.g., vector control for malaria prevention) to frame perceptions and influence the policy agenda (Cole et al., 2011). While decision-making in the agri-food sector has long been dominated by sectoral ideas and interests (Feindt et al., 2021), pesticide risk reduction can only be achieved by taking account of these inherent conflicts and uncertainties. To understand decision-making on pesticide regulation in a nascent subsystem, the idea that participation in the agri-food subsystem is confined to a few privileged policy actors must be replaced by a more inclusive stakeholder perspective. To that end, the first part of the dissertation focuses on three policy actor-related issues: **problem understanding** (article 1), **policy preferences** (article 2), and **coalition building** (article 3) (see also Figure 1).

In the first article, Wiedemann et al. (2022) adopt a contextual approach to **policy actors' problem understanding** in order to *identify potential pathways for safe pesticide management* in Uganda. Based on a transdisciplinary understanding of transitioning to a more sustainable future, the reported study employed a participatory approach to co-produce three different types of knowledge. In a two day-workshop in Waksio District, 33 participants from different sectors and levels discussed the challenges they face regarding pesticide management in Uganda (systems knowledge), how they envision a future for safer pesticide management (target knowledge), and what they need to achieve system transition (transformation knowledge). Combining systematic Design Thinking (Buchanan, 1992; Dorst, 2010; Fischer, 2015) with a participatory approach to facilitate knowledge integration, we gathered relevant written and visual material to develop an actor-centered perspective on the nascent subsystem. Participants discussed ways of enhancing pesticide regulation at different levels, incorporating the views of decision-makers as well as local farmers. In the second article, Wiedemann (2022) investigates **policy actors' preferences** to *identify drivers and barriers related to pesticide regulation*. Specifically, the study focuses on state intervention to prevent pesticide risks in Uganda. Using theoretical insights from social psychology, the collaborative governance literature, and the Ecology of Games framework, the study examined the individual, structural, and institutional determinants of policy actors' preferences. The mixed-methods approach combined an online survey with face-to-face interviews to collect data from 81 national and local policy actors. Correlation and regression analysis were used to understand policy preferences and to identify potential directions for future policy. To consolidate the quantitative data, rich qualitative data from the standardized interviews helped to contextualize and interpret the results. The third study adopts a different perspective on **policy actors and early coalition building** to explore the *different options for pesticide regulation* in Uganda (Wiedemann & Ingold n.d.), illuminating how coalition formation in a nascent subsystem relates to the policy issue of pesticide risks and how like-mindedness emerges in this subsystem. Based on the policy network and collaborative governance literatures, it was anticipated that forum co-participation, collaboration, and similar perceptions of the problem would influence coalition building. The study advances an innovative three-step analysis: an elaborate coding scheme to

identify preferences within the nascent subsystem; hierarchical clustering of beliefs and preferences to identify like-minded clusters among the 32 national policy actors, and regression analysis to identify possible explanations for coalition formation in this nascent subsystem.

The second part of the dissertation investigates pesticide regulation in a mature subsystem. While mature subsystems have produced policy outputs over decades, decision-makers may overlook the problem's dimensions across different scales and levels (Costanza, 2003), so reducing a complex problem to an unduly simplistic account. The public policy literature warns that policies or policy outputs as solutions to policy issues (Howlett, 2009), that fail to capture the problem or context or mismatch means and ends are unlikely to succeed (Ansell et al., 2017; Ingold et al., 2018) and may lead to ineffective state intervention. Rather than silo thinking, policy output related to pesticide risks requires cross-sectoral action encompassing entire life cycles or production processes, multiple sectors, and actors that include industry, consumers, and monitoring agencies. In other words, the negative effects of pesticides extend beyond agriculture to other domains, including environment and public health and along the food value chain, ranging from the production and importation of chemicals to their use and disposal. To reduce pesticide risks, one common solution is to regulate environmental exposure – for example, by filtering pollutants through a wastewater treatment facility. This approach targets the effects of harmful behavior with add-on measures (Frondel et al., 2007) and is popular among decision-makers because it is easily linked to outcomes, as the effects are highly visible. However, to take fuller account of problem complexity, emerging preventive solutions (Metz & Leifeld, 2018; Tosun et al., 2020) should target all stages of the production process by regulating manufacturing, production, distribution, and disposal. Rather than cleaning up after exposure, this preventive rationale targets cleaner production to eliminate potential harm (Kautto & Similä, 2005; Kümmerer, 2010; Mantovani et al., 2017). While this approach assigns higher priority to environmental considerations throughout the production process, its effects are long-term, and increased production costs confront consumers with a trade-off between product performance and environmental impact (Mantovani et al., 2017). To take account of this cross-sectorality, preventive measures for risk reduction are considered crucial as an alternative or addition to the established end-of-pipe response (Metz & Ingold, 2014; Seifert et al., 2019; Xanthos & Walker, 2017). To investigate pesticide regulation in a mature subsystem, then, a cross-sectoral perspective is needed, and the second part of the dissertation addresses policy output **performance** (article 4; see also Figure 1).

The fourth article evaluates the *cross-sectoral performance* of the existing **policy output** addressing pesticide risks in Costa Rica, including legislation, ordinances, and action plans (Wiedemann & Ingold, 2021). By dividing policy output into its substantive and institutional aspects, it was possible to investigate policy instruments and legislation governing pesticide risk reduction for drinking water, the aquatic ecosystem, and occupational health in Costa Rica. To assess policy performance and to highlight the need to address pesticide risks across sectors, the study used state-of-the-art evaluation criteria supported by novel cross-sectoral components. By coding 37 policy instruments derived from action plans, the authors were able to assess policy mix performance in terms of density (a simple count of policy instruments) and intensity (restrictiveness of the policy mix) along with two novel cross-sectoral characteristics: share of source-directed and end-of-pipe instruments and share

of target groups across sectors. To assess institutional performance 21 legal documents (laws, ordinances and decrees) were coded using three criteria with a cross-sectoral component: cross-sectoral formulation of objectives, target group integration, and cross-sectoral institutional coordination.

Contribution

By investigating pesticide regulation in nascent and mature agri-food subsystems, the dissertation contributes to future policy design and to a transformation toward targeted pesticide risk reduction. This section briefly summarizes the dissertation's conceptual, methodological, and empirical contributions to the literature. At a *theoretical* level, this holistic approach to decision-making in the agri-food sector links the subsystem, its distinctive temporal features, and pesticide risk as a policy issue. The overarching distinction between mature and nascent subsystems links the dissertation's different contributions (see road map in Figure 1). While ACF has been broadly applied in both geographic and thematic terms (Pierce et al., 2017; Weible & Sabatier, 2009), relatively few studies have acknowledged this distinctive feature of subsystem formation (Sabatier & Jenkins-Smith, 1999; Weible & Cairney, 2018), or empirically investigated nascent subsystems (exceptions include Beverwijk et al., 2008; Fidelman et al., 2014; Ingold et al., 2017; Stritch, 2015). Drawing on well-established theoretical concepts for its investigation of pesticide regulation in nascent and mature subsystems, the dissertation contributes to the public policy literature in general and in particular to the literature on decision-making for pesticide risk reduction in the agri-food subsystem (Hunka et al., 2015; Rauchecker, 2019; Tosun & Varone, 2021). With its focus on policy actors and policy output, this dissertation contributes furthermore to the policy process literature by advancing on the theory and empirical approaches to grasp drivers and barriers for decision-making.

The first part of the dissertation focuses on policy actors as the main theoretical component of nascent subsystems and addresses problem understanding and related options for regulation; individual, structural, and institutional drivers of policy preferences; and coalition building as pathways for future policy design. In contrast, the second part investigates a mature subsystem, focusing on policy output as the main theoretical component of such subsystems and addressing cross-sectoral policy performance. The analytical framework linking the two concepts (see Figure 1) informs recommendations for future decision-making in both nascent and mature subsystems, including policy goals and target groups in nascent subsystems (article 1; see Figure 1). The dissertation also identifies aspects of the decision-making process that need to be strengthened for enhanced regulation in nascent subsystems (articles 2 and 3; see Figure 1). In contrast, mature subsystems may benefit from additional regulation, and the dissertation suggests how existing regulation can be enhanced to address policy issues across sectors and to promote a coherent regulatory regime (article 4; see Figure 1).

Methodologically, the dissertation makes two major contributions. First, the unique and rich data help to clarify the role of policy actors as key protagonists in nascent subsystems. Based on a participatory approach in which knowledge integration precedes data gathering, written and visual material was gathered to illuminate policy actors' understanding of the problem. Using Design Thinking tools, participants compared their own problem perceptions with others and engaged in a participa-

tory process to identify potential pathways for future regulation (article 1; see Figure 1). Additionally, policy actors were surveyed about their preferences across a comprehensive set of policy instruments, their individual attributes, and the structural realities of the subsystem. Stakeholders included private and public organizations from different sectors and levels. The online survey was complemented by face-to-face interviews, and quantitative data were integrated with the qualitative findings from the interviews (articles 2 and 3; see also Figure 1). This mixed-methods approach yielded a rich data set and in-depth case knowledge that contextualizes the findings and offers a point of departure for future studies. Second, the investigation and assessment of policy output goes beyond state-of-the art assessments and contributes to the literature by introducing a novel cross-sectoral component for policy performance assessment (article 4; see Figure 1). Existing studies assess policy performance in terms of density (a simple count of policy instruments) and intensity (restrictiveness of the policy mix) (see for example, Knill et al., 2012; Schmidt and Sewerin, 2019). To take account of the cross-sectorality of policy problems, the present dissertation draws on the environmental policy integration literature (Jordan & Lenschow, 2010) and the Institutional Resources Regime (Gerber et al., 2009) to specify a new cross-sectoral dimension of policy output performance. The assessment includes a comprehensive content analysis of laws, ordinances, and action plans. The detailed coding frame and data set can be used in future studies of policy performance to assess cross-sectoral policy coordination.

Empirically, the dissertation investigates pesticide risks as a pressing issue for decision makers in the agri-food subsystem (Feindt et al., 2021; Möhring et al., 2020). To account for policy subsystem formation, Uganda was selected as a nascent subsystem and Costa Rica as a mature subsystem. Both countries are rich in biodiversity by virtue of their tropical climate (Fagan et al., 2013; Nsubuga & Rautenbach, 2018), but they face different challenges in relation to agricultural pesticide use. In Uganda, pesticide risks have only recently come to public attention, and policy design is still evolving. Politically, pesticide use remains a neglected issue, especially in the context of smallholder farming (Isgren & Andersson, 2021), and as a result, the policy subsystem has to date produced little targeted output. This may be because the dominant political narrative in sub-Saharan Africa promotes the narrow policy objective of increasing agricultural productivity and food security (Stein & Luna, 2021), yet there is little public spending on the agriculture sector (Isgren & Andersson, 2021). The situation is different in Costa Rica, which relies heavily on vegetable and fruit exports for economic development while the domestic market for those goods is growing rapidly as the population increases (Galt, 2008). For that reason, agricultural expansion at the expense of conservation of natural resources is a constant problem in Costa Rica. Decision-making related to pesticide risk reduction has long been informed by scientific evidence highlighting environmental risks like water pollution (Arias & Alvarado, 2013; Ruepert, 2011) and ecosystem disruption (Castillo et al., 2000) and health problems that include chromosomal aberrations in female workers on banana plantations (Vindas et al., 2004), acute intoxications (García, 1998), various cancers (Partanen et al., 2009), poisonings (Wesseling et al., 1993), respiratory problems, headaches, and nausea (Ruepert, 2011). This is reflected in policy outputs spanning agriculture, health, and environment, but problems associated with pesticide usage persist[2]. These two countries are ideal settings in which to explore the proposed analytical framework

[2]For instance, entire communities left without portable drinking water for weeks have called on the Inter-American

(see Figure 1). This investigation can be characterized as "out-of-the-box", as the public policy literature is making slow progress in mapping decision-making and regulatory outputs beyond Europe and the United States (Fahey & Pralle, 2016; Pierce et al., 2017; Weible et al., 2009).

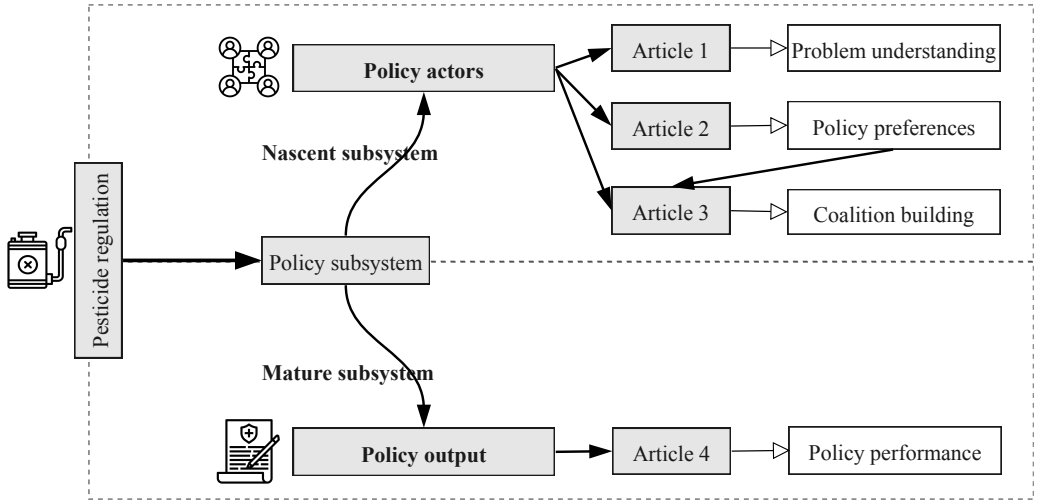

Figure 1: Conceptual framework: Dissertation road map

Empirical findings

This section briefly reports the results of the three articles on pesticide regulation in a nascent subsystem (Wiedemann, 2022; Wiedemann et al., 2022; Wiedemann & Ingold, n.d.), which is the main focus of this dissertation. Those findings are then contrasted with pesticide regulation in a mature subsystem (Wiedemann & Ingold, 2021).

Pesticide regulation in a nascent subsystem

The first part of the dissertation explores *problem understanding*, *policy preferences*, and early *coalition building* among **policy actors** in a nascent subsystem. The first study, which focused on problem understanding, confirmed that the agri-food subsystem in Uganda seeks to promote pesticide risk reduction and safe pesticide management through policy and regulation (Wiedemann et al., 2022). In particular, stakeholders referred to public health and environmental policy reforms to enable this transformation. The findings indicate a need for research to support decision-making by reducing uncertainty and stakeholder consultation to address conflicts in the subsystem. The study identifies state intervention as one potential pathway to regulate pesticides but notes that regulation can be further enhanced by making personal protective equipment more affordable, promoting the professionalization of local pesticide distributors, and fostering the market for organic products. Those results are mirrored in the second study, which analyzes policy actors' preferences in relation to source-directed state intervention (Wiedemann, 2022). The results confirm the potential for this type of regulation but also show that pesticide regulation extends beyond state-led intervention. In particular, enhanced pesticide regulation should combine state intervention with comprehensive private sector efforts to

Commission for Human Rights to act on their behalf, see The Costa Rican Pineapple in front of the Interamerican Commission for Human Rights, in Spanish from April 2015.

address this policy issue. Furthermore, market-based instruments to facilitate risk reduction (such as purchase taxes) are most likely to be rejected by policy actors while more coercive and restrictive measures such as regular inspections or product bans may be more acceptable. The results also indicate that while policy actors who perceive pesticides as a risk are more likely to favor source-directed state intervention, cross-sectoral collaboration and forum participation do not yield the expected results. Individual attributes such as problem perception play a crucial role in pesticide regulation, but the role of relational characteristics requires further investigation. To that end, the third study investigates how like-minded policy actors form coalitions in Uganda as a nascent subsystem (Wiedemann & Ingold, n.d.). The results indicate that policy actors are more likely to form a coalition if they have previously participated in the same forum but not if they differ in their perceptions of how pesticides affect human health, environment integrity, and agricultural productivity. The study also shows that to clarify the potential for pesticide regulation and the influence of the different coalitions, each coalition must be examined separately and in greater depth. In the present case, detailed investigation of the separate clusters showed that a more organized approach and involvement in policy making, collaboration, and regular exchange promotes like-mindedness. For actors who are less involved and differ in terms of beliefs and preferences, similar problem perception and preferences seem likely to facilitate coordination. These results echo the first article, in which stakeholder coordination and consultation were identified as one potential pathway to enhanced pesticide regulation and safer pesticide management in Uganda. As the results show, coordination can be triggered by different impulses, and providing platforms of exchange as well as scientific evidence may prove significant for pesticide regulation in a nascent subsystem.

Pesticide regulation in a mature subsystem

In the fourth study, Wiedemann and Ingold (2021) investigated **policy output** and its *cross-sectoral performance*. The results confirm that the policy mix performed well in terms of density and cross-sectorality. More specifically, the policy instrument mix included source-directed and end-of-pipe measures to target pesticide risk reduction, but low intensity limited reliance on coercive command-and-control provisions. The assessment of institutional performance reveals that current legislation addresses pesticide risks cross-sectorally by referring to the relevant target groups and establishing cross-sectoral coordination. Overall, the subsystem exhibited strong potential for pesticide risk reduction, but enhanced pesticide regulation would require further legal provisions to promote a cross-sectoral approach, as this issue is currently addressed by a policy mix of non-binding action plans with little coercive power.

Conclusions

The combined perspectives in this dissertation show that pesticide regulation can be enhanced by triggering various impulses in nascent and mature subsystems. In a nascent subsystem, both the individual attributes of policy actors and their links to others are likely to shape decision-making and influence regulatory outputs. In a mature subsystem, existing policy output can be understood in terms of the dominant coalition's policy objectives. However, this output may be too weak in

terms of restrictiveness and binding or authoritative state power to significantly reduce pesticide risks. Based on these general findings, the next section elaborates further on policy implications beyond those outlined in the four research articles. The chapter is then closed by a brief reflection on this dissertation's limitations and suggestions for future reserach.

Bottom-up efforts: Acknowledging conflicts in nascent subsystems

In a nascent subsystem, stakeholder organization and coordination is still evolving (Ingold et al., 2017). Decision-making processes are not established. As stakeholders have only recently begun to engage with the topic, consider policy options, or discuss possible directions for policy (Ingold et al., 2017), a closer look at stakeholders serves to clarify what is possible. In this evolving subsystem, stakeholders, values, and beliefs remain unorganized, fluid, and fragmented. The results indicate that conventional top-down approaches based on state intervention to govern and steer target groups may fail to take account of the inherent conflicts within a nascent subsystem. In fact, state intervention is only one option among many (Wiedemann, 2022; Wiedemann et al., 2022), and private sector (Mengistie et al., 2016) or bottom-up community interventions such as self-regulation (Barzman et al., 2015) offer possible alternatives or additions to pesticide regulation at different levels. A mix of bottom-up and top-down initiatives can involve non-government actors that contribute to problem creation as well as to solutions. This multi-perspective approach to pesticide regulation, decision-making, and consultation can help to ensure that all relevant stakeholders assume appropriate responsibility and ownership.

Dissemination and science communication: Addressing uncertainty in nascent subsystems

An understanding of coalition building can help to clarify whether a particular group of stakeholders is likely to push for pesticide regulation and why they share similar convictions in relation to policy options. The present findings indicate that, even in nascent subsystems, like-minded stakeholders can be identified and are likely to organize according to their degree of involvement and their prior contact in policy forums (Wiedemann & Ingold, n.d.). The "glue" that binds a coalition pushing for comprehensive pesticide regulation is similarity of problem perception. It follows that evidence and increased awareness of the issue's urgency can drive coalition building to promote the introduction of pesticide regulation. In nascent subsystems, where trust between different communities may still be evolving, science communication and non-academic dissemination in the form of policy briefs [3] blog posts can help to reduce uncertainty, facilitate exchange, and raise awareness (Cairney & Oliver, 2020; Evans & Cvitanovic, 2018).

Action plans: Enhancing policy cross-sectorality in mature subsystems

In the mature subsystem studied here, the foundation for policy action was laid by stakeholder coordination of values and attitudes and collaboration (as well as mutual resistance) over the last decade to produce policy output addressing pesticide risk, facilitating consideration of the constitutional and

[3] To communicate findings beyond academia, three policy briefs were produced: two within a bigger project (PESTROP) for Uganda and Costa Rica, and one addressing the findings of the second article of this dissertation

legal basis for pesticide risk reduction (Wiedemann & Ingold, 2021). In this context, one option is cross-sectoral state intervention to reduce pesticide risks – not necessarily through coercive legislation but by action plans that are less binding or restrictive. As these action plans often serve as guidelines for implementing the goals of a specific legislative period, they reveal the direction in which the subsystem is headed (Barzman & Dachbrodt-Saaydeh, 2011). However, these documents may also reflect a lack of political will and legislative support for the laws and ordinances needed to prioritize the environment and to allocate responsibilities along the entire food value chain. Given the level of sectoral gatekeeping in agri-food decision-making, less coercive action plans might promote cross-sectoral pesticide regulation more effectively than laws and ordinances.

Limitations

The dissertation has some limitations in terms of theory, research design, and methods. First, the underlying assumption that state intervention is needed to reduce pesticide risks is limited because in practice, some combination of state and market interventions (Mengistie et al., 2016, 2017) and self-regulation may prove optimal. Second, an approach that integrates top-down and bottom-up initiatives may find broader support among decision-makers, farmers, and agents of implementation. These actor groups have been considered only to a limited extent (i.e. not as individuals, but as collective groups, e.g., farmers' associations) even though their support for any type of intervention or policy influences compliance, enforcement, and ultimately policy success. It is therefore premature to conclude that the transition to safer pesticide management is facilitated by high potential for state-led pesticide risk reduction.

Second, while this dissertation presents an in-depth analysis of two distinct subsystems, generalization of the presented results is limited because the distinct case settings make comparison unfeasible. To address this limitation, future studies should employ a cross-sectional research design to compare multiple examples of similar subsystems (e.g., within the Sub-Saharan region or in Central America) in terms of policy preferences and outputs. The present research design is also limited in its focus on a single policy issue. While it provides a detailed account of pesticide risks as a global policy problem, exploring the different policy problems within the agri-food sector can further enhance our understanding of decision-making and the complex dynamics at work within this sector.

Finally, the present methodology only captures the target subsystems at a specific moment in time. A less static approach exploring the evolution and development of policy preferences and output over time would help to clarify the dynamics of policy design. Observations at multiple time points would improve the explanation of decision-making mechanisms in the agri-food sector.

Avenues for future research

In conclusion, these findings point to three avenues for future research. First, policy preferences and policy outputs are crucial components of policy subsystems and shape the policy process. However, we need to develop a fuller understanding of the dynamics of how policy preferences translate into policy output (often referred to as the *value-action gap*) (Dermont et al., 2017; Kollmuss & Agyeman,

2002). Experimental designs such as survey experiments can help to bridge this gap and to make causal inferences about why decision-makers act (or fail to act) on their preferences and values.

Second, despite this dissertation's novel identification of subsystem development as a distinctive feature, policy issues are not solved by good intentions or policy that looks good on paper. To capture the entire policy process by linking output to impact and outcome, there is a need for more thorough investigation of the implementation context (Bressers, 2007; Bressers & de Boer, 2013). Future research should investigate the horizontal and vertical inclusion of implementing agents in these subsystems, focusing on the challenges posed by multi-level governance structures in the agri-food sector in order to understand what policies are implemented and why.

Finally, policy issues in the agri-food sector demand inter- and trans-disciplinary approaches to identify problems, identify desirable futures, and consider pathways for transition. Public policy research has long acknowledged that decision-making around complex problems is a multiactor process and demands a more contextual approach (Ansell & Torfing, 2021; Daviter, 2019; Ostrom, 1996). To that end, public policy research must be participatory and stakeholder-centered to enhance mutual understanding of problem contexts. Where public and private stakeholders shape decision-making, problem-solving can be enhanced through participation, exchange, and consultation that includes local communities.

Acknowledgments

The icons used in Figure 1 are obtained under creative commons license from The Noun Project ("policy" by Lars Meiertoberens, "collaboration" by Eko Purnomo , and "pesticide" by Kahalap).

Participatory knowledge integration to promote safe pesticide use in Uganda

Wicked problems exceed traditional sectoral and jurisdictional boundaries and involve multiple actors as stakeholders, victims, and culprits. Wicked problems inherently feature uncertainty and knowledge gaps. Science plays a crucial role in generating evidence for solving these problems and contributing to societal transformation. However, researchers may perceive and study problems detached from practitioners' perceptions of the world. We use the example of smallholder pesticide management in Uganda and the three types of knowledge approach, a framework borrowed from transdisciplinary research, to disentangle knowledge gaps. To identify these gaps, we integrated and co-produce knowledge in a two-day participatory workshop applying design thinking. Our results show, that a transition towards safe pesticide management depends on changes in the system, such as a revision and implementation of exiting regulation or professionalization of agro-dealers. Furthermore, this transition is only possible if interventions address target groups beyond the individual farmers (e.g. agro-dealers or district government officials). Compared to existing academic knowledge, co-produced knowledge provides a broader systemic perspective and yields more fine grained insights about potential new pathways. This investigation confirms, that practitioners' knowledge is more fine-grained and detailed, thus exemplifying how knowledge integration is essential to avoid a gap between what researchers investigate and what practitioners need.

This article was co-authored by Christian Stamm and Philipp Staudacher. Ruth Wiedemann was the lead author.

Introduction

Amidst ever more complex environmental issues and their inherent interdependencies between stakeholders, jurisdictions, and sectors, society seeks to address so-called wicked problems[4]. Science has the fundamental task of investigating such wicked problems to reduce uncertainty through scientific investigation and provide evidence for new pathways for action (Lemos, 2015). While decision-makers often lack a detailed understanding of problems' characteristics and dynamics (Burger et al., 2015; Ingold et al., 2018; Peters, 2017), researchers may perceive and study problems differently from involved stakeholders, who need applicable knowledge as a basis for decision-making (Kleinschroth et al., 2021; Schäfer & Kröger, 2016; van Stam, 2019). Achieving a societal transformation towards sustainability therefore requires that research questions are aligned with practitioners' perceptions of real-word problems. Evading the "old and powerful myth that any and all science inherently meets society's goals" (Lemos et al., 2018, p. 722), this transformation is only possible if knowledge is co-produced between researchers and practitioners. We use the example of smallholder pesticide management in Uganda to highlight where knowledge gaps appear between what practitioners need and what researchers investigate, and we discuss how closing these gaps might facilitate a transformation towards sustainability.

Global pesticide use has been growing in recent decades (Zhang, 2018); it now requires 3.5 billion kg active ingredients per year and amounts to a global market worth 45 billion US dollars[5]. Most pesticides are used in agriculture to protect crops and yield from unwanted infestation. Balancing the benefits and costs of pesticide use poses a particular challenge for agricultural regions, which often are located in low-and middle-income countries (Schreinemachers & Tipraqsa, 2012). In these contexts, agricultural production is often dominated by subsistence smallholder farming, where awareness and formal education are often limited, making pesticide applications risky, with potentially harmful effects for farmers and the environment.

Problems related to pesticide management are characterized by a high level of uncertainty about causes, effects, and solutions and are thus considered wicked problems (Allen, 2013) (see the Supplementary Material (SM) online). In this context, decision-making is typically challenged by opposing interests and underlying conflicts, and researchers can ameliorate this situation by facilitating innovation and providing knowledge (Delgado et al., 2019). Transdisciplinary (TD) research aims at generating knowledge which is meaningful to practitioners (Klein, 2020) and which creates a com-

[4]We define the following terms: **Wicked problems** are difficult to disentangle, are continuously evolving and have no clear solution. They extend across media such as air, land, and water; across political jurisdictions and landscape boundaries; and across traditional policy arenas. Additionally, it is almost impossible to hold one single stakeholder accountable for the emergence of these challenges (Rittel and Webber, 1973; see also Batie, 2008; Australian Public Service Commission, 2012; and Balint et al., 2011 for an applied definition of **wicked problems**). As **science**, we understand both natural science and social sciences, conceptualized as a quest for knowledge by researchers who investigate phenomena to generate academic knowledge. **Solutions** can take diverse forms. In this text, we consider public policies as one way of solving societal problems. Other solutions may include market interventions and institutional reforms. **Practitioners** are those who practice. We capture non-academic knowledge through their perspective. (For more information about the practitioners within our research, see the Methods section.)

[5]see also Global pesticide and agrochemical market to 2020: Market size growth and forecasts in over 60 countries by Report Buyer, last accessed June 18, 2021

prehensive problem understanding. In TD research, knowledge is conceptualized as being of three types: systems, target, and transformation knowledge. These are gathered, exchanged, compared, and synthesized from various sources, including from academic and non-academic stakeholders while defining strategies to address real-world problems (Adler et al., 2018; Sachs et al., 2019; Schneider & Buser, 2018). This transdisicplinary process yields co-produced knowledge (Howarth & Monasterolo, 2017; Kläy et al., 2015; Pohl, 2008)[6] which provides a holistic problem understanding across different scales and levels (Costanza, 2003). Here, we want to contribute to literature and consciously integrate and confront academic with co-produced knowledge (see Binder et al. (2010), Galvin et al. (2016), and Le Bellec et al. (2012) as examples of knowledge co-production related to smallholder pesticide management). This is why we pose the following first research question (RQ):

RQ 1: What is the evidence for a gap between co-produced and academic knowledge about smallholder pesticide management?

The complexity of sustainability issues requires integrative approaches, which challenge conventional knowledge production and solutions (Maher et al., 2018). To co-produce systems, target and transformation knowledge, participatory approaches are used to to identify practitioners' needs, disentangle their problems, and gather a comprehensive understanding of the problem context [7]. Design thinking (DT) is an approach that explicitly addresses characteristics of wicked problems such as multi-stakeholder perspectives, social complexity, and the difficulty of defining a straightforward solution (Buchanan, 1992; Dorst, 2010; Fischer, 2015). This participatory, bottom–up approach offers opportunities for the actors involved to assume ownership and commit themselves to further developing targeted interventions. In this paper, we use DT as an approach to integrate knowledge and thereby contribute to co-producing the three types as knowledge as we "start with the issue or problem and, through the processes of problem solving, bring to bear the knowledge [...] that contributes to a solution or resolution" (Meeth, 1978, p. 173). The DT approach has been applied in the Global South to resolve design issues in architecture (Katoppo & Sudradjat, 2015), urban planning (Delz et al., 2017; Raynor et al., 2017), and sustainable business models (Geissdoerfer et al., 2016). Regardless of a growing literature on pesticide management in the Global South and the acknowledgement of a gap between academic and non-academic knowledge in this context (see for example Liebig et al., 2016), there is little research about DT as a participatory approach to facilitate a better understanding of the problem context related to smallholder pesticide management. Consequently, we address our second RQ:

RQ 2: How does design thinking support knowledge integration about smallholder pesticide management?

This paper makes a two-fold contribution: first, we match the consecutive steps of DT to the three types of knowledge (Adler et al., 2018). We conducted a participatory workshop at the end of a re-

[6] Co-production of knowledge refers to "a collaborative process of knowledge production that involves multiple disciplines and stakeholders of other sectors of society" (Pohl, 2008, p. 47).

[7] For an overview of different participatory approaches, see Akademie der Naturwissenschaften Schweiz (last access: June 18, 2021); Jacobi et al. (2020) and Lux et al. (2019).

search project to integrate and co-produce knowledge with various DT tools. We then used the results of the workshop to compare our own academic knowledge with the co-produced knowledge to identify knowledge gaps. We conclude with an outline on how this participatory approach contributes to a sustainability transformation through problem definition and identification of actionable solutions. Second, we have selected pesticide management in the Global South as our problem context. Smallholder pesticide management is a rather novel policy issue and the need for risk reduction is often overshadowed by political narratives promoting intensified agriculture to ensure economic growth and food security (Stein & Luna, 2021). Grasping problem perception and co-producing knowledge in this context can help identifying new pathways for safe pesticide use that target different components of the system under investigation.

In this research, we expect to find gaps between the three types of co-produced and academic knowledge. *Systems knowledge* captures how stakeholders perceive the problem. We therefore expect different prioritizations of systems' boundaries, components, and processes. *Target knowledge* captures actors' values and beliefs about a more desirable future. Here, we expect practitioners to prioritize targets that are addressed only to a limited degree by academic work. Furthermore, we expect a target knowledge gap to offer a potential explanation for ineffective interventions due to a focus on artefact problems deduced from prior research as opposed to the real needs of non-academic stakeholders. *Transformation knowledge* captures how to move from the problem situation to a more desirable future. We expect co-produced knowledge to be more fine-grained and adapted to specific contexts, and thus to provide insights into obstacles hindering the successful implementation of research-recommended interventions.

The remainder of this paper is structured as follows: In the Methods section, we introduce our case, the participatory workshop, as a method for knowledge integration, DT as a systematic approach to facilitating this process, and our criteria for evaluating the workshop. In the Results section, we elaborate on the co-produced systems, target and transformation knowledge, and whether the workshop can be considered a success. We then confront the co-produced knowledge with existing literature to discuss the gaps within the three types of knowledge. We close this paper with a brief conclusion, including recommendations for closing the gaps and an outlook for future research.

Methods

Case

Our case is located in Uganda, which offers a typical example of smallholder pesticide management turning into a wicked problem: Agriculture is considered to be the backbone of the country's economy (Rwakakamba, 2009), accounting for around 40% of the GDP and employing 80% of its labor force (Karungi et al., 2011). Many of the farmers operate as smallholders, cultivating their own land, providing food for their own families, and selling their surplus on local markets. A growing number of farmers are cultivating products for commercial purposes. Pesticides are applied to protect crops and livestock and for vector control. On-farm pesticide management is a growing issue: Kateregga

(2012) as well as Staudacher et al. (2020) identify various challenges in pesticide management in Uganda, such as a lack of information on agro-chemicals; violation of the transportation and storage rules; lack of proper storage facilities; inadequate use, handling, and application of products; and inappropriate disposal of empty containers (Kateregga, 2012; Staudacher et al., 2020). The various steps along the pesticide value chain (see Figure 2) are governed by a regulatory framework including acts, regulations, and policies (e.g., the Agricultural Chemicals Control Act of 2006). Despite these regulations, previous studies have underlined a lack of compliance, difficult enforcement, and illegal practices (Oesterlund et al., 2014; Okonya & Kroschel, 2015).

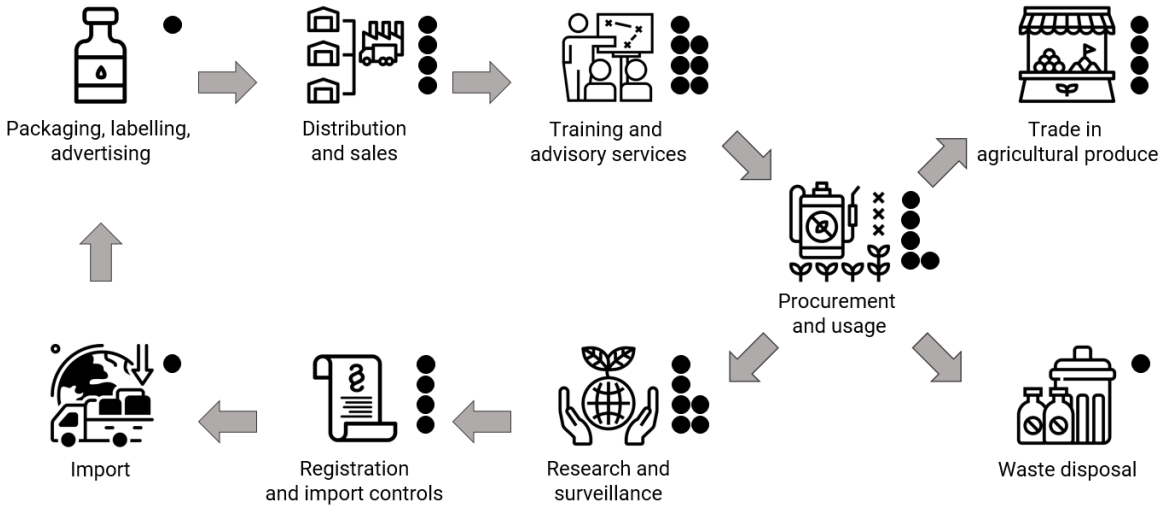

Figure 2: The various steps along the pesticide value chain, own elaboration. This is an ideal-typical representation of a complex value chain; in this simplified chain, we illustrate only the consecutive steps, not interactions that happen across and between steps. The black dots indicate where we would place the 33 workshop participants.

In Uganda, responsibilities for pesticide management are decentralized, making district government the protagonists of enforcement and even of formulating by-laws (Bazaara, 2003). Alongside governmental agencies and ministries, donor organizations and non-governmental organizations (NGOs) play a crucial role in sensitizing and capacitating smallholder farmers about pesticide management (Delgado et al., 2019). These stakeholders from the private sector shape matters related to pesticide management in Uganda, because central and district governments lack the financial and human resources to meet the demand for information provision (Isgren, 2018).

Workshop design and participants

Our goal was to present our research findings and validate their relevance with the local stakeholders (see Winkler et al., 2019 and the SM online for more information about the PESTROP project). We consciously chose to conduct the workshop at this stage of the research process rather than the ideal-typical TD setting, in which knowledge exchange is facilitated at the beginning of and/or throughout the research process (Hoffmann et al., 2019). We took the dissemination of new academic knowledge (output from PESTROP project) as the point of entry for the workshop and used the workshop to compare and validate this knowledge with non-academic knowledge. To disseminate the results from

this research and integrate academic and non-academic knowledge, we invited a diverse group of 33 stakeholders from various levels and sectors (see Table 1 for more detail) for a two-day participatory workshop. Our previous fieldwork in the case study area had acquainted us with the stakeholders influencing or affected by pesticide management. It was our goal to include stakeholders who are crucial to the various steps along the pesticide value chain in Uganda and Waksio District. With support from our local collaborators, we were able to find suitable participants to cover all nine pesticide value chain steps (see Figure 2). Stakeholders originated from diverse decision levels and sectors, which represents the complexity of the issue covered in the workshop. We also selected stakeholders that represented a broad age spectrum (between 25 and 65 years), among whom gender was distributed as equally as possible, and who covered various hierarchical levels (e.g. national government representatives and local smallholder farmers). To ensure privacy, we abstain from providing further detail.

Actor type	**Level**	**Group size**
Representatives of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)	National	4
Agricultural extension workers	Local	4
Environmental and agricultural officers from district government	Local	4
Farmers	Local	5
Representatives of agro-input business (synthetic and organic pest management)	Local/national	6
Representatives of NGOs engaged in the promotion of safe pest management	Local/national	6
Foreign scientists (excluding the three facilitators)	International	4
Total number of participants		*33*

Table 1: Participants of the design thinking workshop

Workshop facilitation and organization was provided by the first and third authors of this manuscript. They did not have any previous experience in conducting DT workshops. The second author was an active participant in the workshop and had never participated in a similar format (for a critical self-reflection of this dual role as authors of this manuscript and facilitators and participant of the workshop, see the SM online).

Structure of the workshop to integrate the three types of knowledge

We follow the general idea of DT as an approach to facilitate participatory knowledge integration, using a variety of tools (see Table 2)[8]. DT can best be conceptualized as an iterative, human-centered process or approach to solving problems through creativity. Various schools and models propose different steps and phases of flare and focus [9] to facilitate DT (see Design Council, n.d.; IDEO, 2015). The workshop was conducted in five separate, consecutive steps: understand, observe, define, ideate, and prototype. Understand, observe, and ideate are steps that allow participants to fully explore other stakeholders' values, worldviews, and perceptions of the problem and solution, which are key traits

[8]For an extensive overview of tools used in DT, see Lewrick et al. (2018) and Plattner (2010).

[9]The flare phase corresponds to broad ways of thinking, where participants generate as many insights and ideas as possible while keeping an open mind. The focus phase entails narrowing down ideas to generate selective problem statements (Woolery, 2019).

of wicked problems. The define and prototype[10] stages seek a synthesis of these diverse problem perceptions and pathways for intervention.

Type of knowledge	Step of DT	Tool
Systems knowledge: Analytical or descriptive knowledge about specific societal problems	Understand	Rich picture: grasp mental models of stakeholders (Checkland, 2000; Cristancho et al., 2015)
	Observe	Speed-meeting: exchange problem perceptions (Long, 2009)
Target knowledge: Normative knowledge about values and norms related to a more desirable future	Define	"Who needs what because of what?" and "5 why's": come up with a problem statement (Lewrick et al., 2018; Plattner, 2010)
Transformation knowledge: Practical knowledge about how to transform an existing problematic situation into a better one	Ideate	Brainwriting: brainstorm about potential solutions (Heslin, 2009)
	Prototype	Storyboard: develop one solution in detail (Andriole et al., 1989)

Table 2: The structure of the workshop following the three types of knowledge and design thinking

Integrating systems knowledge. In steps one and two of the workshop, understand and observe, participants disentangle the specific societal problem, pesticide management, by defining the boundaries, the components, and the relevant processes in the system. The outcomes of the first step are rich pictures (see Table 2). Participants illustrate the components of a complex situation, share their own perceptions and learning from exchange with others (Bell et al., 2019; Cristancho et al., 2015). In the second step, observe, participants in speed meetings discussed their open questions about the issue of pesticides with other participants. This step was followed by group-wise collection of the key insights of the day. To conclude the first flare part of the workshop, we asked participants to prioritize these key insights.

Integrating target knowledge. The third step, define, unveils the target knowledge, which captures values and beliefs about a more desirable future. Although the overall goal, safe pesticide management, had been predefined by the workshop facilitators, we used this step to better characterize the targets that may be critical for a transformation towards safe pesticide management. This step advances beyond simple problem definition and encompasses a design vision for solution ideation (Both & Baggereor, 2009). The groups developed clearly understandable and communicable problem statements with the following formula: *Who (stakeholder group)* needs *what* because of *what (insights)?* (see Table 2).

Integrating transformation knowledge. In the fourth step, ideation, we asked participants to search for new potential solutions to the problem statement previously identified and defined, thus capturing their transformation knowledge (see Table 2). Each participant started explaining a potential option for intervention silently in written form before passing it on to their group members to complement (Lewrick et al., 2018). After three iterations, all options were discussed within the group, and each group constructed three main ideas to solve the issue. After a plenary presentation of their three main ideas, each group received feedback from the other workshop participants, after which each group

[10]DT usually includes a test stage, but this was not conducted in our case due to lack of time.

selected one of their three main ideas to be specified in more detail during the fifth, prototype, phase (see Table 2).

Workshop evaluation

Our second research question addresses the feasibility and benefits of using tools from DT to integrate knowledge. We collected feedback from the workshop participants at the end of the workshop with which to conduct a critical evaluation. We asked each of them for one positive and one negative statement about the workshop. All participants named one or more positive aspects (36 positive remarks), and most participants named one or more negative aspect (24 negative remarks). For this publication, we applied the evaluation criteria from Tobias et al. (2019) (see Table 3), which are typically used to evaluate TD research. We therefore translated and interpreted the participants' feedback to match the evaluation criteria (see Table A1 in the SM online for the original feedback).

Objectives of the workshop	**Criteria specifying the objectives**
1. Achieve a feeling of joint problem ownership among the project participants	All group members' knowledge is considered important.
2. Facilitate the interaction between stakeholders with different problem perceptions	New perspectives/ideas are developed due to the confrontation with other group members' problem perceptions. Joint products are developed (definition of new pathways for safer pesticide management).
3. Enable the workshop participants to link abstract (academic) with case-specific (non-academic) knowledge	Experiences with other knowledge types (both academic and non-academic) are integrated. New interfaces between the different types of knowledge (academic and non-academic) are discovered.
4. Encourage the workshop participants to incorporate the shared knowledge in their real-world situations	The participants are motivated to disseminate the jointly developed knowledge in their real worlds. Ideas are generated for new approaches and activities in the participants' own real worlds. Ideas are developed for new collaborations between groups that have not yet worked together.

Table 3: Evaluation of the DT workshop, excerpt and adopted from Tobias et al. (2019)

Results

The following subchapters present the knowledge co-produced in the workshop following the DT approach and tools.

Systems knowledge

Participants' systems knowledge was integrated in the first two workshop steps: the participants illustrated their perspectives on how they experience and interact with pesticides in their daily lives, first individually (Figure 3) and then in a group discussion among peers of the same stakeholder type (Figure 3, see also Table 1). In the subsequent step, participants paired up and compared their worldviews with their partners', noting the most important insights. These key insights were then gathered group-wise, followed by a prioritization across all key insights. Figure 4 displays the summarized

results: *Agro-input dealers' services* and *gaps in policies and regulations* received the most votes overall, followed by eight other insights.

Based on these first insights, the main stakeholders of interest within the system are farmers, agro-input dealers, government agencies, and society as a whole. Processes concern on-farm management (e.g. pesticide exposure, PPE use), distribution of pesticides (e.g., agro-input dealers and illegal pesticides), and regulatory processes (e.g. governmental policy formulation and sensitization). The boundaries of the system largely correspond to the pesticide value chain (see Figure 2), but components such as training, advisory services, research, and surveillance are of lesser importance.

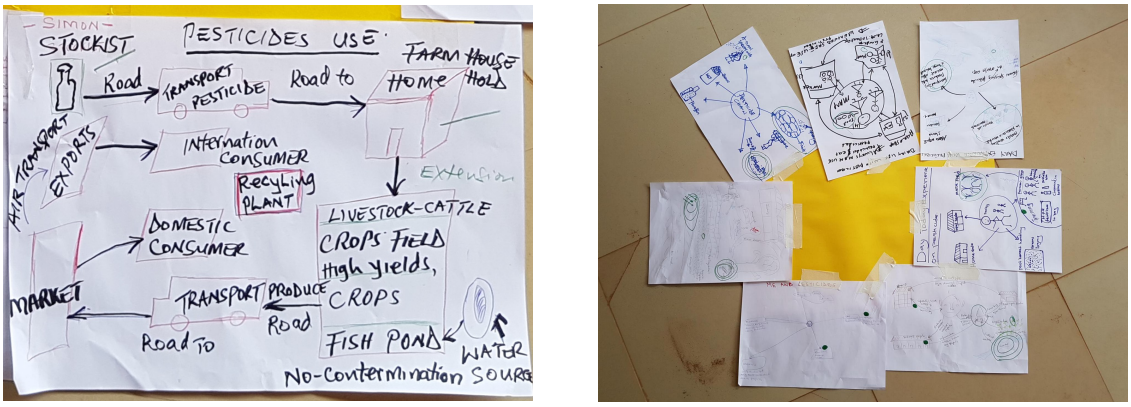

Figure 3: Individual (left) and group (right) rich picture

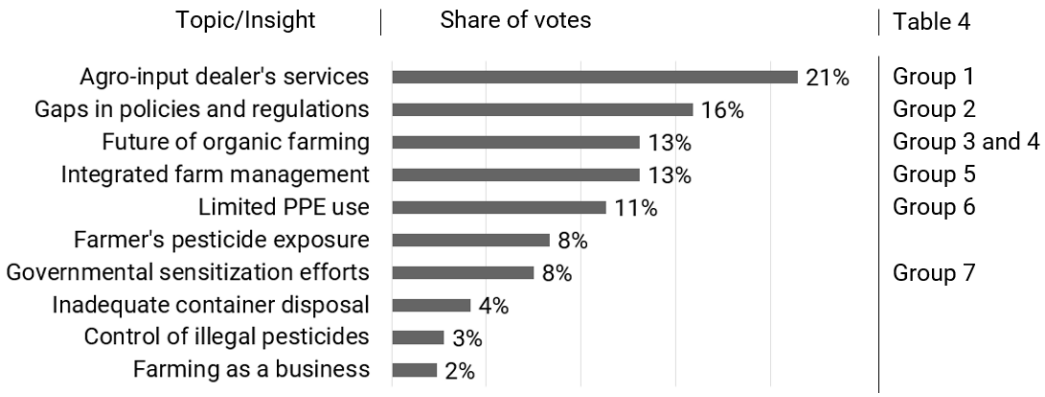

Figure 4: Prioritization of insights: Number at outer end indicates share of total votes per insight/topic. PPE: Personal protective equipment.

Target knowledge

Once the participants had selected their key insights (see Figure 4), they formed seven groups according to their interest in these insights. Each group drafted a problem statement with the following formula: *Who (stakeholder group)* needs *what* because of *what (insights)?* The problem statements capture the importance of goals, or what they regard as relevant target knowledge in the system, to reach the overall goal of safe pesticide management (see Table 4). Substantial interest in the topic of the future of organic farming led us to split the topic between two groups (Table 4). Participants perceived farmers, extension officers, agro-input dealers, and government agencies to be the main

stakeholders mentioned in the targets for safer pesticide management. Although these stakeholders appear along the steps of the pesticide value chain (see Figure 2), industry, research agencies and large-scale pesticide distributors were not regarded as key stakeholders within the targets. Targets in the quest for safe pesticide management are related mainly to enhanced skills, information, and training.

Transformation knowledge

In the ideate and prototype phases of the workshop, participants were encouraged to brainstorm potential new ways forward. The proposed pathways for action (Table 4, 4th column) show which aspects are crucial to consider prior to designing interventions and public policies. At a *macro* level, one important aspect is the decentralization of training and services provided by central government agencies (Group 1). Extension officers and agro-input dealers often lack the financial resources to attend training in a larger town (Group 5). Training activities might thus fail, and these actors lack proper training, which is essential because they are the main information providers to farmers. Incentives such as certificates of attendance (Group 7) and restrictions or penalties (Group 1) are also considered key to enhancing the professionalization of these actors. At a *meso* level, coordination is a key aspect for successful interventions and public policies (Group 5), especially among central and decentralized agencies. To achieve coordination, workshop participants mentioned consultations as a potential platform for fostering collaboration and exchange and linking these agencies via research projects (Group 2). Coordination among initiatives, such as interventions by NGOs and training by extension officers, is also crucial to avoid overlaps and inefficiency. At a *micro* level, financial and human resources are key to compliance and success. Farmers, extension staff, and agro-input dealers need financial support to afford equipment, transportation, and gasoline (Groups 6 and 7). A lack of financial and human resources impedes the system from transforming towards safe pesticide use (see Table 4 for a summary of the co-produced knowledge).

In the paper-based prototype step of the workshop, in which participants elaborated on their preferred intervention, these macro-, meso-, and micro-level components became even more evident. We show one illustrative example of a prototype: the PPE group, which elaborated the bulk purchase of PPE (see Figure 5). The group suggested that farmer associations buy durable, comfortable, high-quality personal protective equipment in bulk. The money saved will be forwarded, benefiting agro-input dealers and farmers.

Using tools from DT to integrate knowledge

We successfully integrated academic and non-academic systems, target and transformation knowledge in the workshop. To evaluate this success, we converted the feedback given by the participants (see Table A1 in the SM online) into evaluation criteria, as described in the Methods section. First, our workshop process achieved joint problem ownership by all participants. Mixing individual, group-wise, and plenary sessions and integrating non-academic and academic participants in each group enabled everybody's voice to be heard, and participants felt that they were part of both problem and

System knowledge (Group formation, original*)	**Problem statement (Original*)**	**Target knowledge (Authors' interpretation)**	**Transformation knowledge (Original*, selected intervention in italics)**
Group 1 Agro-Input Dealers: Are they offering the best service to farmers?	Agro-input dealers need more professionalization because they need to give accurate subscription and instructions along with safe use and handling of chemicals to the farmer	Professionalized agro-input dealers.	*Customized, decentralized training at low cost.* Certification label of for good practices. Restrictions and penalties for noncompliance.
Group 2 Policy and Regulation: Gaps in PR and PR implementation challenges	The government of Uganda needs to revise the existing public health and environmental policies because they need to safeguard consumers from indirect pesticide exposure in food and water	Revised existing public health and environmental policies.	*Research: there is need to undertake research by both public and private players (Research institutions, CSO), to generate facts on consumer exposure to pesticides and existing policy groups.* Bench-marking: relevant policymakers (MAAIF, MoH, MoWE, Parliamentarians on selected committees) need to undertake visits to countries with good consumer protection policies to learn best practices. Stakeholder consultations: The relevant policymakers (see above), need to spearhead the process of consulting different players at different levels to generate ideas on protecting consumers from pesticide exposure to inform policy formulation.
Group 3 Future of Organic Farming A: market access, policies, volumes of biopesticides	Farmers and the entire community need organic farming information and accessibility of organic inputs because they don't know the benefits of organic farming.	Farmers and entire community informed about benefits of organic farming.	*Sensitization through organized community meetings, development of flyers, radio talk shows on organic farming, Whatsapp groups to farmer communities, establish demonstration sites.* Avail organic farming inputs to the community through establishment of organic agro–input centers within the farming communities. Government develop policies that support promotion of organic farming; these can incorporated in work plans and budgets for extension workers.
Group 4 Future of Organic Farming B: market access, policies, volumes of biopesticides	Extension workers need technical explanations because they are the ones who can change farmers' attitudes towards organic farming.	Technically skilled extension officers	Refresher courses for extension workers. *Farmer group formation and establishment of demo sites/exchange visits.* Regular Monitoring + Evaluation.
Group 5 Integrated Farm Management: Prevention before curation	Extension workers need more support because they need to close the farmers' knowledge gap for adopting integrated pest management	Supported farmers by extension officers to adopt IPM.	*Recruitment and training of extension staff.* Coordinate and harmonize activities of involved partners. More resources for doing extension work.
Group 6 PPE use and Pesticide knowledge: Lack of best practice	Farmers need PPE to be less expensive because they cannot afford it.	Affordable PPE.	*Bulk purchase of PPE: Farmers form association/groups for bulk purchase of PPE at discounted amount and reduced transport cost.* Tax reduction: Government to reduce tax on PPE and compensate by increasing a relative percentage of tax on pesticides. Also should create policies that encourage local production of PPE, e.g. low interest rate loan for local manufacturers. Increasing farmers income : through encouraging formation of savings groups/cooperatives/farmer union/associations for cheap and quick access to loan for the purchase of PPE.
Group 7 Sensitization: Missing on all levels	Farmers need more information on pesticide use from the extension workers, NGOs and other organizations because some agro-input dealers also lack information about pesticide use	Farmers informed by extension workers, NGOs and other organizations about pesticide use.	Government trains extension workers and agro-input dealers and awards them certificates. Employ agents which routinely visit the farmers and report back to the extension workers. *Drama group with live music about pesticide use.*

Table 4: Summary of the co-produced knowledge. *Original: indicating unchanged phrasing from the workshop. Abbreviations: CSO, community service organization, IPM, integrated pest management, MAAIF, Ministry of Agriculture, Animal Industries and Fisheries, MoH, Ministry of Health, MoWE, Ministry of Water and Environment, NGO, non-governmental organization, PPE, personal protective equipment, PR, Policy and Regulation

solution. Additionally, rules were defined at the beginning of the workshop that guided the entire process and enhanced ownership of it. Participants mentioned in the feedback session that they felt it was a truly participatory process and that the academic knowledge was integrated well in the workshop. Second, the workshop enabled stakeholders to interact, but only to a limited extent. The workshop delivered some practical ideas for solutions (see Figure 5).

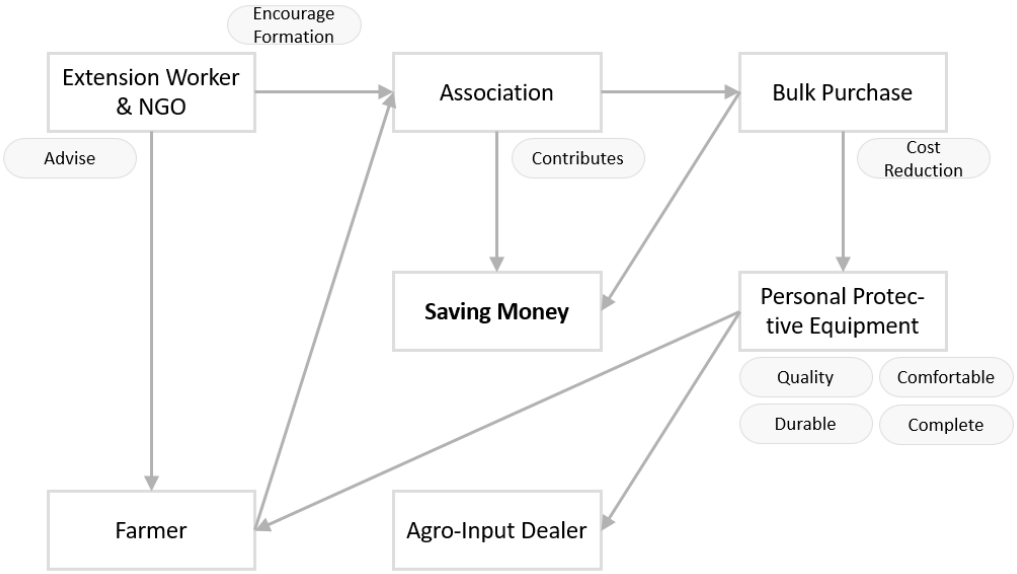

Figure 5: Prototype of the PPE group to purchase PPE in bulk. The original drawing lacked contrast, so we here display a digital rendering of the drawing.

However, time constraints prevented the development of a joint product. Participants thus criticized the workshop for being too short and not including all stakeholders evenly. Third, workshop participants linked academic and non-academic knowledge. Non-academic participants encountered research findings, which was generally considered a positive output. Researchers encountered non-academic knowledge which led to the formulation of new research questions and follow-up research projects (see Discussion). Fourth, even though participants were encouraged to incorporate and apply the knowledge they had gained in future projects by gathering commitments from them in the last part of the workshop, we do not know whether these commitments yielded action. Lastly, we provided space through the extensive breaks, allowing participants to make new acquaintances and develop new opportunities for collaboration.

The workshop was implemented successfully thanks to a range of organizational and informal aspects. First, the same moderators guided the whole process and followed a predefined timeline. Second, the venue of the workshop included a large hall with space for group tables and a plenary with a sound system, beamer setup, and complete catering. Participants felt very comfortable in this space and appreciated the venue. Third, we kept participants active in extensive opening and closing activities on each day. We provided coffee breaks and lunch and made sure to take a group photo and include ice breakers, energizers, and warm-ups to keep the atmosphere friendly. The entertainment component of this workshop was also highly appreciated, and participants underlined that “it was never boring”.

Discussion

Discussing the knowledge gap...

In this paper, we integrated academic and non-academic knowledge to enhance the academic problem understanding of pesticide management. The following chapter discusses the extent to which the co-produced knowledge is different from our own academic knowledge and whether we find knowledge gaps within each of the three types of knowledge. We also discuss the extent to which the DT approach lends itself to integrating diverse types of knowledge and to closing potential gaps.

... in systems knowledge

To our best knowledge, research on pesticide management in contexts related to the Global South has focused on on-farm management among smallholder farmers. However, workshop outcomes indicated that farmers are not exclusively responsible but fall victim to the system actors surrounding them: the agro-input dealers as the most immediate source of information on pesticide management and government agencies as the regulators of pesticide management practices. Agro-input dealers' practices and knowledge have attracted little attention so far (for an exception, see Lekei et al., 2014). Moreover, pesticide policies' formulation and enforcement have been investigated only to a limited extent (Karlsson, 2004a; Mengistie et al., 2017; Van Hoi et al., 2013). Such gaps in research could be closed by integrating insights from participatory approaches: in our case, the participation of practitioners from diverse backgrounds (farmers, district government officials, and pesticide retailers) enabled us to identify more detailed systems knowledge, confirming our expectations about systems knowledge: there are differences in the academic and non-academic prioritization of systems' boundaries, components, and processes.

... in target knowledge

Safe pesticide management is not a straightforward goal, and the participants of the workshop selected seven targets that ought to be reached to ensure safe pesticide management in Waksio District and Uganda (shown in Table 4). The first target identified was professionalized agro-input dealers (Group 1). Often, these actors are the main source of information for the farmers and primarily contribute to how pesticides are applied on the field. Little research has examined agro-input dealers and how they receive and provide information. However, some studies recognize agro-input dealers and retailers as crucial actors of the system and see their key role as information providers (Jallow et al., 2017a, 2017b; Wang et al., 2015). The second target was revised public health and environmental policies (Group 2). This target concerning research and pesticide policies related to environmental and health protection is the subject of scientific investigation (Loha et al., 2018; Mengistie, 2016; Mol, 2009). Most of these studies come to similar conclusions: policy revisions are necessary to protect humans and the environment from pesticide risks. However, we could not find studies characterizing this revised legislation and how politically feasible these options are. Targets three, five, and seven concern informed farmers who need more information related to organic and conventional farming

to improve pesticide management decisions. As mentioned before, research on individual farmers is dense, and many studies have investigated their knowledge, attitudes, and practices in pesticide management. The effects of better information and training on farmers' willingness to adopt organic farming and more sustainable farming practices have also been investigated (Aidoo & Fromm, 2015; Ma et al., 2017). Group 4 considered technically skilled extension officers to be a crucial target for safe pesticide management. Research on extension officers and agents themselves is rare, but they are considered key in farmers' pesticide management practices and clearly play an important role in resolving farmers' unsafe pesticide management (Abadi, 2018; Hashemi et al., 2012; Timprasert et al., 2014). Lastly, affordable PPE is another key target for safe pesticide management. Making PPE more affordable for farmers has been discussed in research, which has even proposed several ways of reaching this goal (Feola et al., 2012; Henry & Feola, 2013).We find that key actors in the system and their needs are addressed to only a limited extent by research, such as questions related to agro-input dealers, government agencies, and consumers. Their needs have to be considered by research to eventually design interventions that actually improve situations. By taking non-academics and their target knowledge into account, researchers can learn to shift their focus and provide the demanded evidence.

... in transformation knowledge

We acknowledge that some pathways for action proposed at the workshop have been covered previously, such as sensitization programs in communities to provide information about the disadvantages of pesticide use (Hashemi et al., 2012; Jørs et al., 2014), the need to establish farmers' cooperatives (Zhu et al., 2014), and the importance of monitoring and surveillance along the pesticide value chain (Houbraken et al., 2016; Vaidya et al., 2017). Nevertheless, the workshop provided essential, context-specific details to enhance interventions and even policy effectiveness at the macro, meso, and micro levels and the feasibility and enforcement of interventions and public policies. Coordination among agencies and the provision of financial and human resources are key for a transformation towards safe pesticide management.

Significance of this research within the wider research scholarship

This research underlines the significance of participatory approaches to integrating and, as a result, co-producing knowledge. In general, the participation of users and target groups of proposed interventions allows us to grasp the full complexity of wicked problems, and to align diverse problem perceptions and to formulate new pathways in accordance with users and target groups (Sanders & Stappers, 2008; Simonsen & Robertson, 2012; Ssozi-Mugarura et al., 2017). Additionally, participatory approaches build bridges and enhance social and cultural understanding between researchers and users and, as in our case, local communities (Sabiescu et al., 2014). In general, our results show that it is crucial to continue to provide venues with room for exchange and collaboration to foster a broader understanding within and across stakeholder groups, which is in line with research on participatory design and participatory action (Bjögvinsson et al., 2012; Luck, 2018; Susman & Evered, 1978). More specifically, our results show that participatory approaches are beneficial to enhancing

mutual understanding for problem contexts between researchers and the researched, and that such an approach is also desirable for linking decision-makers with the governed. Within the workshop, the group focusing on policy and regulation considered stakeholder consultations (see Group 2 in Table 4) as a way of supporting the revision of existing public health and environmental policies in Uganda. This solution has a strong participatory component to it, and policy design research has long acknowledged multi-actor processes and the need for more contextual approaches to tackling wicked problems (Ansell & Torfing, 2021; Daviter, 2019; Ostrom, 1996). In Uganda, where public and private stakeholders shape decision-making about pesticide management, collaborative governance arrangements could be enhanced through participatory processes, which provide the chance for exchange and consultation.

Making a participatory process work

The following paragraph discusses the various aspects contributing to a successful implementation of the workshop as well as cross-fertilization with follow-ups.

An exchange between academic and non-academic stakeholders is desirable at the very beginning of a project, for instance to formulate research questions and to test feasibility, or throughout the project to enable feedback and enhance mutual learning (Hoffmann et al., 2019). We conducted the workshop at the very end of a research project, in the dissemination phase, with the main objective to integrate and validate knowledge, rather than collecting and gathering new data. We conclude that this timing is also beneficial in various ways: First, the complex thematic and societal context in which we operated requires case knowledge, familiarity with the needs of stakeholders, and an established network to conduct and implement a workshop. Thanks to our exceptional long-standing research collaboration with local partners, we had access to a diverse pool of participants and had already been in touch with most of them before the workshop. Second, conducting the workshop at the end of the research project, enabled us to reflect on results with the stakeholders involved in the issue under investigation. The workshop enabled us to validate our findings and we were able to identify the gaps between academic and non-academic knowledge. A major finding of the workshop was the need to investigate agro-input dealers, who play a crucial role both as pesticide distributors and as information sources for farmers. This insight was used to design and conduct a follow-up project investigating the knowledge, attitudes, and practices of 402 agro-input dealers in Uganda (Staudacher et al., 2021). Other key insights, such as the need to revise legislation, has led to another research project investigating how stakeholders from different levels and sectors collaborate to regulate pesticide management.

Strengths and limitations of the DT approach

Wicked problems in the Global South are often investigated by researchers from the Global North. In this research context, mutual familiarization is necessary to overcome socio-economic and cultural differences between practitioners and researchers (Hurni & Wiesmann, 2014). DT facilitates familiarization in a participatory processes and thus lends itself well to discussing wicked problems

and actionable interventions. First, it enables participants to follow a clear structure with alternating elements of flare and focus. The DT sequence of steps forces a systematic approach on the participants, which helps to keep heterogeneous groups in line with the process, and it worked nicely in our case despite the participants' diverse backgrounds. Second, even though the overall structure is set, within the different steps, facilitators are free to try various tools (see tools used, Table 2). Third, the approach balances rigidity and flexibility, thus remaining adaptable to a range of settings and groups of participants.

Similar to other participatory approaches, its dependence on adequate participation of stakeholders is a major limitation of the DT approach. The application of flare and focus elements needs to be clearly guided to avoid participant distraction. Heterogeneity and group dynamics can also impede the DT process: hierarchies, societal norms, prejudice, and differing levels of mental ability and courage need to be addressed by the facilitators and resolved where possible, in our case through ice breakers and an informal setting including coffee breaks and use of first names. Even so, neither long-lasting learning nor a shift towards more responsible pesticide management are guaranteed by this process. A full cycle of knowledge exchange leading to the implementation of the interventions proposed in workshops depends on the willingness and ability of participants and local communities to act on the outputs of such workshops (Bovaird & Loeffler, 2012; Sufi et al., 2018). Nevertheless, the application of such knowledge exchanges as standard tools can support the formulation of research questions.

Conclusions

Our expectations of the knowledge gaps were confirmed in all three knowledge types. A major finding of this research was that not all research represents the practitioners' perceptions of the problem or their needs. Some links, such as between actors and targets only became evident in the workshop and through the successful integration of knowledge (e.g. extension officers need money for fuel to reach farmers and educate them about safe pesticide use). Research may fail to incorporate and reflect the reality of people living within a studied system. Whereas previous studies have investigated farmers' attitudes and risk perception, this workshop has shown that, to achieve a transformation towards safe pesticide use, research needs to broaden its scope away from farmers to other stakeholders such as agro-input dealers and decision-makers. Studying diverse stakeholders, from local farmers to international manufacturers, can provide research with a systemic understanding of the problem situation, thus leading to better-informed decisions. Closing the knowledge gaps requires strong bridges to be built between research and practice through participatory approaches, fostering exchanges, and enhancing understanding. However, doing so requires two essentials that seem difficult to find in research: first, establishing long-term relationships, which are not always compatible with funding schemes; and second, maintaining long-term relationships, which conflicts with the time researchers need for writing publications and applying for funding. Even more, conducting similar studies across national and cultural borders entails strong relationships between collaborators, these collaborations are challenged by short-term nature of project-based research and the long-term nature of academic output production (e.g., development of publication after project termination and peer review processes).

Closing the gap between non-academic and academic knowledge, and thus between practice and research, contributes in various ways to a sustainability transformation. For practice, closing the gap can foster ownership and acceptability of identified pathways forward. The more that various stakeholder groups participate in knowledge production, the more they feel that they are part of the solutions (Fischer, 2015). Closing the gap also allows research to escape the pitfalls of disciplinary silos and oversimplification of complex issues (Francis et al., 2008) and instead use innovative, integrative approaches to understand complex real-world problems (Söderbaum, 2006). For policy, closing the gap is fundamental, as decision-makers need evidence to design targeted public policies, select policy instruments for behavioral change, and implement these to reach desirable societal outcomes. By including stakeholders' perspectives prior to decision-making, issues related to compliance as well as differences between decision-makers and target groups can be addressed and solved upfront (Daviter, 2019; Podestá et al., 2013; Turnpenny et al., 2009). Participatory approaches are therefore valuable to policy analysts to "focus carefully and reflexively on the nature of the policy problems, their evolution, the experience and knowledge of relevant stakeholders and the prospects of effective action in different situations" (Head, 2019, p. 192).

Lastly, we briefly address potential avenues of research. First, this single case study provided contextual insights related to smallholder pesticide management; we thus refrain from generalizing the results. However, participatory approaches are necessary to value non-academic knowledge and enhance target groups' acceptance of proposed interventions. To foster safe pesticide management it is crucial to further integrate and co-produce knowledge, also related to other wicked problems in similar regional contexts (e.g., sub-Saharan Africa) to test the applicability of our results. Future research could benefit from drawing conclusions from comparative case studies and larger populations. Second, the process of participatory workshops could be reported more systematically to allow for quantitative comparisons between academic and non-academic knowledge, making the gaps between them measurable. Third, future research should investigate the effect of these workshop formats on participants. More precisely, the suggestion is for a long-term evaluation of the degree to which researchers include non-academic knowledge in their projects and to which practitioners further develop interventions as proposed in participatory processes.

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To intervene or not to intervene: Potential for targeted pesticide policy in Uganda

Targeted state intervention is needed to tackle complex environmental problems. However, state intervention faces rejection by some actors because these problems are typically cross-sectoral, multi-actor, and conflictual. To explore why some stakeholders nevertheless favor state intervention as an approach to environmental risk prevention, the study examines the case of pesticide risk prevention in Uganda. Using a mixed-methods approach that combined an online survey and face-to-face interviews, stakeholders were asked about their agreement with different policy instruments. In general, the results indicate strong preferences for state intervention in risk prevention, but these preferences vary across actors and levels. Correlation and regression analysis reveal that high threat perception and agreement with precautionary action are associated with preferences for preventive state intervention. However, external drivers like forum participation and cross-sectoral collaboration do not exhibit the expected effects. Based on these findings, the study suggests how future policy making can be enhanced and clarifies which settings promote state intervention to address complex environmental problems.

Introduction

To protect humans and the environment from the negative effects of environmental degradation, state intervention is needed in the form of targeted policies to counteract complex environmental problems and reduce environmental risks. These policies must address the problem in question both before exposure (*risk prevention*) and after (*risk response*) (Seifert et al., 2019). However, any intervention for *risk prevention* is controversial and may face opposition during the decision-making process because it entails behavioral change for target groups (Metz & Ingold, 2014), requires collaboration across different policy domains (Wiedemann & Ingold, 2021), and/or introduces costs that are difficult to estimate (Murphy & Gouldson, 2000). As an understanding of stakeholder preferences is therefore crucial in assessing the potential of state intervention in this context, the present study addresses the following general question: *What drives stakeholder preferences for state intervention in environmental risk prevention?*

To explore the drivers of stakeholder preference in this context, I adopt an innovative nexus-based approach that links the problem, the solution, and the political context. This approach makes four contributions to the relevant literature. First, an integrative approach that links the problem to the solution distances the researcher from conventional categorizations of state intervention (Vedung et al., 1998). Given the uncertainties, cross-sectoral responsibilities, and conflicting interests inherent in complex environmental problems, it is important to understand these problem characteristics in order to formulate adequate policy solutions (Ingold et al., 2018). By beginning from the nature of the problem itself, the study avoids conventional assumptions about risk control and acknowledges the potential of preventive measures as alternative or additional provisions for sustainable environmental management (Metz & Ingold, 2014; Xanthos & Walker, 2017).

Second, in linking solution to context, I draw on theoretical concepts from various literatures. To elucidate stakeholder preferences, I consider drivers explored by environmental and social psychology, including individual factors like threat perception (Vlek & Steg, 2007) and beliefs (Lindenberg & Steg, 2007). Additionally, the collaborative governance literature examines external drivers such as social relations (Metz & Ingold, 2017; Metz et al., 2018). Finally, the Ecology of Games framework scrutinizes the role of policy venues or forums in shaping policy outputs (Lubell, 2013). As settings characterized by uncertainty and limited knowledge, exchanges within these forums can foster shared understanding and joint policy action in relation to a given problem (Fischer & Leifeld, 2015). Together, these different literatures support a holistic investigation of stakeholder preferences and of micro-, meso- and macro-level drivers that are often only considered in isolation.

Third, this research innovates on the complex environmental problem under investigation: I take pesticide management as an example to illustrate the need for problem-driven solutions in environmental management. Farmers use agricultural pesticides to enhance productivity and meet consumer demands, but these pesticides also pose a threat to environmental ecosystems and human health (Bonner & Alavanja, 2017; Hayes & Hansen, 2017). At a global scale, the risks of pollution are high, and 64% of global agricultural land is at risk of pesticide pollution (Tang et al., 2021). This is a complex

problem (Allen, 2013) and solution-seeking necessarily involves multiple actors, values, and power constellations, requiring a multidimensional approach (Lee et al., 2019; Pedersen & Nielsen, 2017; Pedersen et al., 2020). In this context, targeted state intervention is considered necessary to protect natural resources and ensure sustainability.

A fourth and final contribution to the literature relates to the decision to investigate stakeholder preferences in the Global South, where the risks of pesticide use are especially pronounced because of the use of highly toxic or counterfeit products, a lack of protective equipment, and the unsafe disposal of empty containers (Rodenburg et al., 2019; Sharma et al., 2020). In many of these countries, however, pesticide risk prevention is neglected by policy makers, as the prevailing political narrative emphasizes agricultural intensification to ensure economic and food security. For that reason, an investigation of stakeholder preferences in the Global South invites reflection on policy solutions and theoretical assumptions that are currently of concern mainly in the Global North.

As an illustrative case study, I investigate stakeholder preferences and associated driver in Uganda to grasp the potential for state intervention in pesticide risk reduction. As a consequence of market liberalization and privatization of the agricultural sector, pesticide use and the distribution of the latter are ubiquitous in Uganda. In light of government passivity, non-governmental organizations (NGOs) and civil society organizations (CSOs) as well as private domain organizations have led most of the country's pesticide management and risk prevention initiatives (Isgren, 2016). In Uganda, pesticide use threatens environmental integrity, but it has proved challenging to find solutions that can secure the support of all stakeholders.

To collect the data, I used a mixed-methods approach, combining an online survey and face-to-face interviews to investigate stakeholders' individual attributes, including threat perception and agreement with overarching policy goals. To investigate external drivers, I looked at stakeholders' networks and extracted data on cross-sectoral collaboration; I also asked them about forum participation. To analyze the interplay between individual drivers and specific policy instruments, I used Spearmans rank-order correlations and regression analysis to investigate the influence of individual and external drivers on stakeholder preferences. The results are contextualized using qualitative data from the semi-structured interviews. By understanding how stakeholder attributes influence their preferences for state intervention, it was possible to identify aspects of the decision-making process that need to be strengthened to support holistic policy making and comprehensive land use management.

Complex environmental problems, solutions and the context

State intervention and the influence decision-makers exert over the addressees (also referred to as target group) (Hepburn, 2010) can best be captured via an investigation of policy instruments. Policy instruments are the 'active ingredients' of state intervention [11]. They are the tools or techniques that decision-makers have at their disposal to attain policy goals via a change in target group behavior (Howlett, 2014).

[11] The terms (policy) instrument and (policy) measure are used interchangeably throughout this text.

The instruments used to reduce environmental risks can be grouped according to different rationales (Mickwitz, 2003). The most prominent rationale is based on how coercive state intervention is, or in other words, a categorization of instruments according to the *restrictiveness* of state intervention (Thomann, 2018; Vedung et al., 1998). Policy scholars distinguish between three types of instruments of descending restrictiveness: regulatory or command-and-control (e.g. environmental quality or emission standards), economic or market-based (e.g., subsidies for pro-environmental behavior or taxes), and information or voluntary instruments (e.g. public awareness campaigns or guidelines about best agricultural practices) (Kaufmann-Hayoz et al., 2001; Vedung et al., 1998). However, when targeting environmental risks, there is a need to match instrument selection to the characteristics of the problem itself (Howlett, 2018; Krause et al., 2019). In other words, an additional grouping of instruments is based on the *target* of state intervention, or in other words, the phase in which environmental risks occur (e.g., inputs, process, or output) (Mickwitz, 2003; Schaub & Braunbeck, 2020).

Complex environmental problems appear on different scales, meaning that the ones causing the problem (i.e., polluters) are not necessarily the ones suffering from its effects (i.e. victims); the causes and effects are thus not equally distributed (Walls & Palmer, 2001). This conceptualization of environmental problems illustrates their complexity, where different sectors and stakeholders along the value chains of products need to be regulated to prevent and control risks. We can distinguish between preventive and reactive state intervention to address environmental problems (Blair, 2016; Bloemhof-Ruwaard et al., 1995), grouping policy instruments according to the targeted phase of a production process, value chain of a product, or environmental cycle. Even though research agrees that preventive state intervention is needed to effectively reduce environmental risks and to give justice to the complexity of environmental problems (Metz & Leifeld, 2018; Tosun et al., 2020), the potential for their introduction is limited for several reasons: First, preventive state intervention goes hand in hand with behavioral change (Landry & Varone, 2005; Metz & Ingold, 2017), which is why target groups and their representatives are opposed to preventive risk reduction. Second, complex environmental problems are related to uncertainty and contradictory problem frames (Cole et al., 2011; Fischer et al., 2017), which is why the long-term benefits of preventive problem solutions (Murphy & Gouldson, 2000) fall victim to the prioritization of non-environmental interests and successful lobbying for the benefit of short-term economic development. Third, due to uncertainty and increased environmental complexity, the costs of preventive state intervention are often difficult to estimate (Mantovani et al., 2017) and solutions to control risks at the end-of-the-pipe are introduced, as they entail less cross-sectoral collaboration and less behavioral change. Based on the underlying assumption that state intervention targeting risk prevention is less popular than state intervention targeting risk response, I focus on risk prevention as a strategy to target complex environmental problems in the remaining paper.

Linking solutions to the context

Different approaches have been proposed to better understand the potential for state intervention to tame complex environmental problems, including the study of the context to which state intervention

applies. This context is shaped by political constraints that are at work in the system under observation. These include key agents (i.e. policy actors or stakeholders[12]) (Gilabert & Lawford-Smith, 2012), and their attitudes and opinions regarding policy solutions at their disposal. In policy studies, this political constraint is often captured through an investigation of stakeholder preferences. These preferences for state intervention are crucial for the introduction of new policy solutions and are therefore important success factors when it comes to facilitating state intervention (Dermont et al., 2017; Tosun et al., 2020). Stakeholder preferences thus provide an opinion poll and inform about the potential of policy solutions to pass political decision-making in particular and of state intervention in general. Research shows, that in general, stakeholders' preferences for state intervention targeting complex environmental problems are high (Dietz et al., 2007; Metz & Leifeld, 2018; Metz et al., 2018), but some policy solutions face more opposition than others (Kammermann & Dermont, 2018). In a decision-making process, this can be fatal as stakeholders have the power to block these proposals and hamper state intervention (Keohane et al., 1998; Mickwitz, 2003). Stakeholders, in their role as bargaining and potential blocking agents in this process thus represent a crucial political constraint (Gullberg, 2013; Sager et al., 2020).

Complex environmental issues are highly contested and the actors involved in decision-making operate as representatives of subsystems with conflicting interests and goals (Kriesi & Jegen, 2001; Van Bueren et al., 2003; Weible, 2006). In this context, issues related to complex environmental problems concern a broader array of stakeholders (Bodin & Crona, 2009; Prell et al., 2009), including public and private actors[13] (Adam & Kriesi, 2007; Ingold & Fischer, 2014; Weible & Cairney, 2018). To explain how stakeholder preferences come about, literature proposes to study micro-, meso- and macro-level drivers: At the micro-level, environmental psychology provides insights about the role of individual motivations, problem perception, or "problem diagnostics" (Vlek & Steg, 2007, p. 10) as well as goal frames (Lindenberg & Steg, 2007) to shape actors' attitudes. At the meso-level, collaborative governance literature emphasizes the role of social interactions as a driver for stakeholder preferences (Metz & Ingold, 2017; Metz et al., 2018). Lastly, stakeholders' opinions and preferences are impacted by the institutional setting that surrounds them, also referred to as 'planning processes' or 'policy venues' (Lubell & Fulton, 2007, p. 541) in the Ecology of Games literature. In this analysis, I, therefore, consider these three types of drivers that impact stakeholder preferences for state intervention.

Drivers influencing stakeholder preferences for state intervention

Micro-level: Individual drivers

Behavioral studies have long investigated the effects of awareness and perceptions on pro-environmental behavior and claim that this investigation contributes to a better understanding of policy support (Dietz et al., 2007; Dietz et al., 2013). In policy literature, research acknowledges that the salience of the

[12]The terms stakeholder and actors are used interchangeably throughout this text.

[13]The actors are collective actors, a group that includes government agencies; academia; environmental, health or agricultural organizations; NGOs; and interest groups that represent the target groups.

problem at hand and the urgency that actors attribute to a policy issue influences preferences. A study on problem perception and support for different instruments in Israel has shown that the perception of the problem's causes has a greater effect on the preferred policy option than other factors, such as socio-demographic characteristics of the surveyed actors (Lahat, 2011). Furthermore, research in Switzerland has shown that in the case of flood risk management (Glaus et al., 2021) and micro-pollution (Metz & Ingold, 2017) actors' preferences towards targeted state intervention are positively influenced by their problem perception. When actors perceive a complex problem as a potential threat to the environment, they might be more inclined to prefer preventive state intervention to no action at all. The first hypothesis is as follows:

Hypothesis 1: *Actors perceiving the complex (environmental) problem as an increasing threat tend to prefer state intervention in environmental risk prevention.*

Furthermore, the goal frames of stakeholders shape their attitudes and preferences (Lindenberg & Steg, 2007). To be more precise, stakeholders align their preferences with underlying policy principles. Literature about beliefs, and more specifically, policy core beliefs (Weible, 2006; Weible & Sabatier, 2009) capture these principles, and actors are expected to align their preferences for state intervention with their stance on these policy core beliefs (Weible & Cairney, 2018). When it comes to complex environmental problems and risks arising from their occurrence, the precautionary principle is considered a fundamental approach to prevent risks. Complex environmental problems are highly uncertain (Meadowcroft, 2007), and decision-makers are confronted with inconclusive evidence. The precautionary principle embraces this uncertainty and gives the environment "the benefit of the doubt" (Cameron & Abouchar, 1991, p. 1) to act upon threats rather than hard facts. I, therefore, deduce the following hypothesis

Hypothesis 2: *Actors who are in favor of precautionary action tend to prefer state intervention in environmental risk prevention*.

Meso-and macro level: External drivers

The complexity of environmental management is determined by the interdependent web of sectors, levels, and stakeholders operating in different sub-systems (Ingold, 2014; Meadowcroft, 2007). The collaboration between state and non-state actors across different policy fields is considered fundamental in environmental governance (Hamilton & Lubell, 2018; Kenis & Schneider, 1991; Provan & Kenis, 2008; Velten, 2014; Yi, 2018). There is a lively debate in the field of environmental governance scholarship regarding the influence that collaborative governance arrangements have on the final policy outputs and outcomes (Ansell & Gash, 2008; Gerlak & Heikkila, 2011). Due to the high potential for conflict and diverging policy goals, matters related to environmental risk reduction are prone to 'silo thinking' (Kaddoura & El Khatib, 2017). However, collaboration outside the box and across different sectors has various positive effects on solving complex environmental problems (Newig et al., 2018). First, environmental risk reduction is an inherently cross-sectoral endeavor, and being exposed to different views, opinions, and problems faced by the collaboration partners, provides stakeholders with a more holistic understanding of the problem situation (Koppenjan & Klijn,

2004). Second, as mentioned before, complex environmental problems are often associated with high levels of uncertainty. Through cross-sectoral collaboration, actors might lower uncertainty through better access to political and technical information (Hamilton & Lubell, 2018). This leads me to the following hypothesis:

Hypothesis 3: *Actors who collaborate across different sectors tend to prefer state intervention in environmental risk prevention.*

Decision-makers have limited knowledge about the effects on humans or the environment, as well as the costs that result from unsustainable environmental management (Hamlyn, 2015). Conflicts regarding causes and solutions could arise, creating opposing coalitions in the policy process (Malkamäki et al., 2021; Weible & Sabatier, 2009). Exchange of information and positions is crucial when it comes to ameliorating this situation (Crow & Jones, 2018; Gerlak et al., 2018). Policy forums can thus serve as arenas to facilitate exchange and shape policy actors' attitudes (Fischer et al., 2017; Fischer & Leifeld, 2015), which is why I have deduced the following hypothesis:

Hypothesis 4: *Actors who participate in forums tend to prefer state intervention in environmental risk prevention.*

Case, data and method

Uganda as the case to investigate the potential for preventive risk reduction

Countries in the Global South struggle to balance environmental protection with agricultural productivity (Dabrowski et al., 2014; Pingali, 2012). Increased pesticide use is caused by greater demand for food production and a growing need to export to foreign markets coupled with defective agricultural production, which leads to elevated pesticide use (Jørs et al., 2018; Stadlinger et al., 2013) (for more details on case selection, see Supplementary Material (SM) Online). Uganda serves as an illustration of pesticide management contributing to environmental complexity and land use challenges. Ugandan agriculture is considered the backbone of the economy (Rwakakamba, 2009), contributing around 40 % to the annual GDP and employing more than 70 % of the Ugandan labor force (Karungi et al., 2011) (Figure A3 and A4 in SM Online). Ugandan agriculture is shaped by market liberalization and privatization (e.g. of agricultural extension). In this context, farmers can easily access pesticides, and pesticide promotion is ubiquitous (Isgren & Andersson, 2021). While pesticide use rates in Uganda are comparatively low, their growing use is considered alarming or even excessive (Andersson & Isgren, 2021; Kateregga, 2012).

In Uganda, pesticide risk reduction at the different stages of the pesticide management cycle (Figure A2 in SM Online for detail) is not well developed, and lacks comprehensive follow-up regulations to the established act (Wiedemann et al., 2022). Even more, pesticide-related issues are not a political priority, which is why the implementation of existing regulations and introduction of targeted state intervention are hampered (Winkler et al., 2019). Furthermore, decision-making related to pesticide risks is fragmented between government ministries and agencies. Pesticide governance is

highly decentralized over the 135 districts, making local governments the protagonists of enforcement (Bazaara, 2003). Additionally, international organizations, as well as non-governmental organizations (NGOs) play a crucial role in sensitizing and educating smallholder farmers (Delgado et al., 2019), as well as advocacy work to influence decision-making (Isgren, 2018). Pesticide management and decision-making related to pesticide risk reduction is a multi-stakeholder process in Uganda, spanning over different domains (private and public), sectors (i.e. health, environment, and agriculture), and levels (i.e. subnational, national, and even international).

Data collection

To begin, I conducted a comprehensive analysis to identify stakeholders in the domain of pesticide risk reduction in Uganda and to define the boundaries of the network, including both state and non-state actors. Network studies commonly use decisional, reputational, and positional approaches (Knoke, 1993; Knoke et al., 1996) to more precisely identify stakeholders and their roles. The analysis identified 55 international, national, and sub-national stakeholders involved in decision-making related to pesticide risk reduction in Uganda (for details of network boundaries, see section "Stakeholder analysis to define the boundaries of the network" and Table A2 in the SM Online). This list was validated in the pre-testing phase, which involved four expert interviews (see SM Online). In gathering the data, the advantage of the chosen mixed-methods approach was that the qualitative interview data could be used to contextualize the quantitative survey findings, enabling me to interpret and discuss the results in greater depth. I designed a standardized questionnaire for the online survey and a semi-structured guide for the interviews (based on the questionnaire). Data gathering took place between October 2019 and July 2020. For the online survey, I solicited the participation of all identified national (n=49) and international stakeholders (n=4), and also approached all District Agricultural Officers (DAOs) (n=83) and District Farmers' Associations (DFAs) (n=14) where email or phone contacts were available (for more detail, see SM Online), yielding a total of 150 contacted stakeholders. At national level, 38 policy actors responded to the survey (71.7% response rate); at district level, 43 policy actors responded (44.3%), but two outliers were excluded from analysis (Table 5; for more detail, see Table A3 in SM Online). To complement the quantitative data, I conducted 17 semi-structured interviews, which included open questions beyond the confines of the online survey (see Table 5 and Table A3 in SM Online).

Actor type *(Variable name)*	**Survey** *(Total contacted)*	**Response rate**	**Interview**
Government ministry *(Gov.ministry)*	7 (8)	87.5%	3
Government agency *(Gov.agency)*	6 (10)	60%	4
Research institution *(Research inst.)*	5 (7)	71.4%	1
Association and interest group *(Int.group)*	5 (5)	100%	2
CSO/NGO *(NGO)*	12 (16)	75%	3
Pesticide distributor *(Pesticide dist.)*	3 (3)	100%	1
International organization *(IO)*	0 (4)	0%	0
District Farmers' Association *(DFA)*	13 (14)	92.9%	1
District Agricultural Officer *(DAO)*	30 (83)	36.14%	2
Total	**81** ***(150)***	**54 %**	**17**

Table 5: Survey and interview participation by actor type

Operationalization of variables

As a dependent variable, I investigated **stakeholders' preferences for state intervention targeting pesticide risk prevention**. To gather preferences, I surveyed agreement with 15 different instruments, nine for preventive (see Table 6) and six for reactive risk reduction (see Table A5 SM Online), on a four-point Likert-scale (1= strongly disagree, 2= slightly disagree, 3= slightly agree, 4= strongly agree) (Table 7).

Policy instruments to facilitate state intervention (*Variable name*)	**Restrictiveness**
Ban importation and use of particular pesticides (*ban*)	High
Ensure a more restrictive approval process for synthetic pesticides (*app.syn*)	
Make the approval process for alternative/non-chemical products less restrictive (*app.alt*)	
Stricter registration and regular inspection of pesticide importers and distributors, including strengthened border control (*reg.inspect*)	
Establish a coherent system of displaying health and environmental risks on pesticide labels (*labels*)	
Tax for the purchase of pesticides (*tax.purch*)	Medium
Subsidize alternative farming practices (*subsidies*)	
Increase awareness through information campaigns all sectors of society (*info.camp*)	Low
Enhance farmer technical support systems to promote good agricultural practices (*tech.supp*)	

Table 6: Policy instruments facilitating state intervention in pesticide risk prevention

To capture preferences for preventive state intervention, I calculated an additive measure over the nine policy instruments facilitating risk prevention for each actor ranging from 1 to 4. Table 7 shows the operationalization of the independent variables as well as of the control variables. Additional information on the operationalization of the independent variables is provided in the SM Online.

	Variables	**Operationalization**
DV	Preferences for state intervention	Additive measure of agreement with nine policy instruments targeting pesticide risk prevention [1-4]
	Independent variables	
H 1	Threat perception	Additive measure of agreement with four different environmental threats being attributable to pesticide use in Uganda [1-4]
H 2	Secondary policy belief	Agreement with the policy principle of precautionary action (1-4)
H 3	Cross-sectoral collaboration	Level of diversity for actors' collaboration partners in their network across sectors
H 6	Forum participation	Participation in forums (0-6)
	Control variables	
CV	Involvement	less than 25%/25%/50%/75%/more than 75% of portfolio of responsibilities dedicated to pesticide management (0-5)
CV	Representing the agricultural sector	Dummy variable 0/1 (no/yes)
CV	Representing district level	Dummy variable 0/1 (no/yes)
CV	Representing private domain	Dummy variable 0/1 (no/yes)

DV = dependent variable; H = hypothesis; CV = control variables

Table 7: Operationalization of the dependent and independent variables

Methods

For data analysis, I rely on a mixed-methods approach, combing the quantitative survey with qualitative interview data. Descriptive statistics were generated for the different policy instruments and stakeholder preferences across different combinations of actor variables (e.g., actor role and level). I then performed a Spearmans rank-order correlation to analyze overall risk prevention preferences and the effects of individual drivers on agreement with the nine policy instruments. Finally, regression analysis was used to assess the effects of individual and external variables for hypothesis testing. Because of the small sample size, the study was necessarily exploratory, and the findings cannot be generalized beyond the specific research setting.

All of these outcomes were supplemented by contextual insights from the interviews, which were transcribed verbatim and keyword coded for systematic sorting. For present purposes, the most crucial keyword groups are *policy/regulation/law*, *environment/agriculture/health*, *farmers/polluters*, *conflict/collaboration*, *protection from/use of pesticides*, *threats/problems*, and *international/national/district*. Statements were then extracted by means of a keyword search and as signed to different topics (for more detail, see Table A4 in SM Online). In total, 83 relevant statements were extracted, and these provided further detail when interpreting and discussing the findings.

Results and discussion

Potential for state intervention in pesticide risk prevention

Figure 6 summarizes stakeholder agreement with the nine policy instruments for pesticide risk prevention. What is striking at first glance is that agreement exceed 67.5% in every case, and a majority of instruments achieve more than 90% agreement.

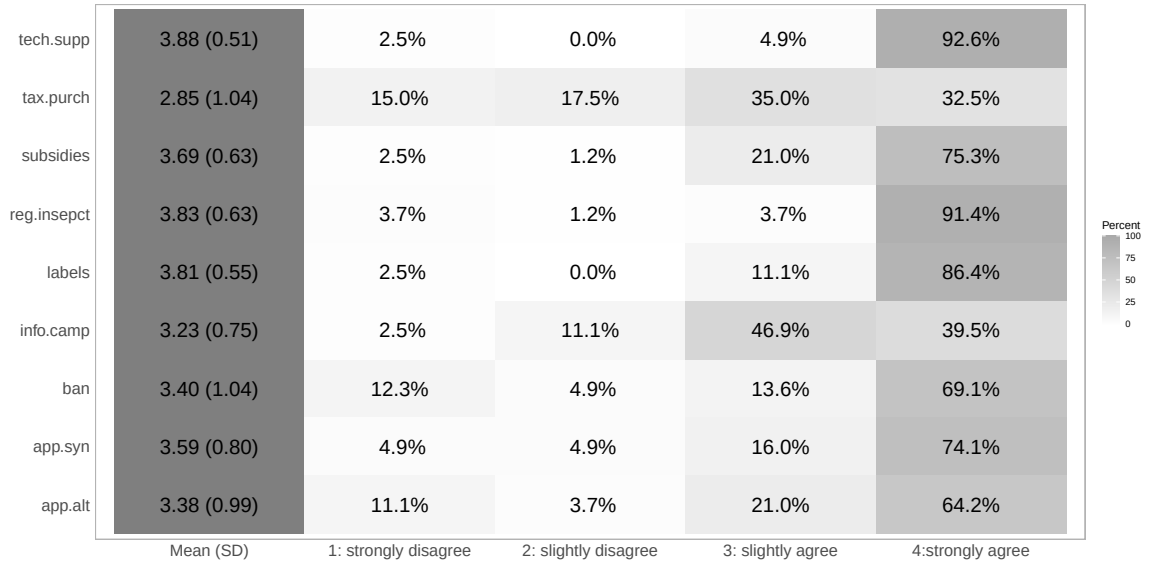

Figure 6: Agreement with policy instruments facilitating pesticide risk prevention

However, 33% of these actors disagree with an economic instrument imposing a tax on pesticide products at purchase (*tax.purch*). This aligns with existing evidence that although stakeholders largely accept instruments that reduce environmental risk, instruments that incur a cost encounter the strongest opposition (Metz & Leifeld, 2018). In the Global South, market-based economic instruments—especially those related to taxation—are often considered difficult to enforce (Xie & Saltzman, 2000), because of a lack of monitoring or corruption (Bell & Russell, 2002). This instrument also encountered particular opposition from the interviewed stakeholders, as they felt it penalized the most vulnerable Ugandan farmers, who would continue to purchase the products in question, even at a higher cost (Interviews 1, 2, 10, 11). For instance, interviewees said they would not agree to measures that *squeeze* farmers (Interview 3) and that a tax would put economic and food security at risk (Interview 10). Interviewees also noted that a tax might not be the most effective option, as it might not have the desired impact; for example, people would not understand the tax as a means of disincentivizing the use of pesticides, or the money would be misused rather than redistributed (Interviews 10, 14).

As a politically feasible means of addressing issues related to pesticide management, the potential for state-led risk prevention is high. However, while this matter has been on Uganda's political agenda for a long time, the risks for consumers and society at large have only recently become an issue, following a comprehensive study of pesticide residues on tomatoes (Atuhaire et al., 2017; Sekabojja et al., 2021). Pesticide risk prevention can therefore be characterized as a "nascent" policy issue (Ingold et al., 2017), as stakeholders agree with state intervention and see the urgent need for action. Many interviewees supported this view (Interviews 8, 9, 10, 12, 13, 17) and emphasized their dissatisfaction with the current situation, which they attributed in part to a lack of coordination (Interview 1), political support (Interview 15), or regulation per se (Interview 13), as well as weak enforcement and noncompliance (Interviews 2, 4).

Breakdown of stakeholder preferences

To better understand stakeholder preferences regarding risk prevention, I combined a number of variables that capture stakeholder characteristics. Figure 7 shows actors' preferences regarding state-led pesticide risk prevention by sector and decision-making role, and Figure 8 shows actors' preferences by sector and domain. Stakeholders from five sectors (agriculture, environment, health, industry, cross-sectoral) responded to the survey; their roles were categorized as policy principal (ministry department leaders with decision-making power), secondary policy principal (government agencies involved or assisting in decision-making), policy implementation agent (DAOs), interest group (associations and NGOs advocating for groups and interests), or knowledge broker (research institutions) (see also Glaus, 2021).

Figures 7 and 8 reveal two distinct trends. First, interest groups representing industry sector actors (e.g., pesticide distributors, umbrella organizations for pesticide distributors) exhibit the lowest acceptance of policy instruments. In Figure 8, private stakeholders from the industry sector exhibit the weakest preferences (for more detail, see Tables A6, A7, and A8 in SM Online). These actors operate

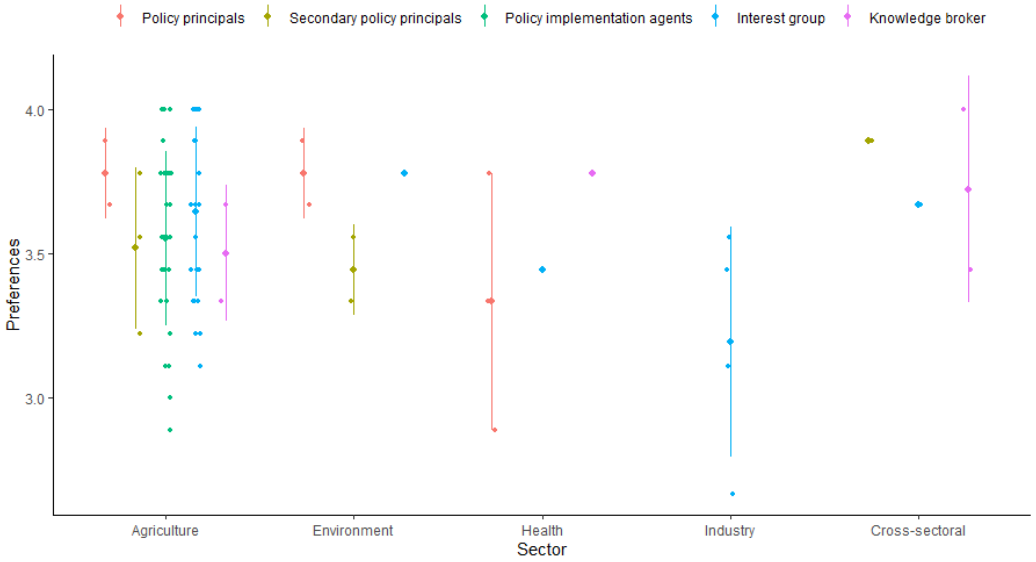

Figure 7: Preferences regarding state intervention in risk prevention by sector and actor role

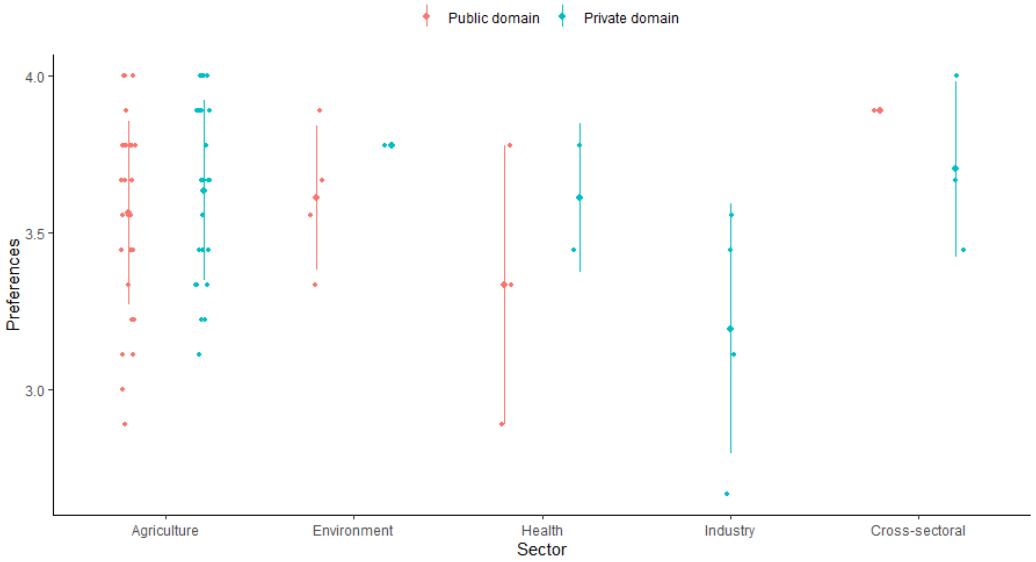

Figure 8: Preferences regarding state intervention in risk prevention by sector and domain

along the pesticide management cycle and may identify as victims, associating these measures with financial burden and inflexibility related to enforcement (Landry & Varone, 2005). These stakeholders represent manufacturers, import and registration agencies, distributors, and farmers. To engage with risk prevention, these actors must take responsibility and accept that they are active contributors to the problem. The interviews underlined the need to penalize polluters rather than taxing products that harm farming communities. Interviewees claimed that fines, along with stricter application of the polluter-pays principle, would effectively pressurize certain polluters (Interviews 1, 5). Second, public stakeholders (i.e., policy principals) in the areas of agriculture and environment expressed the strongest preference for state-led pesticide risk prevention. In contrast, policy principals from the health sector exhibited the lowest preference for such measures among public stakeholders. The inter-

views confirmed that these programs and policies are not aligned with the health sector; for example, vector control or malaria protection measures were seen to interfere with pest control: "*You may find that some pesticides are being used in the nets for covering ourselves, yet in the field, for spaying, they are not allowed*" (Interview 8). As these problems are not regulated in a harmonized and consolidated way across the different sectors, there is conflict and confusion about responsibilities (Interviews 1, 3, 4, 10). To improve this situation, one proposed pathway is to include stakeholders from all sectors in a consultation process to reframe the problem and to adjust programs and coordination accordingly (Wiedemann et al., 2022). Interviewees also emphasized that interventions by private stakeholders should run in parallel with state interventions (see (Mengistie et al., 2016): "*Government [...] cannot control everywhere [...] they don't have the capacity and also, they are not the business people*" (Interview 17). A typical example is the use of spray service providers by pesticide distributors to ensure that pesticides are applied by knowledgeable users (Interviews 1, 6). By mending conflicts, this complementary approach can enhance pesticide risk prevention.

I performed a bivariate analysis to investigate the relationship between acceptance of the nine risk prevention policy instruments (see Figure 1) and the two individual drivers (see Table 8).

	threat perception	**secondary policy belief**
ban	0.24*	0.19
app.syn	0.36**	0.33**
app.alt	0.09	0.28*
reg.inspect	0.03	0.16
labels	-0.02	0.03
tax.purch	-0.04	-0.01
subsidies	0.25*	0.10
info.camp	-0.04	0.03
tech.support	-0.04	0.10
overall preference	0.24*	0.26*

Note: All correlations are Spearman's rank-order$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 8: Correlation coefficients of threat perception and agreement with the precautionary principle to agreement with policy instruments targeting pesticide risk prevention

Table 8 shows a significant positive relationship between individual drivers and preferences for state intervention in risk prevention (overall preferences). This aligns with previous claims that problem perception and policy beliefs influence policy choice (Choi & Wehde, 2019; Glaus et al., 2021). On closer inspection, it becomes clear that these individual drivers are especially relevant in the case of restrictive policy instruments. In particular, stakeholders who exhibit high levels of threat perception are more likely to accept a comprehensive approach to risk prevention combining a ban (*ban*) and more restrictions on synthetic pesticides (*app.syn*) with monetary incentives (*subsidies*) for alternative practices like organic agriculture. Stakeholders who agree with precautionary action are more likely to favor greater restrictions on synthetic pesticides (*app.syn*) and fewer restrictions on alternative products (*app.alt*). While both variables have a strong effect on restrictions related to conventional pesticides, it seems clear that stakeholders are also more open to alternatives. In the interviews, alternatives were a hot topic, and one stakeholder noted the increasing interest in alternative products "*...because they are there. Its not true that there are no alternatives*" (Interview 4), a view accepted by

the national government in adopting the National Organic Agriculture Policy in 2019 (Bendjebbar & Fouilleux, 2022). However, some stakeholders also stressed that more research is needed to promote open dialogue about alternatives to conventional pesticides (Interviews 1, 10). Values for Spearman's rank-order correlation and Cronbach's alpha (0.68, CI: 0.54 0.77) confirmed the consistency of these results.

Explaining preferences for state intervention in risk prevention

A linear regression was performed to determine which drivers are associated with stakeholders' preference for state intervention for pesticide risk prevention. Table 9 shows parameter estimates for three models (with standard errors in parentheses). Model 1 reports the effects of individual drivers only; Model 2 includes both individual and external drivers; and Model 3 reports results for district stakeholders. Additionally, to ensure comparability of coefficients and to improve model convergence, the variables were scaled for regression analysis. (For more detailed results, see summary statistics in Tables A9; and Table A10, and Figures A6 and A7 for regression diagnostics in the SM Online.)

	Model 1 individual drivers only	Model 2 all drivers	Model 3 district level only
Individual drivers			
Threat perception [1-4]	$0.10\ (0.05)^{\cdot}$	$0.07\ (0.03)^{*}$	$0.17\ (0.04)^{***}$
Secondary policy beliefs (1-4)	$0.16\ (0.05)^{**}$	$0.11\ (0.03)^{***}$	$0.10\ (0.04)^{*}$
External drivers			
Cross-sectoral collaboration (0-5)		$-0.06\ (0.03)^{\cdot}$	$-0.07\ (0.04)$
Forum participation (0-6)		$-0.05\ (0.03)$	$-0.10\ (0.04)^{*}$
Control variables			
Involvement (0-5)	$0.05\ (0.03)^{\cdot}$	$0.08\ (0.04)^{*}$	$0.02\ (0.05)$
Policy domain: agriculture	$0.12\ (0.09)$	$0.07\ (0.04)^{\cdot}$	
District level	$-0.06\ (0.09)$	$-0.05\ (0.04)$	
Private sector	$-0.08\ (0.07)$	$-0.03\ (0.04)$	$0.02\ (0.05)$
Intercept	$2.59\ (0.24)^{***}$	$3.58\ (0.03)^{***}$	$3.58\ (0.04)^{***}$
R^2	0.21	0.27	0.45
Num. obs.	79	79	41

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 9: Regression table

The results confirm that both individual and external drivers play a role in shaping stakeholder preferences. **Hypothesis 1** is confirmed by the marginally positive effect of environmental threat perception on preferences for risk prevention in Models 1 and 2. Actors who agreed that environmental threats related to air quality, drinking water quality, wildlife, and lakes are attributable to pesticide use and pesticide management tended to favor state intervention. This aligns with the view that problem awareness and problem perception foster stakeholder agreement with state intervention in general (Metz & Ingold, 2014) and with innovative forms of intervention such as sustainable policy instruments to reduce flood risk (Glaus et al., 2021). As problem awareness seems to be evolving, a more consolidated threat perception of decision-makers can muster support for state intervention.One interviewee noted the lack of awareness among high- level decision-makers: "*even the parliament need this sensitization. So the [lack of] awareness is actually not restricted to the poor family in the village.*

It is also lacking in our policy makers - the parliamentarians" (Interview 1). Regarding **hypothesis 2**, the results confirm that stakeholders' preferences align with underlying policy core beliefs. In Uganda, the Environmental Act established precautionary action as a guiding principle, and in a landmark decision in 2015, the Ugandan Supreme Court reaffirmed the importance of this principle for environmental protection. The basis for preventive action is therefore embedded in the regulatory framework, and the alignment between agreement with this principle and a preference for action confirms earlier findings (Metz, 2017). In particular, interviewees emphasized that precautionary actions like banning a hazardous pesticide could potentially be introduced in this high-dependency context, but only if an effective alternative is proposed (Interviews 1, 6, 9).

In relation to external determinants, **hypothesis 3** must be rejected in light of the marginal negative effect in Model 2 indicating that stakeholders who collaborate with representatives of other sectors tend to oppose state intervention in preventive risk reduction. This result is surprising and counterintuitive because the literature suggests that stakeholders who "think outside the box" are exposed to a broader spectrum of opinions as they become familiar with different problem frames (Koppenjan & Klijn, 2004). Pesticide risk reduction can be characterized as a "nascent" policy issue; according to several interviewees, coordination and collaboration across policy fields and sectors is evolving but is not consolidated in the case of pesticide management: "*As long as we are running parallel programs, we can't succeed on that [in regulating pesticide risks]. We need to maybe make observations together, plan together, implemented together*" (Interview 4). Additionally, pesticide risk prevention is not a popular political strategy because it interferes with the production, registration, and distribution of agro-chemicals, and this lack of political desirability can diminish the effect of collaborative settings. As one interviewee noted, "*it takes a political step because you need to involve stakeholders widely to ensure that they buy in your idea. They must appreciate the risk, you're talking about*" (Interview 1).

Hypothesis 4 must also be rejected, as forum participation had an insignificant negative effect on stakeholders' tendency to favor state intervention. The control variables show two marginally significant effects in Model 2. First, the more involved stakeholders are (in terms of their portfolio and responsibility for pesticide management), the more likely they are to favor state intervention in pesticide risk prevention. Second, stakeholders representing the agriculture sector are slightly more inclined to favor state intervention.

Model 3 shows the regression analysis for district stakeholders only; effect directions remain the same, but threat perception has a highly significant effect on district stakeholder preferences. Local actors in particular play a fundamental role, as their ability to solve problems (Hirschi, 2010; Ingold, 2014; Meyer & Konisky, 2007; Newig et al., 2018) and their knowledge of and closeness to the problem and to target groups is vital for decision-making. Studies of pesticide regulation have emphasized that the inclusion of local actors contributes to a better understanding of the problem and the requisite actions (Huici et al., 2017; Isaac, 2012; Karlsson, 2004b). While the interviewees stressed the need to raise awareness among national stakeholders, these results show that sub-national threat perception promotes acceptance of policy instruments, indicating that efforts to sensitize DFAs and district

government officials to risk prevention should continue. Forum participation exhibits a marginally negative effect; the more district stakeholders participate in forums, the more likely they are to oppose state intervention. District stakeholders, who are close to farmers and understand problems of yield loss and economic hardship, regard pesticides as necessary to ensure food security (Interviews 2, 7). To enhance the potential for state-led pesticide risk prevention, exchanges on forums and other platforms should reflect the local context, including the perspectives of district stakeholders and farmers (Stein & Luna, 2021). Of the 49 forums referred to by interviewees, the most frequently mentioned body was the Agricultural Chemicals Control Board, a highly institutionalized entity that mainly represents the agricultural sector. The Board's function is to oversee the registration of pesticides and to advise the Minister on policy adoption and implementation. In Uganda, where agricultural modernization and development has long shaped the political agenda and discourse (Hickey, 2005; Isgren, 2016), conventional agriculture is seen as the most innovative approach, and alternatives are considered backward and old. Actors who voice concerns about environmental degradation caused by conventional agriculture encounter hostility and are viewed as enemies of progress (Lyons & Westoby, 2014, p. 16). Forums like the Agricultural Chemicals Control Board and other platforms might be used to promote this rhetoric, and the promotion of agricultural growth at the cost of environmental degradation is seen to outweigh the promotion of targeted pesticide risk reduction (Martiniello, 2015).

Conclusion

Targeted state intervention is needed to address complex environmental problems and to prevent risk. However, decision-makers may not support state intervention because of fears about the uncertainty, costs, and conflicts associated with political action. To investigate the potential for state intervention to prevent environmental risks, the present study explored stakeholder agreement with nine policy instruments targeting pesticide risk prevention in Uganda, where high levels of pesticide exposure have had detrimental effects on the environment and on human health. The results show that while there is generally strong support for state intervention, pesticide risk prevention remains a nascent policy problem, and regulation is still developing. The results mirror the current situation in Uganda; stakeholders are in favor of everything as long as action is taken to prevent risk. However, a closer look at the relevant policy instruments reveals that taxation measures are particularly controversial among stakeholders, as they are seen to impose an additional monetary burden on farming communities that are already suffering financial hardship. Instead, stakeholders favor promotion of the polluter-pays principle and its extension to manufacturers, importers, and distributors to disincentivize pesticide use at every stage of the pesticide management cycle. Interest groups from the private sector and policy principals from the health sector exhibit a weaker preference for state intervention in this context. To address conflicts related to pesticide use, promotion of alternatives, and allocation of responsibilities, there is a need for inclusive and systematic coordination of the relevant narratives to promote government and private sector intervention for a more holistic approach to pesticide risk prevention in Uganda.

The present findings also suggest that stakeholders' individual attributes drive preferences for state

intervention in pesticide risk prevention. Specifically, stakeholders are likelier to favor state intervention if they exhibit high threat perception, and agree with the precautionary principle. Closer inspection of the nine risk prevention policy measures reveals differences in the effects of individual drivers, which are significant in the case of highly restrictive measures that ban or restrict the use of synthetic pesticides and promote alternatives. However, external drivers did not have the expected effect on preferences, as cross-sectoral collaboration actually increases the likelihood of opposition to state-led pesticide risk prevention.

More generally, this research contributes to the policy literature in three ways. First, it corroborates the link between psychological determinants and stakeholder preferences, showing that stakeholders' preferences are not driven by rational choice alone but are shaped by complex mental models that call into question conventional explanations based on 'homo economicus' (Burger et al., 2015). This presents an opportunity to raise awareness among farmers and local actors as well as national public actors who may not appreciate the risks of pesticides as against their benefits for agriculture. Since pesticide management was privatized in the 1990s, the private sector has become a key player in the delivery of agricultural services (Isgren & Andersson, 2021; Martiniello, 2015), and NGOs have a crucial role to play in sensitizing farmers (Isgren, 2018). Scientific evidence must also play a part in raising awareness of these issues among national decision-makers and across society as a whole (Cairney & Oliver, 2020).

Second, state intervention and policy adoption do not happen in a vacuum; in other words, stakeholders are influenced by the surrounding social structures (Bressers & O'Toole, 1998; Metz, 2017). In this nascent policy field, the dynamics of environmental governance and collaboration differ from more established governance processes. The present findings invite discussion of how cross-sectoral collaboration can contribute to policy development and the underlying structural dynamics. While the literature suggests that friends or collaboration partners influence stakeholders' attitudes and behaviors, ongoing conflicts reflect a lack of trust in government and state intervention. In the Global South, private sector interventions to address complex environmental problems are the rule rather than the exception (Isgren & Andersson, 2021), and trust must be built in government and institutional venues to promote state intervention.

Finally, a better understanding of stakeholder preferences regarding state intervention makes it easier to predict the likelihood of policy adoption (Glaus et al., 2020; Metz & Ingold, 2017). While preferences in mature policy fields are already well-developed and consolidated (Ingold et al., 2017; Stritch, 2015) problem perceptions and beliefs exert a stronger influence in evolving fields. Focusing on individual drivers and policy instruments that facilitate state intervention enhances our understanding of preferences and potential pathways for action. In this comprehensive investigation of policy preferences, multivariate descriptive and correlation analyses helped to unravel how actors' characteristics influence responses to specific policy instruments. While the small sample size precluded generalization, qualitative interview data helped in interpreting and contextualizing the results and identifying potential pathways for pesticide risk prevention policy in Uganda.

In the broader context of pesticide risk reduction, conventional top-down policy making has been replaced by multi-stakeholder governance (Möhring et al., 2020). Working along different pathways that include advocacy and implementation, these stakeholders play a key role in helping or hindering decision-making and negotiating in relation to state intervention (Sager et al., 2020). Understanding stakeholders' preferences as political catalysts or constraints when addressing complex environmental problems can contribute to a paradigm shift from ignoring such problems and shifting responsibility to actors along the value chain to actively engaging these actors in collective action in pursuit of more sustainable production processes (Seifert et al., 2019).

In acknowledging the need for further research on potential state intervention, it seems clear that stakeholder preferences should be explored alongside other political constraints like public support or financial resources. It remains an open question whether state intervention in preventive risk reduction is effective or feasible in practice, and future research should incorporate performance measures such as political feasibility and policy effectiveness. While the present case study generates contextual knowledge of the potential for state intervention in pesticide risk reduction in Uganda, its main limitations are the lack of data on international stakeholders and the difficulty of accessing remote district actors. Future research must address these stakeholders' problem frames and preferences, as they play a crucial role in policy adoption (e.g., through by-laws and ordinances) and implementation (e.g., by providing extension services to farmers). As these stakeholders are often difficult to reach, conventional research methods should be complemented by participatory elements, working with local NGOs and interest groups to establish links with these stakeholder groups. Participatory research of this kind would facilitate collection of qualitative data about collaboration networks, knowledge exchange, and narratives as the basis for future analyses that enable social scientists to capture the complexity of processes like policy formulation and implementation.

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Building coalitions in a nascent subsystem: Investigating beliefs and policy preferences in Ugandan pesticide policy

According to the Advocacy Coalition Framework, sharing beliefs and policy preferences is one key pre-condition for actors to coordinate actions and to develop or join advocacy coalitions. Joining forces in policy processes is important because many actors lack the power or competencies to decisively impact policy outputs and change on their own. However, we still know very little about this process of joint belief and preference formation in new policies and policy subsystems. Thus, we asked: How can we explain joint beliefs and policy preferences in a nascent subsystem? To answer this question, and using a survey aimed at stakeholders, we investigated pesticide policymaking in Uganda. This is a new policy field in which policy outputs are still lacking. We conducted a three-step approach and selected the types of beliefs and preferences that matter in a nascent policy setting. We then presented an extensive list of possible regulatory instruments to the stakeholders and selected those evaluated as the most relevant or conflictive. Based on this selection, we calculated belief and preference similarity and clustering to identify groups of like-minded actors. Finally, and via regression analysis, we show that joint beliefs are the result of either trust or a similar problem perception, depending on whether the actor is part of a more or less developed belief cluster.

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This article was co-authored by Karin Ingold. Ruth Wiedemann was the lead author.

Introduction

The Advocacy Coalition Framework (ACF) is interested in how public policies and regulations come about, particularly in conflictive settings (Jenkins-Smith et al., 2018). To explain policy outputs and change, the ACF focuses on actors and their beliefs, worldviews, and policy preferences. Actors join forces in so-called advocacy coalitions based on these joint beliefs and preferences and oppose others with divergent beliefs. Linking policies and regulations on one side and actors, their beliefs, and coalitions on the other is interesting for several reasons. The ACF postulates that actors want to see their beliefs translated into policies (Sabatier & Jenkins-Smith, 1993). Thus, the most successful actors or coalitions see their beliefs introduced and implemented through policy programs, laws, or regulations (Pierce et al., 2020). This can be important when trying to explain why a certain policy document in one country or constituency might look very different from another, although the policy problem to solve is very similar (Weible & Heikkila, 2016). Or if someone is interested in the most powerful actors or policy entrepreneurs, it might be relevant to compare actors' policy preferences and beliefs to the final output (Ingold & Varone, 2012; Nohrstedt, 2011). Therefore, in accordance with the ACF, policy beliefs and preferences matter, and actors coordinate actions with like-minded others to increase their impact on the final policy output (see also Henry, 2011). The focus on policy change (and not policy "emergence") suggests that the ACF is mostly applied to established or mature policy subsystems. In mature policy subsystems, beliefs and coalitions are stable (Pierce et al., 2017), and policies have been introduced and are ready (or not) for change. The situation is different for nascent subsystems (Ingold et al., 2017; Stritch, 2015), in which policy outputs have not been introduced, and actors develop policy preferences to regulate societal problems. A nascent subsystem is, so to speak, the start of any new policy field. Not all nascent subsystems become mature. Some new issues are absorbed by other traditional subsystems or fade away before policies materialize. Nonetheless, the study of nascent subsystems is an emergent research field of interest as it gives insights into the moment when actors potentially start to coordinate based on joint beliefs. We further argue that in an uncertain and "new" context, joining forces with like-minded actors is crucial to produce majorities and increase the political feasibility of a potentially new regulatory regime. Thus, we posed the following research question:

How can we explain joint beliefs and policy preferences in a nascent subsystem?

The answer to this question will shed light on the different elements of a policy process in a nascent subsystem. Knowing the beliefs and policy preferences of the political actors involved means not only knowing who is like-minded but also those who are in opposition. It helps identify feasible policy options (e.g., specific policy instruments such as taxes or subsidies or policy goals such as risk reduction targets) supported by majorities and candidates for compromise. Therefore, knowing which policy preferences are more or less prominent among the political elite is also an indicator of which policy instrument or type of regulation has a higher chance of being introduced to regulate a newly identified challenge in society.

Empirically, we investigate pesticide regulation, a true sustainability challenge at the nexus between

food and society, agriculture, the environment, and human health (Falconer, 1998; Lee et al., 2019). In this context, different national and international regimes exist (European Parliament, 2009; FAO and WHO, 2014), but in many regions of the world, regulatory regimes for pesticide regulation are still evolving (Rodenburg et al., 2019; Shao & Edward, 2014). This is particularly true in sub-Saharan Africa. Although agriculture is largely shaped by small-scale farming and strongly dependent on pesticides to enhance food security (Stein & Luna, 2021), policies regulating pesticide risks and applications are largely lacking or nonexistent. More concretely, we examine pesticide regulation in Uganda, where a consistent policy regime for pesticide risk reduction is lacking. To investigate beliefs and policy preferences related to pesticide regulation, we conducted expert interviews and surveyed 32 public and private actors. We propose a three-step approach to examine beliefs and preferences in an emergent policy field and to explain the co-occurrence of actors in so-called belief clusters. First, through document analysis and expert interviews, we included beliefs and a wide range of policy instruments or options that could regulate the emergent issue. Based on the survey results, we selected the most pertinent and conflictive policy instruments for further analysis. Second, we investigated belief and preference similarities and created so-called belief clusters. Third, to answer the research question, we conducted a regression analysis to explain co-occurrence in belief clusters.

The analysis showed that this three-step approach is helpful for examining joint beliefs and preferences in a nascent context. First, this approach allowed us to include a variety of "potential" regulatory instruments in the analysis. Based on a "pre-analysis," only a selected set of beliefs and instruments then constituted the database for the cluster analysis. Finally, the regression results show that the drivers of joint beliefs differ depending on the degree of "maturation" of the belief cluster. In more developed belief clusters with actors who have worked longer on agricultural or pesticide issues, previous collaboration was the most significant driver of joint beliefs. In the nascent cluster, actors with similar problem perceptions occurred in the same belief group.

The remainder of the article is organized as follows. After a short literature review of nascent subsystems in the ACF as well as beliefs and preferences, we present hypotheses regarding drivers for joint beliefs and policy preferences. We then introduce the case and the data-gathering and analysis methods. We present how to select beliefs and policy preferences in a nascent subsystem before we discuss the belief clusters and the regression analysis. We conclude with a discussion and suggestions for future work.

Theory

Before we present joint beliefs and policy preferences and the drivers, we introduce the specificities of (nascent) subsystems.

Specificities of nascent subsystems

The primary unit of analysis of the ACF is the policy subsystem, which includes a geographic scope and a topic or policy problem to solve, alongside the actors engaged in this topic or problem solving (Jenkins-Smith et al., 2018). One way to classify policy subsystems within the ACF has been to

separate subsystems that have existed for an extended period of time ("mature") from those that are in the early stages of forming ("nascent") (Jenkins-Smith & Sabatier, 1999). In a mature subsystem, actors might identify as members of or experts about it (Nohrstedt et al., 2020). Generally, beliefs within a subsystem and coalition are stable, as is the actors' constellation and participation (Sabatier & Jenkins-Smith, 1993). Nascent subsystems behave differently: The actors' participation is fluid, and policy preferences are not always clear or formed (Ingold et al., 2017). Actors might join "coalitions of convenience" rather than stable advocacy coalitions (Stritch, 2015).

Literature on nascent policy subsystems is still limited, for several reasons. The subsystem boundaries are not yet clear; and often even not at the decision level or in the jurisdiction the issue should best be tackled. This makes identifying actors challenging. Additional key "indicators" of a nascent subsystem might be that the issue on the political agenda is new and that no regulation or public policy addresses it. In this early stage of policy regulation, the nascent subsystem (or new issue) might still be caught up in an established subsystem or develop independently (Ingold et al., 2017).

Although investigating a nascent subsystem poses several conceptual and empirical challenges, examining preference formation and the early stage of coalition building (based on joint beliefs) seems crucial for understanding how a new regulatory regime is designed and its pathways.

Joint beliefs and policy preferences

Different theories of the policy process are interested in the policy beliefs and preferences of actors involved in policymaking (Hill & Varone, 2016; Sabatier & Weible, 2007). Following the ACF, actors' and coalitions' belief systems have a three-tier structure with deep core beliefs (normative values and worldviews), policy core beliefs (normative and empirical beliefs bound to the policy subsystem), and secondary aspects (what we call policy preferences that embrace the preferences for selected instrumental means for achieving desired outcomes within the subsystem). A certain hierarchy exists between (deep and policy) beliefs and preferences. Beliefs should guide the choice of policy goals and targets (Sabatier & Jenkins-Smith, 1993).

Thus, policy beliefs typically refer to deep ideologies, worldviews, and the general degree of state intervention an actor wishes to see in policymaking (Jenkins-Smith et al., 2014a). These policy beliefs guide policy preferences (also called secondary aspects; Sabatier and Jenkins-Smith, 1993) that refer to instrumental and technical aspects of policymaking and typically include targets or goals (e.g., degree of pesticide risk reduction), as well as policy instruments (e.g., substance ban or information campaign; see Wiedemann and Ingold, 2021).

However, scholars are interested not only in the relationship between beliefs and preferences but also in the formation of advocacy coalitions based on joint beliefs and preferences (Henry, 2011; Ingold, 2011). This formation follows different premises of policymaking: First, only a few actors have direct access to decision-making. Most interested or concerned organizations must lobby or trade knowledge or other resources with formal "deciders" to impact a portion of the final policy output (Henning, 2009). Second, and more generally speaking, actors do not have enough time, information,

or power to participate in several policy processes at a time (Brandenberger et al., 2020; Smith et al., 2014). All of these are reasons why actors ally with others (see also Weible, 2005).

Knowing what actors believe and prefer, and why they ally with others who have similar beliefs and preferences, might be relevant for several reasons. It helps in understanding how collective action or policy problems are addressed (Calanni et al., 2015), how policy design and implementation come about (Knill & Tosun, 2012), how the actors of a policy process change beliefs and preferences and learn over time (Heikkila & Gerlak, 2013), or how the same policy problem is seen and tackled very differently in diverse constituencies or countries (Cairney et al., 2018).

Drivers of joint policy preferences in a nascent subsystem

From the few studies on nascent subsystems (Beverwijk et al., 2008; Fidelman et al., 2014; Ingold et al., 2017; Stritch, 2015), we know that nascent subsystems follow different dynamics than mature ones. Participation is fluid, and political positions are less clear (Nohrstedt et al., 2020). This seems to make trust and collaboration an important pre-condition for joining forces (see Hatmaker and Rethemeyer, 2008; also Rethemeyer, 2005).

Thus, by knowing each other from joint "activation" of venues (Nohrstedt, 2011), from participation in the same forums (Fischer & Leifeld, 2015; Herzog & Ingold, 2019), or from direct interaction and (former) collaboration (Provan & Milward, 2001) can correlate with having similar beliefs and policy preferences and joining the same (belief) coalition. Although the effectiveness of collaboration for solving societal dilemmas and addressing (politically) defined goals is still very controversial in the literature (Crona & Bodin, 2006; Gerlak et al., 2013), there exists large consensus that "regular" interactions enhance trust building and the capacity to solve collective problems (Berardo & Lubell, 2016; Berardo & Scholz, 2010; Ostrom, 1998; Scholz et al., 2008). Policy actors often rely on preexisting network connections in their search for advice and information about new issues (Henry, 2011; Leifeld & Schneider, 2012; Tindall et al., 2020). We hypothesize that meeting in forums or directly interacting with each other creates opportunity structures for actors to jointly engage in problem solving and thus impacts the way they want to solve the problem. Therefore, we posit the following hypotheses:

Hypothesis 1: *Actors participating in the same forums of the policy process tend to share beliefs about and policy preferences for how to solve a specific policy problem.*

Hypothesis 2: *Actors who collaborated in previous policy processes or subsystems tend to share beliefs about and policy preferences for how to solve a specific policy problem.*

We must note that interactions, such as collaboration, in the political context can take very different forms (Newig et al., 2018). Different political systems provide very different opportunities to actors regarding how and when to interact (Adam & Kriesi, 2007; Fischer, 2014). This interaction can range from strategic (e.g., co-signing letters or position papers) to unintentional exchange (e.g., meeting at a public information day), or can even be provoked or asked by the institutional setting (e.g., a

lead agency responsible for answering questions or demands from political parties or other agencies). Therefore, in Hypothesis 2, we frame collaboration in this very broad way but restrict it to interaction in the past (thus, in policy processes or policy subsystems other than the investigated one). This is very different from how, for instance, the ACF frames "interaction" when talking about coordination (see, for instance, Matti and Sandström, 2011; Weible and Sabatier, 2005. The ACF predicts that actors with similar beliefs tend to coordinate actions to impact policy outputs decisively (Sabatier & Jenkins-Smith, 1993). Thus, in the ACF, collaboration among policy actors is a close, more strategic, and intentional interaction (Weible & Sabatier, 2005) and is different from the type of interaction in the hypotheses we formulate.

Another important aspect when a new issue arrives on the political agenda is problem perception. Problem perception is an important pre-condition for actors to engage in collective action or for a problem entering the political agenda (Ingold et al., 2019; Ostrom, 2009). Problem perception comes during the early stage of public policymaking (Knill & Tosun, 2012) and thus might specifically affect how and when actors join forces. Different actors are differently affected by a problem or a shock (Birkland, 2015; Herzog & Ingold, 2019) why we expect a homophily effect: For example, actors who are being similarly affected by the problem or perceive it as similarly severe tend to develop joint beliefs and policy preferences. Sabatier (1998) included the magnitude of the problem, or its assessment, as an important deep core belief that subsequently affects beliefs and preferences within given subsystems. Based on this discussion, we posit the following hypothesis:

Hypothesis 3: *Actors with similar problem perceptions tend to share beliefs about and policy preferences for how to solve a specific policy problem.*

Methods

Case

Pesticide regulation in Uganda is an ideal setting for investigating joint beliefs and preferences in a nascent subsystem. Uganda lacks consistent policy output to reduce pesticide risks, a circumstance indicating that pesticides and related risks are regulated only in premature policy regimes (Winkler et al., 2019). In Uganda, agriculture is considered the backbone of the economy (Rwakakamba, 2009), contributing around 25% to the annual gross domestic product (GDP) and employing more than 70% of the Ugandan labor force (Karungi et al., 2011; Le Goff et al., 2022). Market liberalization and privatization (e.g., of agricultural extension) have shaped this sector. Thus, farmers can access pesticides easily, and their promotion is ubiquitous (Bendjebbar & Fouilleux, 2022; Isgren & Andersson, 2021). Although pesticide use rates in Uganda are comparatively low, their growing use is considered alarming or even excessive (Andersson & Isgren, 2021; Kateregga, 2012). Academics in Uganda are raising awareness of pesticide residues in the environment and food (Atuhaire et al., 2017; Sekabojja et al., 2021). Although pesticide risks are perceived as a problem and have been for some time, Uganda lacks a consistent policy regime for regulating pesticides and implementing risk reduction. The legislative act that established a framework for addressing pesticide management in Uganda was

adopted in 2006 and lacks the necessary follow-up regulations to address and reduce pesticide risks to human and environmental health (Wiedemann et al., 2022).

Actor identification and survey data

Decisional, reputational, and positional approaches (Knoke, 1993; Knoke et al., 1996) were used to identify stakeholders and their roles (e.g., who is influential or who is affected by decisions related to pesticide risk reduction in Uganda). The stakeholder list and the survey were validated and pre-tested in six expert interviews. The experts represented a government ministry, two research institutions, a nongovernment organization (NGO), an interest group, and a local government. This yielded a list of 53 national stakeholders (including four international stakeholders that had representatives in Uganda). Second, a 12-question online survey was conducted and integrated with 14 face-to-face interviews. Data were collected between October 2019 and July 2020. Thirty-eight policy actors responded to the survey (71.7% response rate); however, nine actors were excluded from the analysis because they had missing values for the variables used for data analysis. This resulted in a sample of 32 actors (see Table 10 for an overview of the survey and interview participants and Table A11 in the Supplementary Material (SM) Online).

Actor type	**Survey** (*Total contacted*)	**Response rate**	**Interviews**
Government ministry	7 (8)	87.5%	3
Government agency	6 (10)	60%	4
Research institution	5 (7)	71.4%	1
Association and interest group	5 (5)	100%	2
CSO/NGO	12 (16)	75%	3
Pesticide distributor	3 (3)	100%	1
International organization	0 (4)	0%	0
Total	**38** (*53*)	**71.7%**	**14**

Table 10: Survey and interview participants

Data analysis methods

To identify (joint) beliefs and preferences in a nascent setting, we suggest a three-step approach.

Step 1: Identifying beliefs and preferences in a nascent subsystem

In nascent subsystems in which policy negotiations are not yet well articulated, it is difficult to identify a portfolio of beliefs and preferences based on an examination of official documents or media analysis for two reasons. Either the documents do not exist, or if official documents exist, they do not contain clear information about potential policy solutions and beliefs justifying them; partially also because actors have not formed opinions. In this context, we identify potential policy core beliefs and secondary aspects (preferences for policy instruments). To identify policy core beliefs related to risk reduction, we relied on previous studies, knowledge from other neighboring subsystems, and research on agricultural policymaking (Metz & Ingold, 2014, 2017; Metz et al., 2021; Vogeler & Bandelow, 2018). Studies on micro-pollutants and agricultural pesticide management outlined two dominant logics of state intervention (Metz & Ingold, 2017; Seifert et al., 2019; Tosun & Leininger,

2017): tackling the problem at the source so that pollution does not occur or the extent is limited (i.e., preventive or precautionary measures, such as substance bans or pesticide taxes) and end-of-pipe measures (e.g., reactive interventions, such as water treatment techniques). Thus, we included two complementary policy beliefs to interactively reduce pollution risks (Metz & Ingold, 2017; Schaub & Braunbeck, 2020; Xanthos & Walker, 2017) (*names as shown in the figures*): risk prevention (*Belief: Preventive action*) and risk control (*Belief: Reactive action*). The secondary aspects included policy instruments for regulating pesticide risks, which we call policy preferences. We selected the policy preferences based on four criteria.

Criterion 1 (*Document research*): We conducted a thorough document search, including reports from the OECD, the EU, and academic literature (Lee et al., 2019; OECD, 2012; Pedersen et al., 2012), to extract 26 policy instruments that are considered effective tools for reducing pesticide risks.

Criterion 2 (*Fitness for context*): Ugandan agriculture is shaped by small-scale subsistence farming. Although the use of pesticides per hectare of land is comparably low, exposure to risk is elevated due to a lack of protective equipment, access to counterfeit and toxic products, and limited knowledge of recommended amounts (Staudacher et al., 2021; Stein & Luna, 2021). Based on this criterion, we excluded four policy instruments and included the remaining 22 in the survey.

Criterion 3 (*Conflictuality 1*): In a nascent subsystem, policy preferences are expected to be fragmented (Beverwijk et al., 2008) or amorphous (Stritch, 2015). We also know that coalitions form based on conflicting or controversial policy preferences (Weible & Ingold, 2018). Thus, we coded the 22 policy instruments based on their standard deviation from the survey and considered them to be conflictive above a standard deviation (SD) of 0.65 (applied to 10 policy instruments).

Criterion 4 (*Conflictuality 2*): Along the lines of the previous criterion, we further investigated the conflictuality of the policy instruments across the 14 face-to-face interviews. We included only policy instruments in which conflict was apparent among the political elite. The degree of conflict is relevant in an ACF investigation, as belief conflict is one way to identify opposing coalitions. Therefore, we considered an instrument to be conflictive or contested among the interviewees if the policy instrument occurred in at least half (seven) of the instruments beyond a simple mention (applied to nine policy instruments).

Criteria 1 and 2 were used to compile an extensive list of policy instruments that were then included in the survey, while Criteria 3 and 4 (conflictuality) were applied to reduce this list and refine the selection of policy instruments for the analysis (for more details, see section "Selection of policy preferences in a nascent subsystem" and Tables A12, A13, A14, A15, and A16 in the SM Online).

First, after the document search, we identified 26 policy instruments that could be used as political tools for reducing pesticide risks (Berthet et al., 2021; Lee et al., 2019; OECD, 2012; Pedersen & Nielsen, 2017). Second, we included only 22 of the policy instruments in the survey because policy instruments such as regulation of precision farming, mandatory spray journals, or covenants do not

fit the context of small-scale farming. Third, we selected policy instruments based on how much potential conflict they had in the subsystem, or in other words, how contested they were among the survey participants. In particular, policy instruments invoking a cost, such as a purchase tax (Mean = 2.5, SD = 1.05) or a redistributive tax (Mean = 2.53, SD = 0.98), were highly contested. Additionally, regulatory instruments introducing a ban on the import or use of specific pesticides (Mean = 3.53, SD = 0.95) and voluntary measures, such as reduction targets from industry and/or civil society (Mean = 3.38, SD = 1.04), held high potential for conflict among the survey participants. Fourth, to further assess the conflictuality, we measured how contested the policy instrument was during the face-to-face interviews. The ban was the most discussed policy instrument (occurred in 13 of 14 interviews). Although the ban was generally considered an effective policy instrument, interviewees discussed hurdles for enforcement due to weak monitoring (Interview 11) and lack of support, because "people wanted very [...] quick solutions. And want food tomorrow—and this where we have the problem" (Interview 5). Interviewees also expressed their skepticism regarding market-based instruments, such as purchase taxes, which occurred in 11 of 14 interviews), because they penalize farmers and their families (Interviews 11, 13, and 15), and because managing tax money is challenging (Interview 3). Based on this four-step selection process, we chose nine policy preferences for analysis (*names as shown in the figures*):

1. Regulation through laws to limit amounts (*Pref: Regulation through laws*)
2. Ban (on substance import) (*Pref: Ban particular products*)
3. Fewer restrictions on alternatives (other than pesticides) (*Pref: Less restrictions alternatives*)
4. Zoning (agricultural spatial planning) (*Pref: Zoning*)
5. Redistributive tax (on pesticide purchases) (*Pref: Redistributive taxes*)
6. Purchase tax (without redistribution) (*Pref: Purchase tax*)
7. Emission tax (effluent taxes) (*Pref: Taxes to charge emissions*)
8. Commitments (with the private sector) (*Pref: Cross-sector commitments*)
9. Voluntary measures (by the private sector and civil society) (*Pref: Voluntary measures*)

These policy preferences cover the three categories into which policy instruments are typically divided in policy studies: regulatory or command-and-control instruments, economic or market-based instruments, and persuasive or voluntary instruments. Preferences for these different types of policy instruments indicate the actors' agreement with the degree of state intervention and their level of restrictiveness (Kaufmann-Hayoz et al., 2001; Vedung et al., 1998).

Step 2: Identifying belief clusters

To identify clusters of like-minded actors, we created a distance matrix from the two core beliefs and the nine policy preferences that came out of Step 1 (see Table A13 in the SM Online for the summary statistics of the beliefs and policy preferences used for the distance matrix). The actor × belief matrix was then transformed into an actor × actor adjacency matrix, where every cell indicates the Manhattan distance between the two actors (see also Metz et al., 2021). The bigger the number, the larger the disagreement regarding beliefs and preferences between two actors. Through hierarchical

cluster analysis using the ward.D2 method, the distance matrix was then transformed into clusters with low belief distance among the actors. Based on a calculation of the optimal number of clusters for hierarchical clustering (see Figure A8 in the SM Online), we identified three clusters of actors. Given the small data set, we are confident that hierarchical clustering is well suited for identifying groups of like-minded actors (Kammermann & Dermont, 2018).

Step 3: Constructing the regression model

We used the belief clusters from Step 2 to construct the dependent variable for Step 3 and to assess the drivers of belief cluster co-occurrence in a regression analysis. Specifically, we used standard logistic regression for binomial data to test whether collaboration, forum participation, and similar problem perception influenced the co-occurrence of the actors (yes = 1, no = 0) in the same belief and preference cluster. All model calculations were performed with the glm package for generalized linear models in the statistical computing environment R (R Development Core Team, 2014).

To explain co-membership in the three belief and preference clusters, the following variables and controls were considered (see also Table 11 and section "Building the regression model" in SM Online for a more detailed discussion of all variables included in the regression models).

	Name	**Name in model**	**Data**
DV	Actors' co-membership in the (same "belief and preference") cluster	-	Co-occurrence of actor pairs (0,1)
IV1	Actors' forum participation	Participation in the same forums	Co-occurrence of actor pairs in forums (0-3)
IV2	Actors' collaboration	Collaboration previous 3 years	Directed binary matrix (0,1)
IV3	Actors' problem perception	Similar problem perception	Distance matrix (Manhattan) between actor pairs' problem perception related to nine threats (1–4)
CV1	Actor type	Same actor type	Co-occurrence of actor pairs as actor types (0,1)
CV2	Actors' involvement	Shared responsibilities	Co-occurrence of actor pairs along steps (0–7)
CV3	Actors' reputation	Similar reputation	Distance matrix (Manhattan) between actor pairs' reputation (0,1)

DV = dependent variable; IV = independent variable; CV = control variables

Table 11: Operationalization of variables

First, forum co-participation data were gathered with an open question, and the respondents named forums in which they participated in matters related to pesticide management in Uganda. A total of 49 different forums were mentioned by the surveyed actors, covering regulatory committees, roundtables, and networking events. Second, to gather actors' collaboration partners, we asked the participants to check off all the organizations with which their own organization had worked closely during the previous three years while performing activities related to pesticide regulation. Close collaboration was defined as discussing new findings, developing policy options, exchanging positions, and evaluating alternatives. Third, we assessed actors' problem perception through stakeholders' consideration of threats attributable to pesticide use in Uganda (1 = not at all attributable to 4 = completely

attributable). The nine threats covered different domains: health (public health, and occupational health), environment (air quality, groundwater/drinking water, wildlife and plants, and watercourses and lakes), and agriculture (food security, food security, and agricultural livelihoods).

Results

The analyses presented here are based on the two preselected beliefs (preventive action and reactive action) and nine policy preferences, as outlined in Step 1 in the Methods section. Before presenting the results of the regression analysis, we discuss the clusters of like-minded actors.

Belief clusters

Figure 9 reports the results of the hierarchical clustering based on the distance matrix of the two core beliefs and the nine policy preferences. The optimal distribution resulted in three clusters (Figure 1): Cluster 1 (20 actors, violet), Cluster 2 (10, orange), and Cluster 3 (2, green).

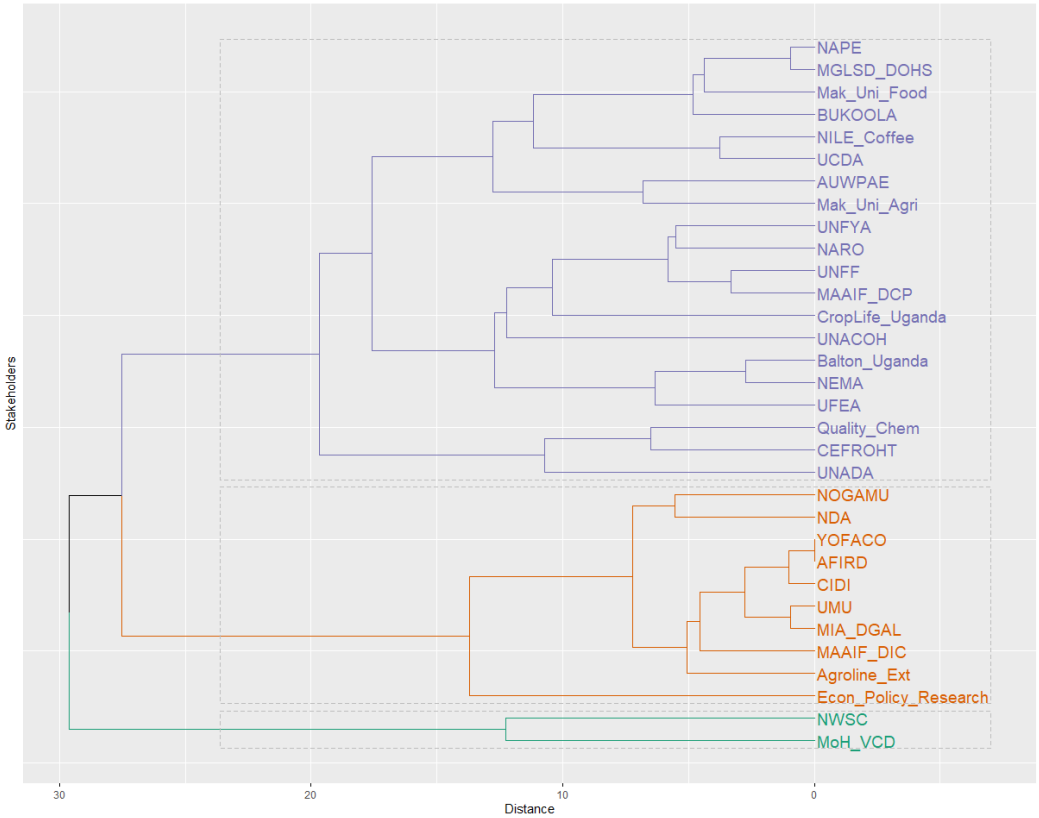

Figure 9: Cluster analysis results

The actors in Cluster 1 were the "usual suspects" of agricultural policy in Uganda (Kansiime et al., 2017; Yami et al., 2019). All of the surveyed pesticide distributors, including the well-established Croplife Uganda as well as the associations and interest groups that represent the interests of farmers (e.g., the Ugandan National Farmers' Federation [UNFF] and industry (e.g., the Ugandan National Agro-dealer Association [UNADA] or the Ugandan Flower Exporter Association [UNFA]),

are in Cluster 1. Alongside major government bodies, such as the Department of Crop Protection (MAAIF_DCP) and the National Agricultural Research Organization (NARO), the actors in Cluster 1 were experts in matters related to agricultural policy and pesticide management. They had long-standing experience and were considered influential stakeholders by the survey participants (see Table A17 in SM Online). In Cluster 2, influential stakeholders such as the Department of Crop Inspection (MAAIF_DIC), and the National Organic Agriculture Movement of Uganda (NOGAMU) are mixed with less important actors. The two actors in Cluster 3 can be considered outliers: two policy actors from the government level, one from the health sector focusing on vector control (MoH_VCD) and one representing the National Water and Sewage Cooperation (NWSC).

Figure 10 highlights the belief and policy preferences across the 11 items for each actor and across the three clusters (the darker the tiles, the higher the policy actors' agreement).

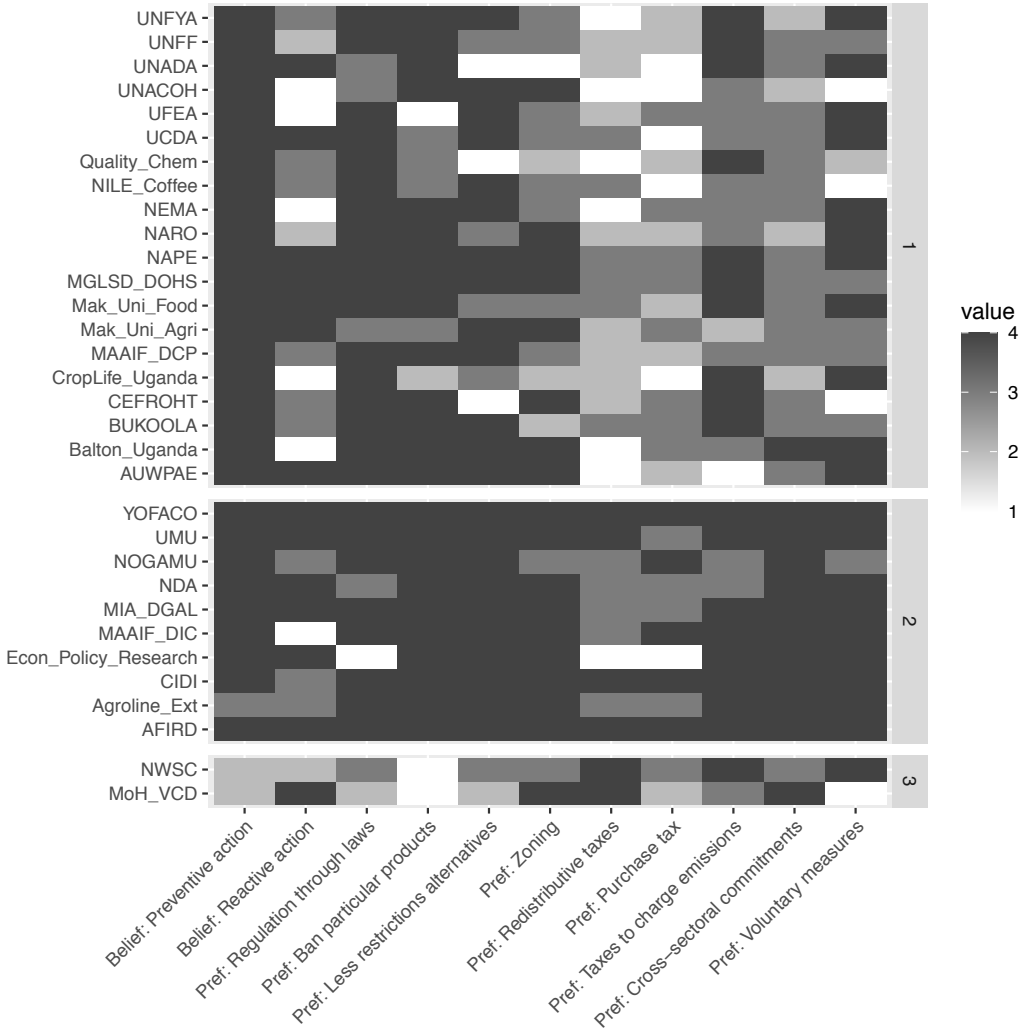

Figure 10: Belief and policy preferences in all three clusters

In Cluster 1 (the most influential stakeholders), the actors tend to prefer preventive to reactive state intervention. Specifically, all actors in Cluster 1 strongly agreed with preventive state intervention,

and some key players, such as Croplife Uganda (the umbrella organization of pesticide distributors), as well as the National Environmental Management Agency (NEMA) also rejected reactive state intervention (i.e., risk reduction after pesticide exposure). On average, the actors in Cluster 1 preferred regulatory and voluntary measures and largely opposed market-based policy instruments (with the exception of taxes). In Cluster 2, no clear belief and policy preferences patterns were found: Most of the actors exhibited strong preferences for all approaches of state intervention and all surveyed policy instruments. This indicates that the actors in this cluster had unclear preferences or had not formed a consolidated opinion about how to address pesticide risks politically. The two actors in Cluster 3 rejected most of the instruments, and they preferred only a single instrument, redistributive taxes.

When examining the overall picture and color distribution in Figure 10, we see that reactive state intervention as a policy belief, as well as economic measures like taxes, are much less preferred by a majority of the sample, and mainly by the actors of Cluster 1. Instead, preventive state intervention to reduce pesticide risks, as well as voluntary measures and direct regulation (e.g., laws to limit the dosage of certain products and fewer restrictions on alternative products such as biopesticides), are the measures to address pesticide risks most preferred by the 32 surveyed actors.

All three clusters were heterogeneous in terms of the actor type distribution (see Table 12). Cluster 3, with only two actors, was the most straightforward; both actors were government representatives. Clusters 1 and 2 included different types of actors, but Cluster 1 was, besides NGOs, also strongly dominated by interest groups and pesticide distributors that were not in clusters 2 and 3.

Actor type	**Cluster 1**	**Cluster 2**	**Cluster 3**
Association/interest group	5	0	0
CSO/NGO	5	5	0
Government agency	3	1	1
Government ministry	2	2	1
Pesticide distributor	3	0	0
Research institution	2	2	0
Total	**20**	**10**	**2**

Table 12: Distribution of actor types within the three clusters

Regression results

Table 13 displays the parameter estimates of the models with standard errors in parentheses resulting from the logistic regression to understand what drives actors' tendency to be "belief and preference" co-members. We modeled co-membership in three ways. We calculated three separate models: Model 1 for the likelihood of two actors co-participating in general (if they co-participated in any of the three clusters), Model 2 for the likelihood of being in Cluster 1, and Model 3 for the likelihood of being in Cluster 2.

For overall co-participation, we confirmed that participation in the same forum increased the likelihood of co-participation to a significant extent. Actors named 49 forums in which they participated in matters related to pesticide management. The forum mentioned the most (13 times) was

	Model 1 overall	Model 2 Cluster 1	Model 3 Cluster 2
Intercept	-0.09 (0.09)	1.76 $(0.22)^{***}$	-1.77 $(0.22)^{***}$
Participation in the same forums	0.28 $(0.10)^{**}$	0.21 (0.22)	-0.19 (0.22)
Collaboration during the previous 3 years	0.12 (0.10)	0.54 $(0.23)^{*}$	-0.52 $(0.23)^{*}$
Similar problem perception	-0.18 $(0.09)^{\cdot}$	-0.71 $(0.21)^{***}$	0.70 $(0.21)^{***}$
Same sector	0.15 (0.09)	-0.00 (0.18)	0.02 (0.18)
Shared responsibilities	0.25 $(0.10)^{*}$	0.52 $(0.24)^{*}$	-0.47 $(0.23)^{*}$
Similar reputation	0.06 (0.10)	0.04 (0.18)	-0.08 (0.18)
AIC	670.08	214.32	213.59
BIC	699.53	238.57	237.83
Log Likelihood	-328.04	-100.16	-99.79
Deviance	656.08	200.32	199.59
Num. obs.	496	236	236

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\cdot}p < 0.1$

Table 13: Results for the logistic regression

the highly institutionalized Agricultural Chemicals Control Board (ACCB; established via the Agricultural Chemicals Control Act of 2006), which hosts a cross-sector consortium of actors who make decisions regarding pesticide management in Uganda. The act established who participates in this forum; thus, participation in the ACCB is limited to the actors mentioned explicitly in the act. In the investigated context, this closed forum plays a crucial role in matters related to pesticide management in Uganda. The actors also mentioned other forums that are less exclusive and open to a broader range of actors, such as the National Pesticide Dialogue, the Pesticides Health, and Environment Project. Additionally, stakeholders mentioned actors who were part of the survey that organized forums and platforms, for example, the UNACOH and the Ministry for Agriculture (MAAIF). Almost a third of the actors did not participate in any forum, including the two actors in Cluster 3. In clusters 1 and 2, forum participation was again heterogeneous, but there was a clearer trend of co-participation for Cluster 1 (Table 14).

Number of forums mentioned	**Cluster 1**	**Cluster 2**	**Cluster 3**
0	5	3	2
1	4	1	0
2	3	3	0
3	3	1	0
4	2	1	0
5	3	0	0
6	0	1	0
Total	**20**	**10**	**2**

Table 14: Forum participation within each cluster

In Model 1, however, we did not find (significant) effects for collaboration or for similar problem perception on co-participation. Therefore, hypotheses 2 and 3 were not supported.

Models 2 and 3 examined the likelihood of participating in Cluster 1 (pro-preventive, violet) and Cluster 2 (pro-integrative, orange), respectively. The direction of significant effects is the opposite

in both models, which is interesting. The preference similarity in the two clusters was based on different reasons. In Cluster 1, co-occurrence was based on previous collaboration and negatively related to problem perception, while in Cluster 2, the two variables were significant but in opposite directions. Co-occurrence in Cluster 2 was based on a similar problem perception but negatively related to previous collaboration.

We also examined each variable (i.e., collaboration and problem perception) independently. Although not significant, in Model 1, collaboration was positively related to overall cluster co-occurrence. Collaboration had a marginally but significant positive effect on co-occurrence in Cluster 1 and almost the same negative and significant effect for Cluster 2. When we examined the densities in the collaboration network of the two clusters, the collaboration network in Cluster 1 was much denser than that in Cluster 2 (see Figures A12 and A13 in the SM Online). Highly central actors in this cluster are the Ministry of Agriculture's Department of Crop Protection (MAAIF_DCP), the NEMA, and the UNFF. These actors, who preferred preventive and coercive state intervention, had a high potential to assume a gatekeeper position and control the flow of information and resources (see also betweenness centrality in Table A17 in the SM Online for a description of the collaboration network). Network density in Cluster 2 was lower, and the actors that held the network together and prefer integrative state intervention were the NOGAMU and the Department of Inspection and Certification (MAAIF_DIC). That collaboration was not a predictor of belief congruence means that many actors tied to those two central actors (NOGAMU and MAAIF_DIC) did not share their beliefs and policy preferences (see Figures A12, A13, and A14 in the SM Online for a visualization of the networks).

Similar problem perception, a strong predictor, was negative overall and in Cluster 1 and positive in Cluster 2. We also examined how the different cluster properties are related to problem perception. To simplify the illustration of the results, we bundled actors' problem perception into three sectors (environment, agriculture, and health) and calculated the overall problem perception per actor (across all three sectors for each policy actor distinguishing among the three clusters). The heat map in Figure 11 shows the problem perception in the clusters. It is very heterogeneous but seems to be more congruent in Cluster 2 than in the two other clusters.

The control variables showed one significant effect: The overall co-occurrence of stakeholders in Cluster 1 was more likely if the stakeholders shared areas of responsibilities related to pesticide management in Uganda. The opposite held true for Cluster 2. The other control variables did not yield any significant effect in any of the three models.

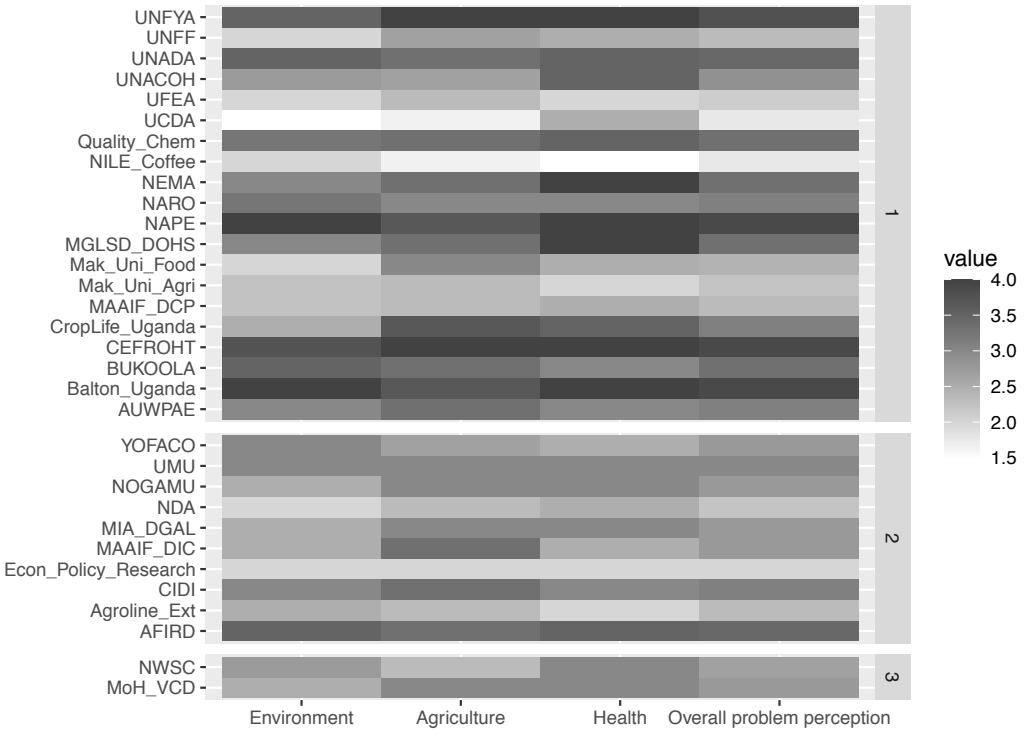

Figure 11: Threat perception across sectors for the three clusters

Discussion and conclusion

In this article, we analyzed political actors in pesticide regulation in Uganda and investigated their potential for shared policy beliefs or preferences. Pesticide regulation in Uganda can be classified as a so-called "nascent subsystem" in which policy outputs are largely missing, and clear organization among actors has not yet developed. In such a setting, it might be crucial to investigate joint preferences for regulation and state intervention to anticipate in what direction policies might develop and which majorities might impact final regulatory decisions.

We conducted a survey and interviews with more than 30 actors to understand their beliefs and preferences regarding pesticide regulation. Among other things, we presented two policy core beliefs and nine different policy instruments to the respondents, such as substance bans or pesticide taxes, and asked which instruments they preferred. Based on the respondents' answers, we clustered the actors. As the first result, we identified an optimal distribution of the actors into three clusters. These clusters show the nascent character of the subsystem. Only one cluster (Cluster 1) showed clear preferences for certain policy instruments (opposition to taxes and support for prevention). This cluster was big and dominant, with 20 actors, but very heterogeneous in terms of actor type. Cluster 2 was smaller but still heterogeneous, with preferences for all sorts of state intervention and policy measures. In contrast to Cluster 1, the actors in Cluster 2 were not yet well organized and seemed not fully integrated in agricultural or food policy or, more concretely, in the process of pesticide regulation. Cluster 3 consisted of two government representatives who opposed prevention to reduce pesticide risks, which was in contrast to all the other actors in this subsystem. Thus, we confirmed imprecise and widespread policy preferences for pesticide regulation in general, which seems typical for a nascent policy subsystem (Stritch, 2015) but also for the domain of pesticide regulation in general (Lee et al., 2019). However, at least one of the three clusters (Cluster 1) seemed "more mature" than the other two.

We then formulated three hypotheses and predicted that joint forum participation, previous collaboration, and joint problem perception positively impact belief cluster co-membership. Overall, and considering all the political elite actors in this study, forum participation seemed to positively impact cluster co-membership, while problem perception also had a significant but negative impact on cluster co-membership. Nevertheless, these results must be qualified and carefully assessed. When we separated the regression models and analyzed joint beliefs for clusters 1 and 2 separately, we discovered opposing or different results. Although for the bigger, more organized Cluster 1, where stakeholders had clearer beliefs and preferences, collaboration was a significant and positive driver for belief cluster co-membership, for Cluster 2, collaboration was negative (Table 4). For Cluster 2, which had less pointed beliefs and preferences, similar problem perception was the major and significant driver, which was, in contrast, negative for Cluster 1. Therefore, in each of the models (Table 4), we confirmed one different hypothesis, but the other hypotheses were not supported. This is an important result, showing that within one nascent subsystem, the different belief clusters (or "potential coalitions") also have different degrees of maturity. Thus, it is wise to analyze them separately, as different factors affect the actors' development of joint beliefs and potentially their subsequent coordination patterns. It seems particularly interesting that for the new or not yet well-organized actors

(Cluster 2), problem perception or affectedness seems key. The new issue might act as an external shock (Birkland, 2015) or at least put actors under certain pressure to engage in policymaking, but their beliefs and preferences are not yet well defined.

From an empirical and methodological point of view, this also has crucial implications, as considering the whole sample of actors can lead to erroneous results or interpretations. It is important to cluster actors according to their preferences and to consider the groups of like-minded actors separately, rather than as a whole integrative subsystem.

To assess nascent subsystems, we conclude that the proposed three-step approach makes a lot of sense. We started with an explorative approach in Step 1 to compile a broader list of beliefs and potential policy instruments in this subsystem. We then presented the list of policy instruments to the political elite actors in a survey to reduce the list for further analysis and kept only the instruments that were evaluated as relevant or conflictive by the surveyed actors. Steps 2 and 3 were more analytical. In Step 2, we created clusters of like-minded actors that were then transformed into the dependent variable in Step 3, when we conducted a regression analysis to explain belief cluster co-occurrence among the subsystem actors.

The results are limited to a specific case, which is why we did not generalize them. However, by applying fundamental concepts of the ACF to a nascent subsystem in the Global South, we showed that these considerations hold in such a context but that investigations must be more comparative. The results indicate that the dynamics within each cluster vary, and a detailed investigation of each cluster is needed. To explain differences across clusters, future research might compare coalitions across different nascent subsystems or confront nascent subsystems that address pesticide risks across different countries (e.g., other countries in sub-Saharan Africa). For similar explorative studies, additional and more detailed analyses are necessary. Future investigations might apply additional methods of data gathering (e.g., network mapping or approaches to understanding stakeholders' mental models) to integrate and triangulate survey data. This can be beneficial to better grasp stakeholder beliefs and contextualize results. This avenue has much potential to compensate for limited response rates and missing data. For this study, we relied on local collaboration and university partnerships, which contributed to a successful data-gathering process. Involving local collaborators and engaging in academic partnerships thus seem key for similar explorative investigations.

The results allow us to make suggestions to design future policies in Uganda for reducing pesticide risk. Preventive state intervention, or more specifically, state intervention that targets the risk before humans and the environment are exposed, was supported by the majority of the surveyed political elite actors. State intervention targeting risks in a reactive manner was much less preferred. Thus, stakeholders in Uganda prioritize environmental considerations at the very beginning of the production process (Kautto & Similä, 2005) to abate pesticide-related risks. In the words of Cameron and Abouchar (1991), preventing (as opposed to reacting to) risks is a step away from the convention "solution to pollution is dilution" approach, and the literature on micro-pollutants has emphasized the crucial role of preventive measures to avoid pollution-related risks at the source (Tosun et al.,

2020). Furthermore, stakeholders in Uganda show a tendency to reject market-based policy instruments, which is in line with research suggesting that instruments for reducing environmental risks are highly accepted by stakeholders, but they also tend to reject measures that invoke a monetary penalty and financial burden for the target groups (Metz & Leifeld, 2018). Moreover, in the Global South, market-based instruments, especially taxes, are difficult to enforce (Xie & Saltzman, 2000) due to a lack of monitoring or corruption (Bell & Russell, 2002). Our investigation showed that less coercive measures involving the private sector and fostering risk reduction through raising awareness were highly accepted by all actors. In Uganda, pesticide management is highly decentralized and partly privatized, making the private sector a key player in delivering agricultural services (Isgren & Andersson, 2021; Martiniello, 2015), and NGOs play a crucial role in raising awareness and sensitizing farmers and society in general (Isgren, 2018). Due to limited enforcement and monitoring capacities, less coercive measures seemed to be more feasible and thus had broad support from the investigated stakeholders.

Overall, this study showed that the investigation of "not yet well defined" beliefs in a nascent subsystem is possible with "standard" techniques of data gathering and analysis, such as survey data, interviews, and regression analysis. However, we emphasize that it seems important, at least in the first step of the investigation, to be open about what types of beliefs or preferences might be relevant to the actors and within the nascent subsystem. Furthermore, it seemed wise to triangulate the survey data with expert interviews. Finally, we encourage researchers to aim at a longitudinal research design if possible and accompany the subsystem over time to make conclusions about what seems inherent to the topic and the specificities of the subsystem or the political system and what factors might change with the maturation of the policymaking process.

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Solving cross-sectoral policy problems: Adding a cross-sectoral dimension to assess policy performance

Many policy problems such as climate change, water pollution, or biodiversity loss originate in one sector or location but deploy their effects elsewhere and so require comprehensive regulation that is both source-directed and cross-sectoral. But, how can we assess a country's cross-sectoral policy performance when it comes to solving complex (environmental) problems? To answer this question, the study examines pesticide regulation in Costa Rica. Synthetic pesticides are widely used to sustain agricultural production, but they constitute a risk for humans and nature. To assess policy performance, both the substantive (policy instruments) and institutional (legislation) aspects of policymaking targeting pesticide risks mitigation are considered for evaluation. More specifically, the policy mix of instruments in respective action plans as well as legislation in respective laws and regulations are analysed. To assess the cross-sectoral dimension and to add to literature on policy density and intensity, criteria like formulation of objectives, target group integration, coordination and policy instrument types are used. The findings indicate that policy mixes in the water and health sector exhibit high cross-sectoral performance in terms of source-directed instruments, but cross-sectoral performance in the overarching legislation is limited.

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Introduction

In recent years, comparison of policy mixes across countries or over time has attracted increasing research interest (Lieu et al., 2018; Rayner et al., 2017; Schmid et al., 2020) for a number of reasons. First, there is interest in how countries comply with international pledges when introducing domestic policies (Pischke et al., 2019; Tobin, 2017; Tobin et al., 2018). Second, policy mix comparison can shed light on policy diffusion and learning by highlighting who 'copied' whom or which prospective diffusion pathways seem more promising than others (Metz & Fischer, 2016). Finally, policy mixes are evaluated and compared to assess how well a country performs in addressing a specific problem (Capano et al., 2020; Schaffrin et al., 2015). In this context, policy performance is defined as the policy mix's ability to reach specified targets, without limiting its assessment only to the criteria of effectiveness, but also taking other dimensions of policymaking into consideration. It follows that studies most typically focus on density and intensity to evaluate policy mix performance (Knill et al., 2012), based on the assumption that policy performance improves as more instruments are introduced (density) and their content in terms of scope or budget increases (intensity) (Schaffrin et al., 2015).

To augment the existing literature, the present study argues that assessment of policy performance should be refined to incorporate an additional cross-sectoral dimension, especially in the case of complex environmental problems produced by different actors in diverse sectors or affecting different entities (humans, species, and ecosystems). To that end, the study addresses the following research question

How can we assess a country's cross-sectoral policy performance when it comes to solving complex (environmental) problems?

To answer this question, we add two innovations to the existing literature: First, policy performance evaluation is extended to include a cross-sectoral dimension. The ideal cross-sectoral policy mix would include comprehensive instruments that target all sources and/or benefit diverse victims (Lee et al., 2019). In evaluating the quality of policy instruments, we utilise criteria like the share of source-directed (as compared to end-of-pipe) instruments and comprehensive integration of target groups.

Second, the present study extends the assessment of cross-sectoral performance to include both substantive elements (instruments of the policy mix) and institutional aspects (legislation) of policymaking. Laws and regulations specify the policy domain's general objectives and target groups, and assign competences to relevant public and private actors. To evaluate cross-sectoral institutional performance, evaluation criteria should also be including cross-sectoral formulation of objectives, integration of diverse actors groups contributing to the problem, and coordination across agencies and organisations.

This study examines pesticide use in Costa Rican agriculture, which is considered a "global leader in both, conservation and intensive tropical agriculture" (Fagan et al., 2013, p. 2) and therefore offers a 'typical case' in which to investigate cross-sectoral challenges. Using state-of-the-art and cross-

sectoral criteria, the study evaluates the policy mix and laws governing pesticide regulation in relation to drinking water, the aquatic ecosystem, and occupational health. This approach links two previously distinct strands of the literature (Metz & Glaus, 2019): the one that focuses on institutions regulating natural resources (Gerber et al., 2009; McGinnis & Ostrom, 2014); and the other that is invested in the choice of policy instruments (Doern, 1992; Schaffrin et al., 2015). We thereby seek to highlight the relevance of substantive and institutional aspects of policy design (Dupuis & Knoepfel, 2016; Tosun & Leininger, 2017) alongside politics and decision-makers' preferences (Howlett et al., 2015; Metz & Ingold, 2017).

Based on systematic search and coding of legal texts, the study results provide insights into the cross-sectoral performance of Costa Rica's policy response to pesticide risks. To our knowledge, this is the first evaluation of Costa Rica's pesticide policy, cross-sectoral or otherwise. In general, this joint evaluation of institutional and substantive aspects of policymaking represents a novel addition to policy performance assessment.

Institutions, policy design and expectations

As outlined in the Introduction to this special issue (Schaub et al., forthcoming), most (wicked) policy problems are currently addressed by more than one policy instrument, so-called policy mixes (Schaffrin et al., 2015). There are different reasons for this, and often the reasons are cumulative. Because wicked problems tend to be cross-sectoral and multi-level, actions typically involve different programmes and jurisdictions (Ingold et al., 2018). Additionally, instruments are rarely abolished; instead, further instruments are introduced over time in pursuit of the same goal (Kivimaa & Kern, 2016; Metz & Glaus, 2019). Finally, a single well-designed instrument (probably source-directed) can potentially solve much of the problem, but such instruments tend to lack public or political support (Landry & Varone, 2005; Metz & Ingold, 2014). Together, these factors account for the prevalence of policy mixes as response to (wicked) policy problems. The present study explores how a policy mix meets cross-sectoral requirements. In addition to the well-known criteria density and intensity, we thus add a cross-sectoral dimension to evaluate the policy performance in both, the substantive (policy mix) and the institutional (legislation) aspects of policymaking. While the focus here is on policy design rather than implementation, we acknowledge that the realities of implementation clearly contribute to a policy's problem solving capacity.

Defining policy performance in terms of how well various policy instruments are bundled together as a single mix (Capano & Howlett, 2020), we argue that cross-sectoral coherence and capacity are as relevant to policy performance as the number of instruments (density) and the quality of state intervention (intensity). This approach is summarised in Table 15, which highlights the two innovations (see italics for cross-sectoral dimension (criteria) and institutional aspects of policymaking (object)).

Objects of evaluation: substantive and institutional aspects of policymaking

Studies of policy instruments and mixes can be assigned to different strands of the literature (see also Tosun, Treib, et al., 2018). First, many scholars are interested in the classification and analysis of

Objects of evaluation	Criteria of evaluation	Relevant literature	Relevant concepts
Policy mix (substantive)	Density Intensity	Knill et al. (2012) Bauer and Knill (2014) Schaffrin et al. (2015) Li and Taeihagh (2020) Pollex and Lenschow (2020)	
	Cross-sectoral dimension	Stein et al. (2016)	Policy coherence (Instrument types)
		Metz and Glaus (2019)	Target group integration
Legislation (institutional)	*Cross-sectoral dimension*	Howlett and Cuenca (2017)	Policy coherence (Formulation of objectives)
		Zinngrebe (2018)	Policy capacity (Coordination)
		Gerber et al. (2020)	Target group integration

Table 15: Policy performance: Objects and criteria of evaluation

policy instruments (for an overview, see Howlett et al., 2015; Metz, 2017) and how they perform, based on criteria that include coerciveness and moral appeal (Doern, 1992; Landry & Varone, 2005). Among these, Vedung et al. (1998) classification of sermons, carrots and sticks, referring to increasing levels of state intervention, is perhaps the most well known. More recent research has related policy instruments to decision-making processes (Schmid et al., 2020), innovation (Kern et al., 2019), and transition (Rogge & Reichardt, 2016), as well as investigating the capacity of such instruments to alter target group behaviours (Burger et al., 2015; Howlett, 2018; Vlek, 2000).

The hierarchical nature and mutual effects of substantive and institutional aspects of policymaking are often implicitly assumed. According to Ostrom (1990) Institutional Analysis and Development (IAD) framework, policies are embedded in a multi-level arrangement in which the 'constitutional choice level' of laws and regulations specifies general guidelines for tackling a problem while the 'collective choice level' specifies concrete measures for addressing that problem. On this logic, constitutional choice impacts collective choice, and the (cross-sectoral) logic that determines how a law is designed should then also impact the (cross-sectoral) logic of instrument selection (Bauer & Knill, 2014). In contrast, Howlett and Rayner (2007) and Tosun and Leininger (2017) highlighted the impact of substantive policies on institutions. The literature on policy integration suggests that institutional and substantive aspects are strongly entangled (Runhaar, 2016); in other words, policy instruments should target goals outlined in the overarching legislation rather than new policy goals. In turn, collaborative arrangements for policy implementation can affect the institutional anchorage of such collaborations in future decision-making processes (Lange et al., 2013). In summary, the strong entanglement of substantive and institutional aspects of policymaking means that both must be considered in assessing policy performance (see Table 15), without – an a priori – assumption of a causal link in either direction (i.e. from instruments on laws, or vice versa).

Criteria of evaluation: adding a cross-sectoral dimension

Various criteria have been developed to compare the performance of policy mixes and related institutional arrangements across sectors or countries; among these, density and intensity are probably the

most prominent (Knill et al., 2012). *Density* is a proxy for state activity to address a problem, based on a 'simple' count of instruments integrated in the policy mix, where the density of the mix increases with the number of policy instruments. *Intensity* refers to the quality and content of these instruments and may be evaluated in terms of the budget allocated to implementation of the instruments in a policy mix or sanctions for non-compliance. Perhaps the most prominent indicator of policy intensity is *coerciveness*; the more coercive the policy instruments, the greater the allocated budget and sanctions for non-compliance, the more intense the mix.

A number of studies have investigated both density and intensity (or proxies thereof) of policy mixes to shed light on a country's or jurisdiction's ability to engage in larger socio-technical transitions (Kern et al., 2019; Rogge & Reichardt, 2016; Schmidt & Sewerin, 2019) or to address wicked problems such as climate change (Bauer & Knill, 2014). In one policy analysis of pesticide regulation, Lee et al. (2019) concluded that a mix of different policy instruments types and different degrees of state intervention was most effective in reducing pesticide risks. Like other wicked problems, pesticide risks typically arise in one or more sector but may have wider effects. To date, this cross-sectoral dimension has not been explicitly considered when evaluating policy mixes, and we argue here that the environmental policy integration (EPI) literature (Jordan & Lenschow, 2010) suggests diverse pathways to that end.

EPI research proceeds from the normative claim that the environment or, more specifically, sustainability (Norton, 2010), biodiversity (Zinngrebe, 2018) and climate (Widmer, 2018) should be incorporated in other policy sectors. A growing body of analytical work has outlined conceptual and empirical guidelines indicating how one sector or issue (e.g. climate, pesticides, biodiversity) might be anchored in or coordinated with other sectors. These guidelines can also be applied to the cross-sectoral dimensions of policymaking; borrowing from studies of policy coherence and capacity, we identified four criteria for assessing the cross-sectoral aspects of policy performance (see Table 15).

Policy coherence measures the extent to which different objectives and policy instruments in a given sector complement each other without introducing conflicting incentives or compromising effectiveness and efficiency in producing one outcome rather than another (Zinngrebe, 2018, p. 3; see also Tosun and Leininger, 2017). The following cross-sectoral criteria can be borrowed from the policy coherence literature:

Cross-sectoral formulation of objectives: Policy goals and targets should take account of the two (or more) sectors or problems involved. In the present case, for example, this might mean that the drinking water legislation would include concrete targets to reduce pesticides in surface waters.

Cross-sectoral instrument types: Policy instruments must target two or more sectors. For example, a tax on agricultural pesticides might incentivise reduced usage or alternatives to conventional pesticides, with direct implications for human health, biodiversity conservation and environmental, soil and water protection.

Policy capacity refers to mechanisms and structures that anchor one sector or issue in others (Weidner

& Jänicke, 2002; Zinngrebe, 2018) In relation to policy instruments and mixes, this involves establishing assessment procedures, control mechanisms or management routines across different agencies and organisations (Zinngrebe, 2018), providing a further criterion for cross-sectoral evaluation.

Cross-sectoral coordination: The extent to which different sectoral agencies and public or private organisations coordinate and collaborate during policy formulation (for example, through inter-administrative consultation procedures), especially with regard to implementation and monitoring.

Additionally, objectives or instruments need to target the various actors that are either causing the problem or are affected by it, and identifying the 'right' target group is crucial for effective and efficient policy implementation (Mavrot et al., 2019). This is not straightforward in cross-sectoral contexts, as different actors come into play at the source (e.g. industry, agriculture) and at the end of the pipe (e.g. consumers, citizens, households) as potential targets of state intervention. Target group integration is therefore a relevant criterion for policy mix evaluation (Metz & Glaus, 2019), to which we can add an explicit cross-sectoral perspective.

Target group integration: Along with target groups from sectors contributing to the problem in question, policy and introduced policy instruments must also take account of victims of the problem, whether as targets for end-of-pipe measures (e.g. protective clothes for pesticide users) or as beneficiaries of anticipated compensation.

Case, methods and operationalisation

To investigate the cross-sectoral performance of Costa Rican policies to reduce pesticide risks, we compared three regimes (drinking water, the aquatic ecosystem and occupational health), evaluating both the mix of policy instruments (i.e. the substantive aspects) and the relevant legislation (i.e. institutional aspects). To assess substantive and institutional cross-sectoral performance, an original coding scheme was developed (see 3.2.2 and 3.2.3), based on the four criteria outlined in 2.2.

Pesticide use and regulation in Costa Rica

Costa Rica is home to one of Latin America's "most stable and vibrant democracies" (Lehoucq, 2005, p. 140). As the country relies heavily on agricultural production for export purposes (Wang et al., 2019) and there is intensive application of agricultural pesticides (Echeverría-Sáenz et al., 2012; Galt, 2014), it was identified as an ideal case study for present purposes. Costa Rica's increasing population means there is also a rapidly growing domestic market (Galt, 2008). Costa Rica is "the leading consumer of pesticides per hectare of agricultural land in the world" (Araya et al., 2014, p. 9), and the challenges posed by agricultural expansion at the expense of conservation of natural resources are reflected in stringent legislation and exemplary provisions for environmental protection (Fagan et al., 2013; Fletcher & Breitling, 2012). In short, Costa Rica exemplifies the trade-off between agricultural and economic development and the protection of human and natural resources.

Operationalisation of key variables

Following a summary of 'state-of-the-art' criteria for assessing policy mixes (section "Density and intensity of policy mixes"), this section details cross-sectoral additions to coding schemes for the substantive (section "Cross-sectoral performance of policy mixes", Table 16) and institutional aspects of policymaking (section "Cross-sectoral performance of the legislation", Table 17).

Density and intensity of policy mixes (substantive)

To evaluate the instrument mix, we analysed the 15 programmes and action plans that comprise all measures targeting pesticide risk reduction (see list of documents in Supplementary Material (SM)). In total, 38 policy instruments were found to address pesticide risk reduction.[14] Of those, 17 related to the drinking water mix, 14 to the aquatic ecosystem mix and 15 to the occupational health mix. Some instruments were clearly associated with more than one mix while eight instruments targeted pesticide risk reduction but were not associated with any of the three relevant mixes (e.g. in the agricultural sector only).

To begin, the three different policy mixes were evaluated in terms of the state-of-the-art criteria density and intensity.

Density ratio: Density was operationalised here as the simple count of policy instruments in one mix (Schaffrin et al., 2015). The share of instruments addressing the drinking water-pesticide nexus was calculated as a percentage of all instruments regulating pesticide risks, and this procedure was repeated for the other regimes. This way, each of the 38 instruments was assigned a 'regime tag' referring to drinking water, aquatic ecosystem or occupational health. For example, as the National Action Plan for Food Security makes payments to farmers for ecosystem services, impacting directly on pesticide risk reduction in the drinking water sector and influencing the aquatic ecosystem, this instrument is associated with both of those regimes.

Intensity (Balance): Coerciveness and state intervention are traditionally key indicators (Vedung et al., 1998; see also Pacheco-Vega, 2020). However, Schmidt and Sewerin (2019) have recently argued that the mix with the most coercive instruments is not necessarily the most effective; instead, a balance of different instrument types facilitates implementation of fundamental or controversial changes. In this sense, a combination of softer and more stringent instruments seems more acceptable to a significant portion of the target group(s) (Dermont et al., 2017). Each of the 38 instruments was categorised as persuasive, market-based and/or regulative.

[14] Policy instruments were extracted systematically in a two-step process. First, the documents were scanned for keywords such as 'pesticides', '(agro)chemicals', 'pollution' and 'risk', and documents that did not contain these terms were excluded from the data analysis. Second, within the 15 selected programmes, instruments specifically targeting pesticide risk reduction (e.g. incentives for cleaner production or public awareness campaigns to sensitize the public about risks) were extracted and assigned to the three policy mixes. Some instruments overlap across mixes.

Cross-sectoral performance of policy mixes (substantive)

In line with the conceptual argument elaborated above, two criteria can be advanced for evaluating the cross-sectoral performance of policy mixes. As outlined in "Density and intensity of policy mixes (substantive)", the same 38 instruments were evaluated in this way.

Source-directed versus end-of-pipe: From policy fields regulating pollution and chemical substances, we know that source-directed measures (e.g. substance bans, taxes) have the greatest cross-sectoral effects but lack political support (Lee et al., 2019; Metz & Ingold, 2014). This largely reflects opposition to those policy instruments from the designated target group, who are likely to favour less costly and more flexible measures (Metz & Ingold, 2017; Pedersen et al., 2020), and leads to the introduction of end-of-pipe solutions. In the case of pesticide risk reduction, these measures may involve the promotion of improved application equipment and practices to reduce risks to human health (Lee et al., 2019). These targeted end-of-pipe measures usually relate to a single sector, but comprehensive pesticide risk reduction requires action across policy fields; source-directed measures are more cross-sectoral in nature. For example, a source-directed measure such as a tax can influence multiple sectors to protect environment, water and humans. Accordingly, the 38 instruments were classified as source-directed, end-of-pipe or both.

Target group integration: This criterion was used to evaluate whether policy instruments addressed actors that contribute to the problem or benefit from risk reduction (Metz & Glaus, 2019). We assessed whether actors belonged to the same or different sectors and whether they were aligned across the entire food value chain (from production to transportation to consumption). As Pedersen et al. (2020) demonstrated, even a single target group can be heterogeneous and may react differently to the same policy instruments – not least because they may belong to diverse sectors or different stages on the food value chain. Inductive inquiry yielded nine categories of target group: drinking water operators (public and private), employees, employers, farmers, general public, health professionals, industry, polluters in general, and public authorities. Not all of the nine appear in all three mixes; for example, health professionals appear in the occupational health mix but not in the other two. For each of the 38 instruments, the analysis extracted the target group(s) and counted the number of target groups associated with each regime.

State-of-the art criteria	Cross-sectoral criteria
Density: Number of instruments addressing pesticide risk reduction in each of the three regimes (share of the 38 instruments)	**Source-directed versus end-of-pipe**: Share of source-directed or end-of-pipe instruments (or both) in each policy mix
Intensity: Share of persuasive, market-based and regulative instruments in each policy mix	**Target group integration**: Share of target groups across sectors and along food-value chain

Both state-of-the art and cross-sectoral criteria were used in this research (see SM for a summary of the coding scheme).

Table 16: Evaluating policy mix performance: State-of-the art and cross-sectoral criteria

Cross-sectoral performance of the legislation (institutional)

The institutional analysis included highest-level legal texts such as laws, decrees or ordinances (see SM for complete list). These legal documents regulate the three regimes (drinking water, aquatic ecosystems and occupational health) and address conflicts between those regimes and pesticide use. After systematic screening of the websites of all relevant Ministries and examination of the Constitution and the Civil Code, we compiled a list of 21 relevant legal texts. Eight of these documents related to drinking water, eight to the aquatic ecosystem, and six to occupational health; some of the documents overlap – for example, the General Health Law relates to both the drinking water and occupational health regimes. Five other legal documents were considered relevant to all three regimes as general framework documents that shape those regimes indirectly (e.g. Law on Plant Protection, Constitution of Costa Rica).

To evaluate institutional cross-sectoral performance, we borrowed three criteria from the IRR, which are traditionally used to assess so-called 'institutional coherence'. These state-of-the-art criteria were refined to gain a cross-sectoral perspective (see Table 17) on the formulation of objectives (i.e. relating pesticide use directly to drinking water, aquatic ecosystem and occupational health), the definition of target groups, and the coordination across administrative agencies and public and private organisations.

State-of-the-art criteria	Cross-sectoral criteria
Formulation of objectives: Definition of the collective problem and objectives of state intervention	**Cross-sectoral formulation of objectives**: Problem definition: pesticide use and regime; objectives formulated to relate the regime directly to pesticide use.
Target group integration: Logics of intervention based on specifying who/what is causing the problem	**Target group integration**: Assignment of target groups to the nine categories (drinking water operators (public and private), employees, employers, farmers, general public, health professionals, industry, polluters in general, public authorities); cross-sectoral performance assessed as high if target groups are distributed across sectors and along the food-value chain.
Institutional coordination: Agencies with responsibility for designing and implementing public policies	**Cross-sectoral institutional coordination**: Different agencies coordinate policy design and implementation actions across sectors and between public and private spheres.

Adapted from Gerber et al. (2009); only the cross-sectoral criteria (in grey) were used (see SM for a summary of the coding scheme).

Table 17: Evaluating institutional performance: State-of-the-art and cross-sectoral criteria.

Results

Density, intensity, and cross-sectoral performance of the three policy mixes

The three policy mixes constituted 40–50% of the instruments in the 'overall' mix addressing pesticide risk reduction. Among slight nuances, the density ratio (number of instruments in the regime relative to the 38 pesticide risk reduction instruments) ranges from 44% (drinking water mix) to 39% (health) and 36% (aquatic ecosystem) (see Figure A15 in SM). Regarding density, the two water

mixes are quite balanced in terms of market-based and persuasive instruments (see Figure 12). Few command-and-control instruments appear in any of the three mixes. The occupational health mix is unbalanced, focussing almost exclusively on persuasive instruments. All three mixes returned similar scores for cross-sectoral performance evaluated through source-directedness; across the three mixes, 85–100% of the instruments are source-directed or have a source-directed component (e.g. tackling the problem at source through substance bans or taxes, in contrast to water filters that are end-of-pipe) (Figure 13).

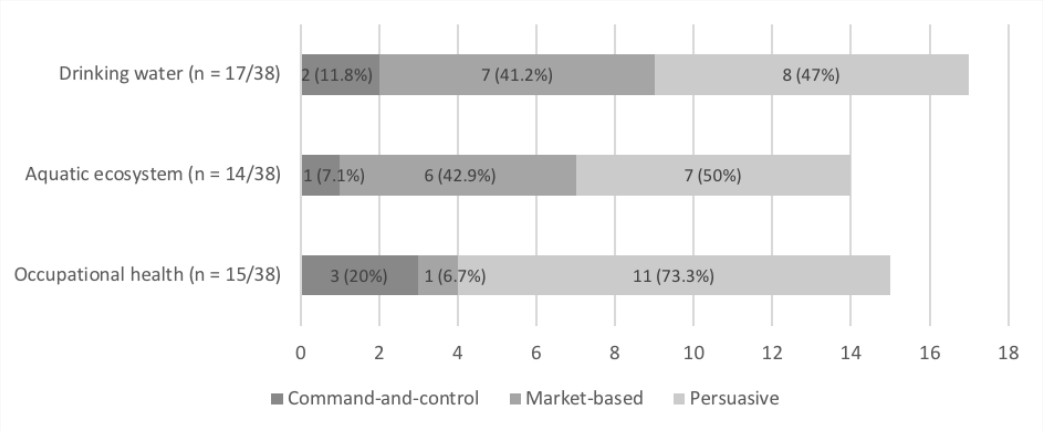

Figure 12: Density and intensity (balance) of policy mix

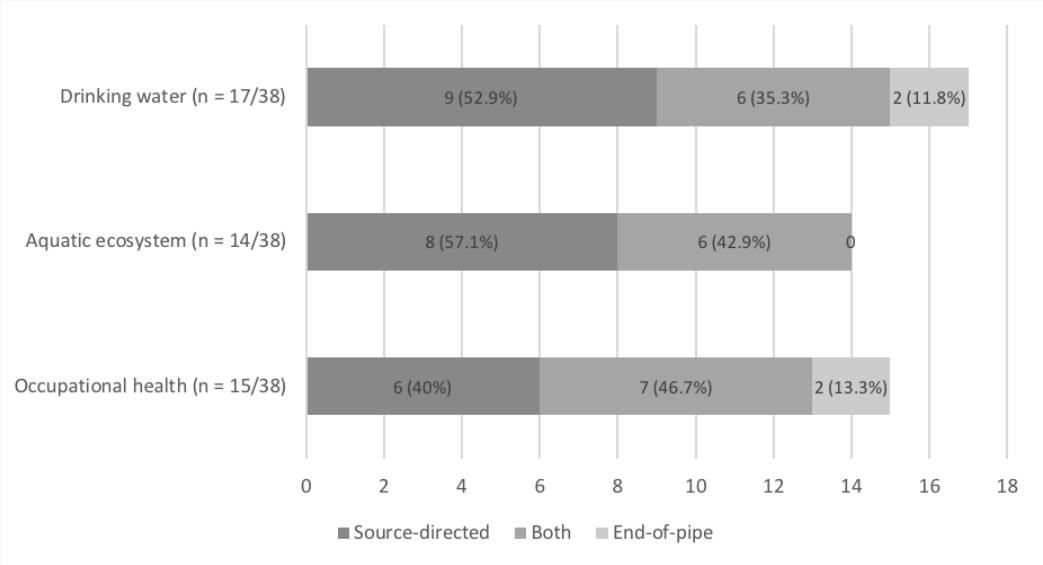

Figure 13: Cross-sectoral performance of policy mix (source-directed versus end-of-pipe)

While there were no major differences between the three policy mixes, some specific details are worthy of mention. The drinking water instrument mix is quite intense; the key reference documents are the Water Agenda (2013), the National Water Policy (2009) and the National Plan for Integrated Water Management (2008). In addition, more recent and more cross-sectoral documents explicitly target protection of drinking water against pesticide use. This policy mix treats diffuse pesticide contamination as a collective problem primarily requiring market-based and persuasive instruments (with only two command-and-control measures). These include subsidies for farmers adopting best

agricultural practices and economic penalties for diffuse agricultural contamination. More than half of the political measures in the mix are source-directed, and the mix spans the entire food value chain, including relevant target groups such as industry, pesticide distributors, drinking water operators and, most importantly, farmers (see Table 18). In conclusion, the drinking water policy mix is both dense and intense, with a significant share of source-directed instruments, but it is less intense in terms of balance (for overall performance assessment, see Table 19).

Regimes	**Target groups outlined in the legislation**	**Target groups in the policy mix**	**Overlap**
Drinking water	Drinking water operators General public Public authorities	Drinking water operators General public Public authorities Farmers Industry Polluters in general	50%
Aquatic ecosystem	Drinking water operators General public Public authorities	Drinking water operators General public Public authorities Farmers Industry Polluters in general	50%
Occupational health	Employees Employers General public Health professionals Public authorities	Employees Employers Farmers General public Health professionals Industry Public authorities	62.50%

Table 18: Target group overlap.

	Indicator	**Drinking water**	**Aquatic ecosystem**	**Occupational health**
Policy mix (substantive)	Density	High (1)	High (3)	High (2)
	Intensity	Medium (1)	Medium (2)	Low (3)
	Source-directed versus end-of-pipe	High (2)	High (1)	High (3)
	Target group integration	High (1)	High (2)	High (3)
Legislation (institutional)	Cross-sectoral formulation of objectives	Medium (1)	Medium (2)	Medium (3)
	Target group integration	Medium (2)	Medium (2)	High (1)
	Cross-sectoral institutional coordination	Medium (2)	Medium (2)	High (1)

Numbers in brackets indicate ranking of the three regimes for each indicator (1 being the first, 3 the last rank)

Table 19: Performance of the policy mix and legislation.

The same is almost true for the instrument mix addressing the reduction of pesticide risks for the aquatic ecosystem. The mix is quite intense; key documents include the National Water Policy (2009) and the National Plan for Integrated Water Management (2008). More recent documents in the agricultural sector also target the reduction of pesticide risks for the aquatic ecosystem. All instruments have a source-directed component, and no instrument is exclusively end-of-pipe (e.g. environmental quality norms). General polluters and (most importantly) farmers and industry are addressed in the

aquatic ecosystem mix (see Table 18). However, it is less balanced than the drinking water policy mix (Table 19), with only one command-and-control instrument (i.e. land use planning and division into catchments to avoid pollution). A majority of the instruments are persuasive (e.g. good agricultural practices, public-private partnerships) or market-based (e.g. subsidies for good agricultural practices). In conclusion, the aquatic ecosystem mix is less dense and less intense than the drinking water mix (Table 19), with no end-of-pipe instruments and fewer command-and-control instruments.

Measures to protect occupational health from pesticide risks are mentioned in seven documents, most importantly the National Policy for Occupational Health (2015), the National Action Plan for Occupational Health (2015) and the Action Plan for the Strengthening of Responsible Pineapple Production and Trade in Costa Rica (2013). The occupational health mix mainly targets public authorities, with only three command-and-control measures that include programmes to educate the population about the health risks of pesticide use and the introduction of inspectors to monitor working conditions. The great majority of persuasive instruments in this mix target bottom-up capacity building (beginning with farmers) to enhance awareness about the risks of pesticide use. As in the other two, the occupational health mix is intense in terms of source-directedness (Table 19) but specifically targets two important groups: the State in its role as health risk educator and farmers as targets of public media campaigns and awareness raising programmes (Table 18).

In conclusion, the three policy mixes are comparable in terms of their significant density and cross-sectoral performance, although the aquatic ecosystem mix is a little less developed (Table 19). In terms of intensity, all three mixes are characterised by their limited use of command-and-control measures, especially in the case of the occupational health mix, which relies almost exclusively on persuasive instruments.

Cross-sectoral performance of the legislation

We evaluated cross-sectoral formulation of objectives in the drinking water regime as medium (see Table 19). The Regulation on Drinking Water Quality establishes maximum permissible levels of pesticide residues for risk reduction. However, there is no legal definition of a measurable objective in this context (such as overall pesticide use reduction by a certain percentage). Target group integration was also evaluated as medium. The drinking water regime targets specific users and risk reducers, but there is no mention of the agricultural sector even though it is a major source of water pollution in Costa Rica (Table 19). Cross-sectoral institutional coordination was again evaluated as medium. Policymaking competences related to pesticide risk reduction for drinking water are assigned to a range of clearly identified government agencies, including the Ministry of Health, the Ministry of Agriculture, the State Phytosanitary Service and others. This indicator only achieved a medium rating because of the lack of coordination across these agencies, no one of which is assigned bundled responsibilities or leads decision-making.

In the aquatic ecosystem regime, we evaluated cross-sectoral formulation of objectives as medium because (as in the drinking water regime) no overall objective is mentioned (e.g. reduction of pesticides by a specified percentage). Nevertheless, pesticide use is considered problematic in this regime,

notably in the Regulation for the Evaluation and Classification of the Quality of Surface Waters, which limits the permissible amount of organochlorine and organophosphate compounds in surface waters. Additionally, the Biodiversity Law and associated regulations invoke the precautionary principle and define environmental damage to reduce risks to the aquatic ecosystem. As in the drinking water regime, target group integration was assessed as medium because farmers and the agricultural sector are not considered relevant target groups. Cross-sectoral institutional coordination was also evaluated as medium; although competences are assigned to various clearly identified government agencies (e.g. the Ministry of Environment and Energy), there is again a lack of clear coordination.

In the case of occupational health legislation, cross-sectoral performance almost achieved a maximum rating. Occupational health is considered a matter of general public interest, and the Labour Code establishes the need to protect workers' health, preventing damage to their physical and mental integrity and preventing work-related risks. In addition, the Health Law and other relevant decrees clearly identify pesticide use as potentially contributing to accidents and illnesses. However, as the occupational health regime again lacks any specific policy objective (e.g. reducing pesticide poisoning to a specified level), we evaluated cross-sectoral formulation of objectives as medium. In contrast, target group identification was evaluated as high because the current occupational health regime targets agricultural workers and producers, as well as industry and pesticide distributors. These target groups are typically users or at-source actors whose behaviour can influence risk prevention. As risk reducers such as employers, medical staff and public authorities are also mentioned, target group identification is quite comprehensive. Cross-sectoral institutional coordination was also assessed as high because while different ministries (Labour, Transport and Health) share responsibilities in their own sectors, an overarching agency ensures coordination of occupational health-related matters.

Discussion and conclusion

In this article, we proposed an approach to evaluating the cross-sectoral performance of policy mixes and overarching legal texts involving a refinement of earlier work on policy density and intensity (Schaffrin et al., 2015) and institutional coherence (Gerber et al., 2009; see also Metz and Glaus, 2019). To that end, we added four criteria that take explicit account of the cross-sectoral dimension in evaluating policy performance: objectives formulated across sectors, target groups identification across diverse sectors, cross-sectoral administrative coordination and different types of policy instruments.

The study analysed pesticide risk reduction in Costa Rica and evaluated how well policy mixes and the relevant legislation take account of pesticide risks in the water and occupational health sectors. From a substantive perspective, we conclude that the cross-sectoral performance of policy mixes related to pesticide risk reduction in these sectors is high. More specifically, in respect of density ratio, almost half of the instruments in the three policy mixes form part of Costa Rica's overall risk reduction instrument portfolio, and more than half of these measures are source-directed. At the institutional level of laws and regulations, cross-sectoral performance ranges from medium to high in all three regimes (Table 19), as they address the issue of pesticide risks, identify the most relevant

target groups, and establish cross-sectoral coordination.

The occupational health regime over-performs in cross-sectoral terms (Table 19); in this regard, two details are of particular interest. First, while density and substantive and institutional cross-sectoral performance are rated high, intensity is low in this regime. Coercion is low, and the policy mix almost exclusively comprises persuasive instruments. We can therefore conclude that cross-sectoral performance is not inevitably associated with output performance or effectiveness. Second, although persuasive and 'soft' instruments are generally considered less effective than their more coercive counterparts, command-and-control or market-based instruments are less attractive in certain policy sectors and domains for several reasons. For example, an order prohibiting the flushing of drugs down the toilet for water safety reasons can never be monitored or controlled because of privacy issues. Alternatively, taxing health products because they contain substances that impact negatively on the environment is likely to disadvantage only poorer households, and such inequalities are not desirable. Typically, then, the health sector as a political domain employs persuasive instruments that are effective only if they deliver convincing information or evidence to the target group. These examples confirm the importance of cross-sectoral performance in developing a theory-based account of how well a policy mix might cope with complex or wicked problems. However, other criteria such as different aspects of intensity remain relevant when evaluating the effectiveness or long-term effects of a policy mix (Kammerer et al., n.d.; Metz & Glaus, 2019).

In general, the present findings indicate that cross-sectoral performance as outlined in the legal texts correlates with the cross-sectoral policy mix. However, this is not true for all of the applied criteria; for example, it is notable that most of the instruments in all three mixes are source-directed. The mix thus goes further than the legal texts in this cross-sectoral aspect. The same is true of target group integration (Table 18); in this regard, the mixes go further than the legal texts, which take account of fewer target groups. This raises the question of whether the policy mixes as outlined in the action plans, which are usually introduced much later than the legal texts, are compensating for a lack of cross-sectoral performance at the institutional level. This issue relates back to the literature on feedback effects and the interplay of policies, processes and institutions (Rogge & Reichardt, 2016; Runhaar, 2016; Schmid et al., 2020).

The present study is qualitative, and while comparing different regimes (water and health) it refers to a single case. To fully evaluate the added value of integrating the cross-sectoral dimension in the assessment of policy performance, further comparative and longitudinal research is needed. For example, qualitative comparative analysis may help to disentangle the diverse factors that determine policy performance. By clarifying the criteria for simultaneously evaluating substantive and institutional aspects (see Metz and Glaus, 2019) or issues of design and implementation (Rogge & Reichardt, 2016), it may be possible to develop a more complete picture of a policy's ability to address a given problem and the relevance of the cross-sectoral dimension. Finally, assigning a definitive time-stamp to articles of legal texts and the introduction of the policy instruments may help to clarify how policy feedback works or fails to work (Schmid et al., 2020).

At a practical level, what do these findings mean for Costa Rica's approach to pesticide risk reduction? The policy instrument mix seems fairly complete and tackles the problem at the source. The challenge now is to ensure the effective and efficient implementation of the different measures at all institutional levels and across different sectors. In this sense, cross-sectoral challenges persist throughout the design and implementation stages in terms of the substantive, institutional and procedural aspects of policymaking.

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Appendix

Appendix A: Supplementary Material Online for *Participatory knowledge integration to promote safe pesticide use in Uganda*

Pesticide management as wicked problem

Many environmental challenges facing society today, such as climate change and integrated water management, have been described as "wicked problems" due to their biological, physical, and social complexity. Within our research, we consider pesticide management to be such a wicked problem, because traditional, linear analytical approaches might fail to solve this problem for the following reasons: First, pesticides are applied for agricultural purposes, but deploy their negative effects in other sectors such as water and health. To be more specific, pesticides are used in agriculture to protect crops from infestations and guarantee productivity. Benefits of pesticides include the protection of yield, reduction of costs for labour and fuel, improving human health by controlling vector diseases (Bourguet & Guillemaud, 2016), improving food quality (Aktar et al., 2009), hygiene, as well as pest free groceries due to pesticide use in the packaging process (Damalas & Koutroubas, 2018). As a result, pesticides are beneficial for humans, and economic productivity. However, uncontrolled, excessive, "uneconomic or unnecessary" (Eyhorn et al., 2015, p. 4) pesticide use outweighs the afore mentioned positive effects for humans, environment and economic prosperity. Agricultural pesticides are directly applied in the environment, which has negative effects on environmental integrity and can have (in)direct effects for public health (Bonner & Alavanja, 2017; Hayes & Hansen, 2017). For humans, direct pesticide exposure through skin contact or the inhalation of the sprayed chemicals is most common (Damalas & Eleftherohorinos, 2011). Environmental health is threatened through pesticide spraying in the environment, resulting in soil degradation, water contamination, pest resistance, biodiversity loss (Reynolds et al., 2015), and loss of ecosystem functions (e.g. pollination of crops, see Sánchez-Bayo and Wyckhuys, 2019). Second, pesticide management happens along the so-called pesticide management cycle (see Figure 2 in manuscript), which ranges from production and import of the chemicals until the disposal of the latter. Across the different steps boarders might be crossed, different stakeholders might be influential and affected, and jurisdictions and responsibilities might shift (Shammi et al., 2017). This is why pesticide management and considerations related to the promotion of safe pesticide use are complex processes where a multitude of state and non-state, as well as academic and non-academic stakeholders from different sectors interact and potentially collaborate. Third, wickedness in pesticide management is enhanced by a high degree of uncertainty, as to causes and effects and a lack of conclusive evidence about both. This uncertainty leads to differences in framing and perception among involved stakeholders (Cole et al., 2011). To conclude, to reach a state of safe or sustainable pesticide management, solution design is not straight-forward, because it is a cross-sectoral challenge with diverse stakeholders and diverging problem perceptions involved. The afore mentioned characteristics of this problem correspond to the traits of wicked problems (see

Australian Public Service Commission, 2012; Rittel and Webber, 1973), meaning that pesticide management can be defined as a wicked problem (Allen, 2013).

The PESTROP project

The PESTROP ("**Pest**icide Use in **Trop**ical Settings") project conducted four disciplinary studies within Wakiso district, Uganda (see Figure A1). The study site was located 15 km north of the country's capital Kampala, which is surrounded by a belt of farms, providing agricultural products to its demanding citizens. The study area of the *environmental assessment* covered parts of the Mayanja river catchment, where streams, wells and boreholes were studied for pesticide residues. In parallel, 302 farmers from the area were assessed regarding their *pesticide exposure, knowledge, attitude and practices*, medical history as well as human health effects measured through biomarkers in blood and urine (Staudacher et al., 2020). Additionally, an *institutional analysis*, assessed legislation on district and national level regarding their suitability and enforcement of protection from downsides of pesticide use. And lastly, through the *socio-psychological assessment* farmers' information behaviour (Diemer et al., 2020), as well as behavioral factors affecting the use of personal protective equipment (PPE) were investigated (for details on the results of the different work packages of the PESTROP project, see Winkler et al., 2019).

Figure A1: Uganda and Northern Wakiso District. Red mark denotes approximate study area. (© OpenStreetMap contributors, data is available under the Open Street Map Licence, last accessed June 8, 2021)

Critical self-reflection of authors as facilitators and as participant in the workshop

Our dual roles as authors of this paper and either facilitators or participant of the workshop demands for critical self-reflection. First, throughout the manuscript, we remain transparent about our roles and dedicated a part of the Methods' section to it. Within the PESTROP project, integration of the different disciplines and stakeholder groups was challenging and the workshop was a tool to facilitate integration. This way of confronting our own academic experience and knowledge with non-academic knowledge proved beneficial for our own research agendas (e.g., we re-formulated research questions, extended our network and gained trust of stakeholders). Even more, this way of co-producing knowledge changed our own approach to research and we shared our experience in various conferences and presentations. The second author also held a dual role, as co-author and an active participant in the workshop. As a participant, he had no prior experience with a DT workshop and has no active role in planning and implementing the event.

Second, our dual-role might tempt us to be biased towards presenting the workshop as successful. To measure success, we collected feedback from the participants which is reported on in the Results' section. On the one hand, we claim that this workshop was successful, because participants exchanged knowledge and on the other hand, because it informs our own research. This shows that participation at such workshops can enhance researchers' own understanding of complex problems, and support project design as in our case.

Third, we discuss a gap between non-academic and academic knowledge and while we gather the non-academic knowledge systematically, we fall back on our 'own' academic knowledge to analyze the gap. In this sense, we don't claim that our 'own' academic knowledge represents the entire academic knowledge, but the workshop and the insights into non-academic knowledge enable us to unveil aspects of pesticide management which we were not able to deduce from existing literature. Furthermore, these non-academic insights are key for a better understanding of real-life problems (which is the justification to engage in TD research), hence we were able to gain knowledge which is of utmost importance to the academic world.

Participant Feedback

Positive	Negative
Organization	
Clear plan, good first try	Too few time/more days needed
Everything very clear	Workshop should consider more/all stakeholders
Process was easy to understand	Number of participants should be increased
Never boring	Too little time for the speed dating
	Role of researchers not clear from the beginning
Methodology	
Interaction nice	Tasks were challenging (writing down things)
Positive, because they moved a lot	Difficult to articulate themselves precisely, some might more time than others
Didnt know what to expect, good to have everybody on board	
Engagement of people	
Looking forward to the second day	
Participatory/interactive approach	
Practical approach	
Group discussions	
"one was to use the brain"	
Facilitation	
Participants had their first name on the name tags	Give examples of exercise/tasks
Introduction of participants missing	Time management
Time keeping	Music sound interactions
Good communication	More guidance needed throughout tasks/table hosts needed
Creativity	Facilitator per table would be needed
	The person passing by should give more detailed instructions at the beginning, not when the group is already in the process of working
Content	
Research findings very vital/understandable	Provide recommendations
Looking forward to the second day	Topics not fully exhausted
Technical issues	
	Sometimes noisy
	Voice of speakers sometimes too low/microphone requested
	Slides presented too briefly
	Handout of presentations requested
Other	
Energizer	Too much food makes tired
Atmosphere rated positively	
Enhancing contacts	
Commitment to actions	
Welfare (food and hosting)	
Ambience in the room, venue was perfect	

Table A1: Participant feedback

Appendix B: Supplementary Material Online for
To intervene or not to intervene: Potential for targeted pesticide policy in Uganda

Case

Pesticide risk reduction as complex environmental problem

Farmers continue to rely on agricultural pesticides to enhance and guarantee agricultural productivity (Hamlyn, 2015). However, pesticides "indiscriminately kill the bad and the good" (Sánchez-Bayo, 2017, p. 79), resulting in serious negative effects for human health and the environment (Allsop et al., 2015; Becker, 2017; Hoppin & LePrevost, 2017; Kishi, 2012). Pesticide management contributes to environmental complexity, because questions related to the causes and effects of these agricultural chemicals are still highly uncertain (Bonner & Alavanja, 2017). To be more specific, research has reported on the detrimental effects of pesticides on aquatic ecosystems, birds, amphibians, and biodiversity in general (Casado et al., 2019; Deknock et al., 2019; for an overview, see Hayes and Hansen, 2017). Even more, research has reported on public health concerns related to agricultural pesticide use, such as cancer, chronic diseases and neurological impairment (Jørs et al., 2018). However, linking pesticide exposure to diseases such as cancer is highly difficult and evidence remains inconclusive. Additionally, related to environmental effects, it is difficult to determine the culprits of pesticide contamination due to up- and down-stream dynamics as well as lack of monitoring. These uncertainties as well as the benefits of pesticides for public health (e.g. vector control) are exploited by interest groups and lead to differences in framing and perception among involved stakeholders (Cole et al., 2011).

Furthermore, pesticide management is highly interdependent, because while pesticides are applied in the agricultural sector, they deploy their negative effects in others, such as environment or public health (Wiedemann & Ingold, 2021). Furthermore, pesticide management happens along the pesticide management cycle (see Figure A2, which ranges from production and import of the chemicals to the disposal of the latter). Across the different steps, sectors and boarders are crossed, different stakeholders are influential and affected, and jurisdictions and responsibilities shift (Shammi et al., 2017). These sectors jointly regulate different aspects of the pesticide management cycle to reduce environmental and human health-related risks (Baird et al., 2016; Mengistie, 2016).

Pesticide policy is chronically failing and policy effectiveness to reduce risks for humans and the environment is limited (OECD, 2018; Pedersen et al., 2017; UN Special Rapporteur, 2017). In Europe, Swiss investigators have found that pesticide residuals in small streams exceed the legal norms (Mangold et al., 2017; Spycher et al., 2018), and a Danish study underlines that effects of pesticide policies are limited (Pedersen & Nielsen, 2017). Internationally, two reports lament the incapacity of existing regulations to protect humans and the environment from the negative consequences of agro-chemicals (OECD, 2018; UN Special Rapporteur, 2017). Other Studies have investigated the effectiveness of

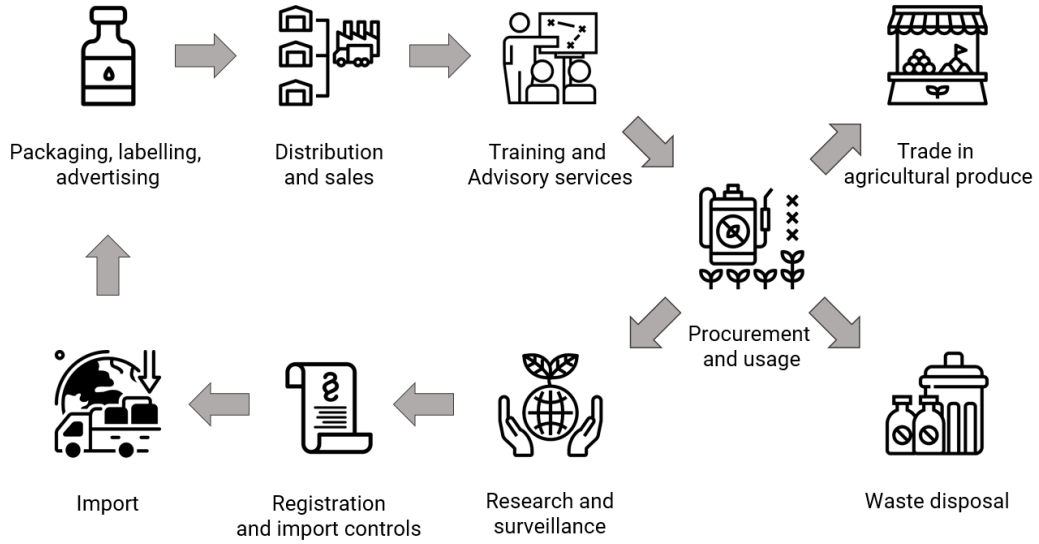

Figure A2: Pesticide management cycle, it shows an ideal-typical representation of the pesticide management cycle or also often referred to as pesticide value chain. This illustration does not account for inter-dependencies across the different steps (for example between research and application (own elaboration)

state intervention to reduce pesticide risks and to ensure sustainable pesticide management. Even though, decision-makers usually use the 'conventional' command-and-control instruments (Slunge & Alpizar, 2019) to reduce pesticide risks, economic instruments, such as pesticide taxes (Finger et al., 2017) or also as complementary measure to promote cleaner agricultural production (Lefebvre et al., 2015) have to be considered. In a systematic literature review, Lee et al. (2019) have assessed the effectiveness of instruments targeting pesticide risk reduction in Europe (Lee et al., 2019). While they do not provide a golden bullet for which instrument is most adequate, they claim that decision-makers should not only take the *degree* of coercion, but also the *target* for state intervention into account: policy mixes which encompass different levels and sources of pesticide management are expected to provide better outcomes (i.e. risk prevention). Targeted state intervention is thus needed to address problems more holistically and do justice to the complexity of risk prevention, and eventually promote sustainable pesticide management (see 6 in the main manuscript for an overview of policy instruments facilitating pesticide risk prevention).

Setting the focus in the Global South

In the Global South, pesticide usage per hectare of farmland is often reported to be low (Schreinemachers & Tipraqsa, 2012), but and more specifically, countries with strong export agriculture, like Costa Rica, Colombia or South Africa report a high intensity of pesticide usage per hectare of cropland, while many African countries like Niger, Uganda and Ghana use less pesticides per hectare of cropland. However, this evaluation and classification of countries based on pesticide use intensity tells only one part of the story. Where pesticide usage is low, exposure intensity is often high. To be more precise, in these countries, farmers are often smallholder, subsistence farmers who cultivate small areas of agricultural land to provide for their families and sell surplus to the local markets.

Smallholders are prone to use pesticides which are banned in the European Union and are considered hazardous for environmental and human health (Sarkar et al., 2021) (see also Ndayambaje et al., 2019; Tambe et al., 2019). Furthermore, many of these products enter countries through illegal ways and trade and distribution of these counterfeit products is thus particularly challenging (Rodenburg et al., 2019; Shao & Edward, 2014). A study investigating chemical weed control in rice farms in 22 Sub-Saharan African countries found that 62% of the used chemicals are not registered (Rodenburg et al., 2019). The use of counterfeit and hazardous products puts farmers and farm workers as well as entire ecosystems at risks. To promote protection, use of personal protective equipment (PPE) and safe disposal of empty pesticide containers are the strategies considered most adequate (Sharma et al., 2020). However, due to economic as well as infrastructural (and many other) hurdles, farmers and farm workers abstain from engaging in these safe use practices (Afshari et al., 2019; Okoffo et al., 2016; Zapata Diomedi & Nauges, 2016). To conclude, intensity of exposure is particularly alarming in countries of the Global South, were farmers use comparatively low rates of pesticide per area of cropland, but pesticide are often unregistered counterfeits and mismanagement of agricultural pesticides puts environmental integrity at risk.

Uganda

These are two maps of Uganda, one a comparative map showing the workforce employed in agriculture on the African continent (Figure A3). The other one shows a map of Uganda with the capital Kampala (Figure A4).

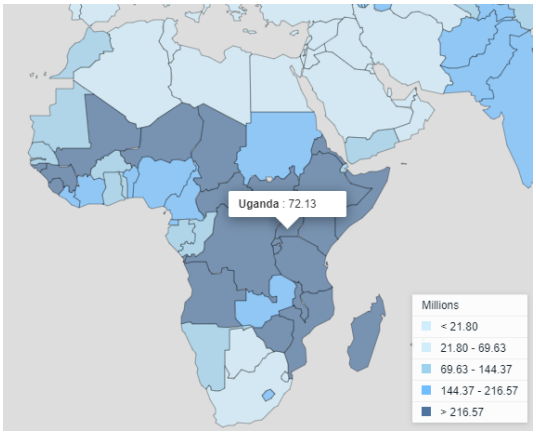

Figure A3: Employment in agriculture 2019 (% of total employment (ILO, 2019)

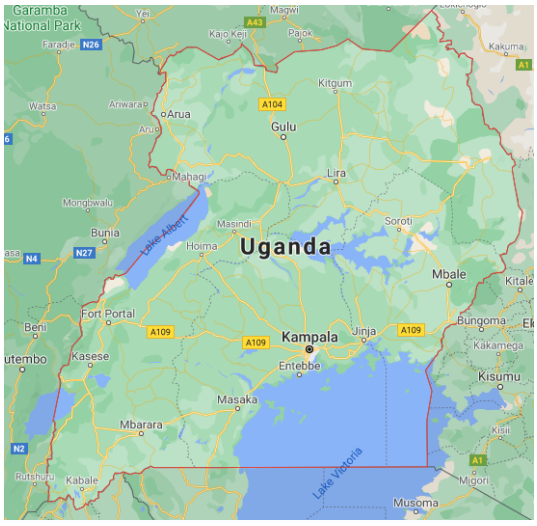

Figure A4: Map of Uganda

Data & Method

Data gathering

Stakeholder analysis to define the boundaries of the network

Key actors are identified according to the the commonly used (in the social sciences) decisional, positional, and reputational approaches (Knoke, 1993). Data for the decisional approach, thus on who is central in political decision-making, was gathered via literature and document analysis [15]. This preliminary list of stakeholders was then validated in four expert interviews to consolidate and complement the list based on the reputational (i.e. who has a reputation to be influential in or affected by decisions) and positional (i.e. central actors who act as brokers or linkage between conflicting coalitions) approaches. Additionally, to get all central actors in the network and to validate the boundaries of the network, I included a question about who stakeholders consider influential in matters related to pesticide management in Uganda. In Table A2, stakeholders are sorted based on their normalized importance (how often survey and interview participants mentioned them as an influential stakeholder). The stakeholders marked in bold are the part of the sample for data analysis. The Department of Crop Protection is the stakeholder considered to have most influence with regards to pesticide management in Uganda (mentioned by 85% of the surveyed stakeholders). Both sub-national groups (DFAs and DAOs) are also highly relevant in matters related to pesticide management. The survey participants cover the most influential stakeholders with the exception of donor organizations like FAO, USAID and WFP. Even though I sent out several reminders, this stakeholder group opted against survey participation as they feared repercussions and did not feel comfortable to act as representatives of the entire organization. Based on the overlap between influential stakeholders and survey participants (except for the international donor organizations), I am confident that the gathered data represents a robust sample of the policy network of pesticide management in Uganda.

Stakeholder name	Importance
Ministry of Agriculture, Industries and Fisheries, Department of Crop Protection (MAAIF_DCP)	0.85
Ministry of Agriculture, Industries and Fisheries, Department of Inspection and Certification (MAAIF_DIC)	0.73
District Agricultural Officers (DAOs)	0.73
National Agricultural Research Organization (NARO)	0.72
National Environment Management Authority (NEMA)	0.72
Uganda National Agro-Dealers' Association (UNADA)	0.71
Food and Agricultural Organization (FAO_Uganda)	0.68
Uganda National Farmers Federation (UNFF)	0.65
Makerere University School of Agricultural Science (Mak_Uni_Agri)	0.63
United States Agencz for International Development (USAID)	0.63
Uganda National Bureau of Standards (UNBS)	0.62
District Farmers' Associations (DFAs)	0.61

[15] See for example National Assessment Report on policy and legislation of chemicals management in Uganda, Crop pests and disease management in Uganda: status and investment needs, or Pest Management Plan, last access: March 17, 2021

Stakeholder name	Importance
World Food Program (WFP)	0.61
Ministry of Health, Environmental Health Division (MoH_EHD)	0.58
National Agricultural Advisory Services (NAADs)	0.58
Ministry of Water and Environment, Directorate of Environment Affairs (MWE_DEA)	0.57
Ministry of Gender, Labor and Social Development, Department of Occupational Health and Safety (MGLSD_DOHS)	0.56
National Drug Authority (NDA)	0.56
Vector Control Division (MoH_VCD)	0.53
Uganda Coffee Development Authority (UCDA)	0.53
Makerere University School of Public Health (Mak_Uni_Pub_Health)	0.53
Uganda National Association of Community and Occupational Health (UNACOH)	0.53
Ministry of Internal Affairs, Directorate of Government Analytical Laboratory (MIA_DGAL)	0.52
Makerere University School of Food Science and Technology (Mak_Uni_Food)	0.52
National Organic Agriculture Movement of Uganda (NOGAMU)	0.51
BUKOOLA	0.49
CropLife_Uganda	0.47
Balton_Uganda	0.47
National Water and Sewerage Corporation (NWSC)	0.46
Cotton Development Organization (CDO)	0.46
Uganda Flower Exporters' Association (UFEA)	0.43
Quality_Chem	0.43
Diary Development Authority (DDA)	0.42
Gulu University School of Agriculture (GULU_Uni)	0.42
Regional Universities Forum for Capacity Building in Agriculture (RUFORUM)	0.42
Ministry of Health, Clinical Services Division (MoH_CSD)	0.41
International Labor Organization (ILO)	0.39
Economic Policy Research Centre (Econ_Policy_Research)	0.38
AgriProFocus (APF)	0.38
Uganda Martyrs University (UMU)	0.37
Participatory Ecological Land Use Management (PELUM)	0.37
Food Rights Alliance (FRA)	0.35
Coordination Center for Control of Trypanomiasis in Uganda (COCTU)	0.34
Young Farmers Federation of Uganda (UNFYA)	0.34
Community Integrated Development Initiatives (CIDI)	0.33
National Association of Professional Environmentalists (NAPE)	0.33
Caritas_Uganda	0.33
Association of Professional Women in Agriculture and Environment (AUWPAE)	0.30
Young Farmers Coalition of Uganda (YOFACO)	0.30
Uganda Water and Sanitation NGO Network (UWASNET)	0.29
Agency For Integrated Rural Development (AFIRD)	0.25
Nile Coffee Farmers' Association (NILE_Coffee)	0.23
Action for Rural Women's Empowerment (ARUWE)	0.22
Center for Food and Adequate Living Rights (CEFROHT)	0.20
Agroline Extension (Agroline_Ext)	0.18

Table A2: Stakeholders of the pesticide management network in Uganda

Detailed list of survey and interview participants

To gather data, I contacted 49 national stakeholders (covering all stakeholders within the network boundaries see Table A2), 4 international stakeholders (also from within the pesticide management network in Uganda) and 97 stakeholders from the sub-national level (14 DFOs and 83 DAOs). For the international and national stakeholders, I relied on websites, reports and lists of previous events related to pesticide management to gather their contacts. For sub-national stakeholders, I relied on contacts provided by UNACOH who is active on the community level. I offered a face-to-face interview to stakeholders (n=17) who preferred a personal meeting, and was thus able to gather qualitative data in a semi-structured interview. This additional data source and the mixed-methods approach are important to contextualize findings of the online survey and gather fine-grained and detailed information related to the governance of pesticide risks. The face-to-face interviews covered different sectors and levels, and provide a representative sample of stakeholders in agricultural pesticide management in Uganda. Table A3 displays the contacted stakeholders providing information about their participation in the data gathering and their characteristics.

Contacted	Survey	Interview	Actor type	Sector
MAAIF_DCP	yes	yes	Gov.ministry	Agriculture
MAAIF_DIC	yes	yes	Gov.ministry	Agriculture
MoH_EHD	yes	no	Gov.ministry	Environment
MoH_VCD	yes	yes	Gov.ministry	Health
MoH_CSD	no	no	Gov.ministry	Health
MWE_DEA	yes	no	Gov.ministry	Environment
MGLSD_DOHS	yes	no	Gov.ministry	Health
MIA_DGAL	yes	no	Gov.ministry	Environment
NARO	yes	yes	Gov.agency	Agriculture
NDA	yes	yes	Gov.agency	Agriculture
NEMA	yes	yes	Gov.agency	Environment
NAADs	no	no	Gov.agency	Agriculture
NWSC	yes	no	Gov.agency	Environment
UNBS	no	no	Gov.agency	Others
COCTU	no	no	Gov.agency	Health
CDO	no	no	Gov.agency	Agriculture
UCDA	yes	yes	Gov.agency	Agriculture
DDA	no	no	Gov.agency	Agriculture
Econ_Policy_Research	yes	no	Research inst.	Science
Mak_Uni_Pub_Health	yes	no	Research inst.	Science
Mak_Uni_Agri	yes	yes	Research inst.	Science
Mak_Uni_Food	yes	no	Research inst.	Science
UMU	yes	no	Research inst.	Science
GULU_Uni	no	no	Research inst.	Science
RUFORUM	no	no	Research inst.	Science
UNFF	yes	no	Int.group	Agriculture
CropLife_Uganda	yes	yes	Int.group	Agriculture
UNADA	yes	no	Int.group	Agriculture
UFEA	yes	yes	Int.group	Agriculture

Contacted	**Survey**	**Interview**	**Actor type**	**Sector**
NILE_Coffee	yes	no	Int.group	Agriculture
PELUM	yes	no	CSO/NGO	Agriculture
AFIRD	yes	yes	CSO/NGO	Agriculture
AUWPAE	yes	yes	CSO/NGO	Agriculture
FRA	no	no	CSO/NGO	Agriculture
UNFYA	yes	no	CSO/NGO	Agriculture
YOFACO	yes	no	CSO/NGO	Agriculture
CIDI	yes	no	CSO/NGO	Agriculture
ARUWE	no	no	CSO/NGO	Agriculture
APF	no	no	CSO/NGO	Agriculture
CEFROHT	yes	no	CSO/NGO	Environment
UNACOH	yes	no	CSO/NGO	Health
Agroline_Extn	yes	no	CSO/NGO	Agriculture
NOGAMU	yes	yes	CSO/NGO	Agriculture
NAPE	yes	no	CSO/NGO	Environment
UWASNET	no	no	CSO/NGO	Environment
Caritas_Uganda	yes	no	CSO/NGO	Agriculture
BUKOOLA	yes	no	Pesticide dist.	Industry
Quality_Chem	yes	no	Pesticide dist.	Industry
Balton_Uganda	yes	yes	Pesticide dist.	Industry
FAO_Uganda	no	no	IO	Agriculture
WFP	no	no	ILO	Agriculture
IO	no	no	IO	Agriculture
USAID	no	no	IO	Health
DFA (N=14)	13	yes	DFA	Agriculture
DAO (N= 83)	30	yes	DAO	Agriculture
150	**81**	**17**		

Table A3: Stakeholder list (contacted, participated, and characteristics)

Keywords and topics covered in the qualitative interviews

To systematically extract the statements relevant for this investigation, I proceeded in two steps: first, I identified six keyword groups: *policy/regulation/law*, *environment/agriculture/health*, *farmers/polluters*, *conflict/collaboration*, *protection from/use of pesticides*, *threats/problems*, and *international/national/district*. This enabled me to scan the text and find the important text passages. Second, within each keyword group I identified three to five topics to which the statements relate. This helped me to categorize the statements and to facilitate integration with quantitative results. Table A4 displays the keyword groups, topics and number of statements and interviews per topic.

Keyword group	**Topic**	**Statements**	**Interview #**
Policy/regulation/law	Implementation	4	3,4,11,17
	Current state of regulation	9	1,4,5,7,13
	Specific policy instruments	11	1,3,9,10,11,13,14
	State intervention vs private	9	1,4,5,7,14,17
	Risk prevention	8	1,8,9,10,12,13,17
Total	*5*	*41*	
Farmers/polluters	Farmers	5	2,3,10,15,16
	Other polluters	1	2
Total	*2*	*6*	
Collaboration/conflicts/coordination	Need for consolidation/harmonization	3	4,8
	Cross-sectoral problem	6	1,3,8,10
	Conflicts	2	3,14
Total	*3*	*11*	
Protection from/use of pesticides	Risk prevention	4	1,3
	Use is necessary	4	1,2,7,10
	Alternatives	3	4
Total	*3*	*11*	
Threats/problems	Lack of awareness: central level	2	1,8
	Lack of awareness: district	2	4
	Overall problem perception	4	4,5,13
Total	*3*	*8*	
International/national/district	Decion-making national	2	1,13
	Decision-making district	3	7,10
	Influence international	1	3
Total	*3*	*6*	

Table A4: Keywords and topics used to extract statements from semi-structured interviews

Operationalization of independent variables

Micro-level: individual drivers

To measure individual drivers and the explanatory variable for **hypothesis 1**, I assessed whether the stakeholders consider the occurrence of environmental threats attributable to pesticide use in Uganda (1= not at all attributable to 4= completely attributable). The four threats covered different environmental components: air quality, groundwater/drinking water, wildlife and plants, water courses and lakes. For **hypothesis 2**, I asked survey participants to rank their agreement (from 1-4) with taking

precautionary action to address pesticide risks in Uganda.

Meso- and macro-level: External drivers

To capture cross-sectoral collaboration as an external driver (**hypothesis 3**), I asked stakeholders the following question: *Please check all the organizations your organization has worked closely with in the last 3 years while performing activities related to pesticide regulation*. Close collaboration is defined as: discussing new findings, developing policy options, exchanging positions, and evaluating alternatives. Responses were coded as a dummy in an actor × actor matrix identified as comprising the network related to pesticide management in Uganda (see Table A2). For each node in the network, I count the number of actors of different sectors the surveyed actors name as collaboration partners. I categorized actors into 5 different sector types: agriculture, health, environment, industry, and others. An actor can therefore have a maximum value of 5 on the diversity measure. As second external driver, I investigate the forum participation for **hypothesis 4**, I asked survey respondents to indicate "*the most important projects, programs, forums or planning processes that your organization participates related to pesticide regulation*". Actors named a maximum of 6 forums and some actors did not mention any forum they participated in. An actor can thus have a maximum value of 6 on the forum participation measure.

In-depth results

Differences between preferences for state intervention in risk prevention and risk response

Besides surveying stakeholders' agreement with nine policy instruments (as a proxy for preferences for state intervention) targeting risk prevention, I also included seven policy instruments targeting risk control (see Table A5).

Policy instruments for pesticide risk control (*Variable name*)	**Restrictiveness**
Establish standards and regular surveillance of pesticide residues in water, air and food (*standards*)	High
Strengthen chemical waste disposal systems and monitoring (*disposal*)	
Tax effluent or emission charge (*tax.emiss*)	Medium
Establish reduction targets and objectives via agreements with the private domain (industry agreements) or between different domains (public-public partnership) (*ppps*)	Low
Promote research and knowledge generation to enhance scientific evidence, formation of expert groups/information platforms (*research*)	
Establish voluntary measures by industry and civil society (e.g. to set specific targets, collection of empty containers) (*volunt*)	

Table A5: Policy instruments facilitating state intervention in pesticide risk response

Figure A5 shows the descriptive results for the preferences for state intervention targeting risk control. When looking at the differences between the two targets of risk reduction, stakeholders agree slightly less with instruments targeting preventive risk reduction. The t-test confirms that the means for both types of state intervention differ significantly (Wilcox t-test, *p-value = 0.01118*). Even though both means are high (preventive = 3.57, reactive = 3.69), this confirms the underlying assumption that risk

response measures have higher potential to be introduced than measures targeting risk prevention.

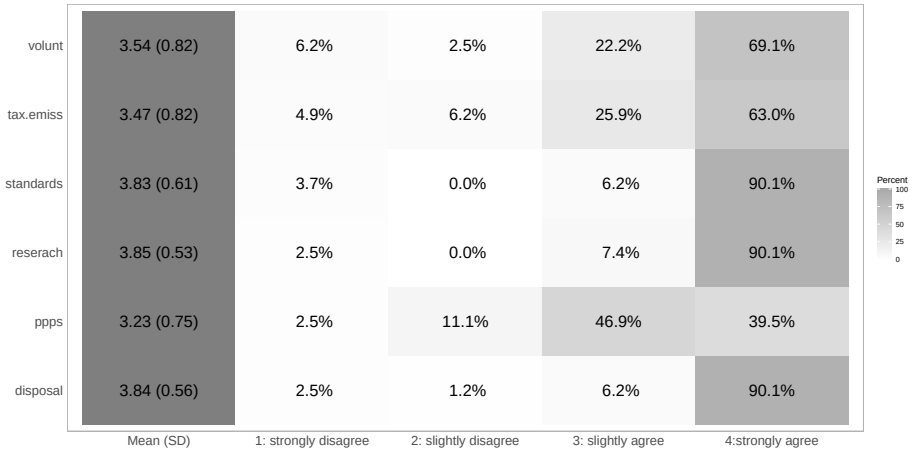

Figure A5: Agreement with policy measures targeting pesticide risk control

Summary statistics for all nine policy instrument

The following tables report the summary statistics for all nine policy instruments and overall preferences for state intervention to prevent pesticide risks by actor role (Table A6), domain (Table A7), and sector (Table A8).

	PP	**SPP**	**PIA**	**IG**	**KB**
ban	3.14	3.33	3.31	3.62	3.80
app.syn	3.71	3.67	3.41	3.81	4.00
app.alt	3.00	3.50	3.45	3.50	3.60
reg.inspect	4.00	4.00	3.83	3.91	4.00
labels	4.00	4.00	3.93	3.81	3.80
tax.purch	3.00	2.83	3.10	2.61	2.50
subsidies	3.86	3.83	3.66	3.88	3.40
info.camp	3.57	3.00	3.31	3.19	3.60
tech.supp	4.00	3.83	3.97	3.94	4.00
overall preference	3.59	3.56	3.55	3.59	3.64

Table A6: Agreement with policy instruments and overall preferences for state intervention in pesticide risk prevention by actor role (Abbreviations **PP** = Policy principals, **SPP**= Secondary policy principals, **PIA**= Policy implementation agents, **IG**= Interest group, **KB**= Knowledge broker

	Private	**Public**
ban	3.65	3.29
app.syn	3.84	3.50
app.alt	3.51	3.38
reg.inspect	3.92	3.88
labels	3.81	3.95
tax.purch	2.60	3.05
subsidies	3.81	3.71
info.camp	3.25	3.31
tech.supp	3.95	3.95
overall preference	3.59	3.56

Table A7: Agreement with policy instruments and overall preferences for state intervention in pesticide risk prevention by domain

	Agriculture	**Environment**	**Health**	**Industry**	**Cross-sectoral**
ban	3.49	3.40	2.80	3.25	4.00
app.syn	3.62	3.80	3.60	3.75	4.00
app.alt	3.54	3.40	2.80	3.00	3.25
reg.inspect	3.92	4.00	4.00	3.25	4.00
labels	3.90	4.00	4.00	3.25	4.00
tax.purch	2.92	2.80	2.67	1.75	3.00
subsidies	3.75	4.00	3.80	3.75	3.50
info.camp	3.25	3.40	3.20	3.00	4.00
tech.supp	3.95	4.00	4.00	3.75	4.00
overall preference	3.59	3.64	3.44	3.19	3.75

Table A8: Agreement with policy instruments and overall preferences for state intervention in pesticide risk prevention by sector

Summary statistics for regression variables

Table A9 contains summary statistics of the dependent, independent and control variables.

	Data unscaled (N = 79)
DV: Preferences for state intervention	
min	2.66666666666667
max	4
mean (sd)	3.58 ± 0.30
H1: Threat perception	
min	1
max	4
mean (sd)	2.73 ± 0.68
H2: Secondary policy belief	
min	1
max	4
mean (sd)	3.72 ± 0.70
H4: Cross-sectoral collaboration	
min	0
max	5
mean (sd)	3.20 ± 1.51
H5: Forum participation	
min	0
max	6
mean (sd)	2.22 ± 1.92
CV: Involvement	
min	0
max	5
mean (sd)	2.18 ± 1.18

Table A9: Summary statistics

Diagnostics linear regression

Variance Inflation Factor

The Variance Inflation Factor (VIF) for all three models (see Table A10) is above 1 and below five, which is why I conclude that there is correlation between the variables, but it is not severe and I can exclude multicollinearity between the predictor variables in all three models.

	Model 1	**Model 2**	**Model 3**
Threat perception	1.15	1.19	1.30
Secondary policy belief	1.07	1.08	1.07
Cross-sectoral collaboration		1.25	1.31
Forum participation		1.18	1.16
Involvement	1.15	1.25	1.87
Agricultural Sector	1.55	1.65	
District level	1.84	1.91	
Private domain	1.39	1.41	1.91

Table A10: VIF for all three regression models

Normal distribution of observations

Figure A6 shows the distribution of observations, they are normally distributed, I thus conclude that residuals and standard errors in the regression analyses (Model 1-3) are normally distributed and results are unbiased.

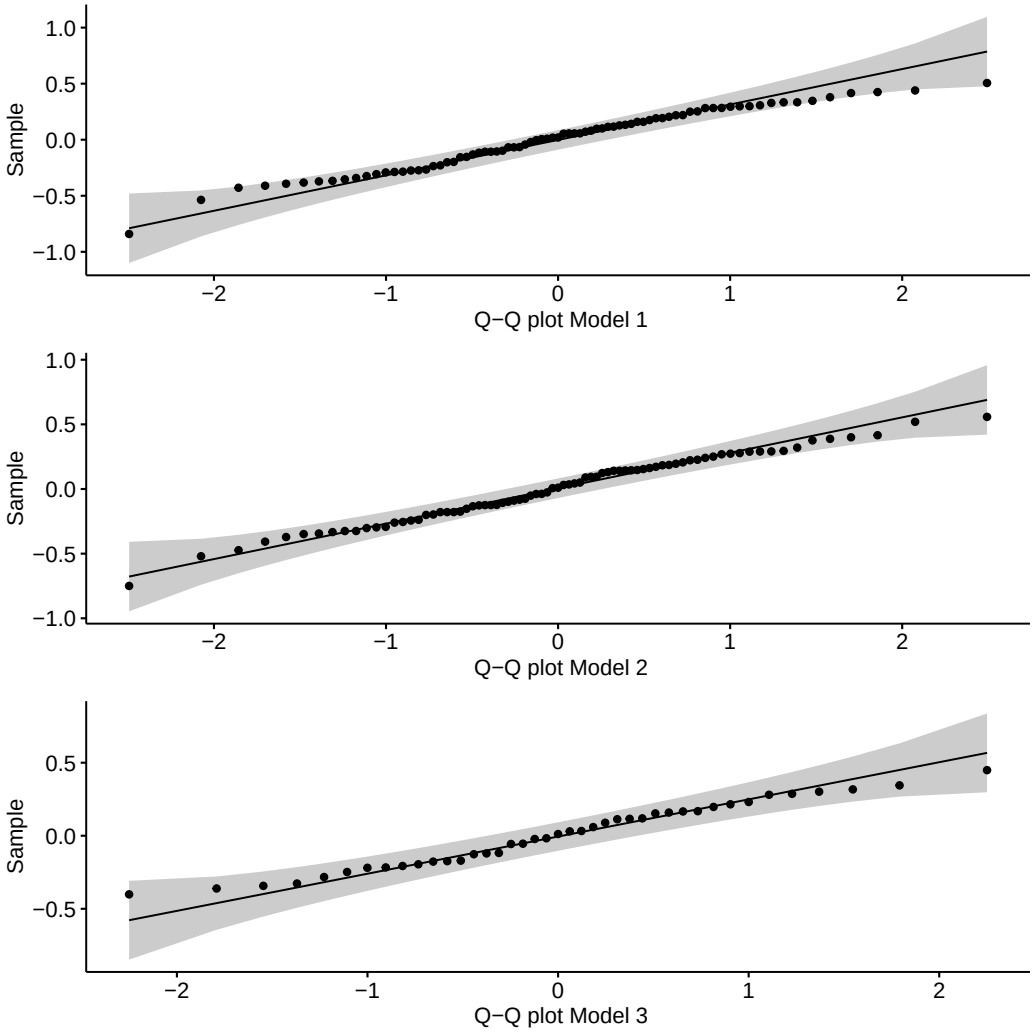

Figure A6: Q-Q plots for the regression models

Marginal effect plots

The following Figure A7 report the marginal effects of the predicted probabilities for the stakeholder preferences.

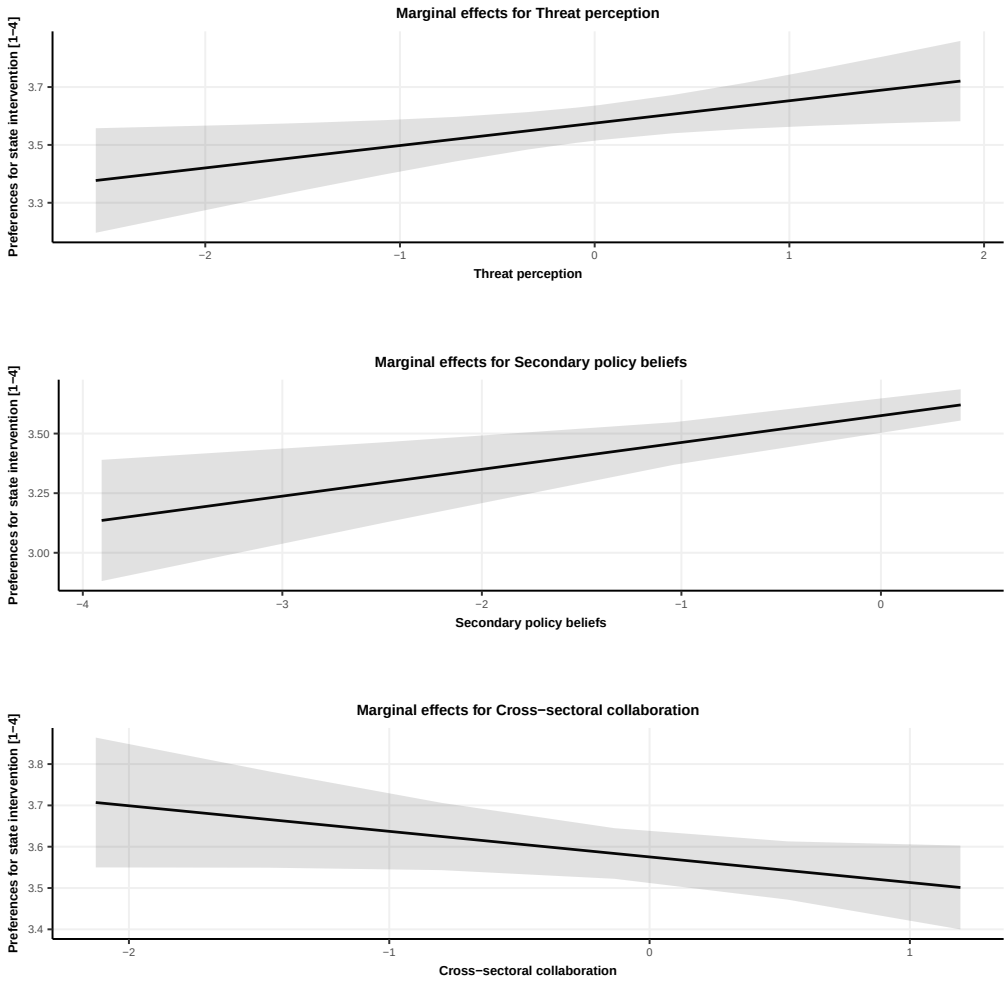

Figure A7: Marginal effect plots for variables with significant effects

Acknowledgments

The icons used in Figure A2 are obtained under creative commons license from The Noun Project (“regulation” by Martin Markstein, “importers” by priyanka, “chemical” by DinosoftLab, “distribution” by monkik, “training” by Creative Mania, “Farmer market” by Becris, “PESTICIDE” #2208129, “garbage dumb” by Eucalyp, “sustainable development” by Vectors Point)

Appendix C: Supplementary Material Online for

Building coalitions in a nascent subsystem- Investigating beliefs and policy preferences in Ugandan pesticide policy

Survey participants

Name of organization in full	Acronym in analysis	Actor type
Ministry of Agriculture: Department of Crop Protection	MAAIF_DCP	government ministry
Ministry of Agriculture: Department of Inspection and Certification	MAAIF_DIC	government ministry
Minsitry of Health: Vector Control Division	MoH_VCD	government ministry
Ministry of Gender, Labour and Social Development: Department of Occupational Health and Safety	MGLSD_DOHS	government ministry
Ministry of Internal Affairs: Directorate of Government Analytical Laboratory	MIA_DGAL	government ministry
National Agricultural Research Organisation	NARO	government agency
National Drug Authority	NDA	government agency
National Environment Management Authority	NEMA	government agency
National Water and Sewage Cooperation	NWSC	government agency
Coffee Development Authority	UCDA	government agency
Economic Policy Research Centre	Econ_Policy_Research	research institution
Makerere University School of Agricultural Science	Mak_Uni_Agri	research institution
Makerere University School of Food Science and Technology	Mak_Uni_Food	research institution
Uganda Martyrs University	UMU	research institution
Uganda National Farmers Federation	UNFF	association/interest group
CropLife Uganda	CropLife_Uganda	association/interest group
Uganda National Agro-Dealers' Association	UNADA	association/interest group
Agency For Integrated Rural Development	AFIRD	CSO/NGO
Association of Professional Women in Agriculture and Environment	AUWPAE	CSO/NGO
Young Farmers Federation of Uganda	UNFYA	CSO/NGO
Young Farmers Coalition of Uganda	YOFACO	CSO/NGO
Community Integrated Development Initiatives	CIDI	CSO/NGO
Center for Food and Adequate Living Rights	CEFROHT	CSO/NGO
Uganda Flower Exporters' Association	UFEA	association/interest group
Uganda National Association of Community and Occupational Health	UNACOH	CSO/NGO
National Organic Agriculture Movement of Uganda	NOGAMU	CSO/NGO
Nile Coffee Farmers' Asscociation	NILE_Coffee	association/interest group
Agroline Extension	Agroline_Ext	CSO/NGO
National Association of Professional Environmentalists	NAPE	CSO/NGO
BUKOOLA	BUKOOLA	pesticide distributor
Quality Chemicals	Quality_Chem	pesticide distributor
Balton Uganda	Balton_Uganda	pesticide distributor

Table A11: List of surveyed stakeholders

Selection of policy preferences in a nascent subsystem

Catalog of the four criteria

To select policy instruments for the survey, we used Criteria 1 and 2. To select policy preferences for our analysis, we used Criteria 1-4. A policy preferences was selected for analysis, if it satisfied all four criteria or Criteria 1, 2 and 4 and Criterion 3 is equal or bigger than 0.75.

Criterion	Indicator	Detail	Value
1	**General**: Document Research	Instrument derived from the literature	1 = applies 0 = does not apply
2	**Case**: Instrument fits the context of small-scale farming	Small-scale farming context, subsistence farmers, family farming, little equipment and low intensity of use rather high intensity of exposure	1 = applies 0 = does not apply (is not included in the survey)
2	**Case**: Survey data	Instrument contested in the survey (SD of each of the 22 surveyed instruments)	1 = SD >0.65 0 = SD <0.65
3	**Case**: Interview data	The instrument was contested in the interviews (n=14) (percentage of discussion across all interviews)	1 = contested in at least 50%of the interviews 0 = contested in less than 50% of the interviews

Table A12: Detailed criteria catalog

Summary statistics of the policy preferences selected and excluded for the analysis

	Overall (N=32)
q5atsource	
Mean (SD)	3.844 (0.515)
Range	2.000 - 4.000
q5endofpipe	
Mean (SD)	2.969 (1.150)
Range	1.000 - 4.000
q6ban_import_use	
Mean (SD)	3.531 (0.950)
Range	1.000 - 4.000
q6lessrestrictiveprocess_org	
Mean (SD)	3.500 (0.950)
Range	1.000 - 4.000
q8regulations	
Mean (SD)	3.688 (0.693)
Range	1.000 - 4.000
q8zoning	
Mean (SD)	3.406 (0.798)
Range	1.000 - 4.000

	Overall (N=32)
q6tax_pestpurchase	
Mean (SD)	2.500 (1.047)
Range	1.000 - 4.000
q8red.taxes	
Mean (SD)	2.531 (0.983)
Range	1.000 - 4.000
q6tax_emission	
Mean (SD)	3.500 (0.718)
Range	1.000 - 4.000
q6reductiontargets	
Mean (SD)	3.250 (0.672)
Range	2.000 - 4.000
q6voluntarymeasures	
Mean (SD)	3.375 (1.040)
Range	1.000 - 4.000

Table A13: Summary statistics included beliefs and policy preferences

	Overall (N=32)
q6restrictiveprocess_syn	
Mean (SD)	3.875 (0.336)
Range	3.000 - 4.000
q6standards_resid	
Mean (SD)	3.969 (0.177)
Range	3.000 - 4.000
q6registration_import_dist	
Mean (SD)	3.906 (0.390)
Range	2.000 - 4.000
q6chemwastedisposal	
Mean (SD)	3.938 (0.246)
Range	3.000 - 4.000
q6farmer_techsupport	
Mean (SD)	3.938 (0.246)
Range	3.000 - 4.000
q6pestlabels_env	
Mean (SD)	3.812 (0.397)
Range	3.000 - 4.000
q6subsidies_alternfarming	
Mean (SD)	3.781 (0.491)
Range	2.000 - 4.000
q6awarenessraising	
Mean (SD)	3.250 (0.672)
Range	2.000 - 4.000
q6reserach_platforms	
Mean (SD)	4.000 (0.000)
Range	4.000 - 4.000
q8bans	

	Overall (N=32)
Mean (SD)	3.781 (0.553)
Range	2.000 - 4.000
q8monitoring	
Mean (SD)	3.844 (0.369)
Range	3.000 - 4.000
q8penalties	
Mean (SD)	3.688 (0.535)
Range	2.000 - 4.000
q8subsidies	
Mean (SD)	3.656 (0.602)
Range	2.000 - 4.000
q8certifications	
Mean (SD)	3.875 (0.336)
Range	3.000 - 4.000
q8education	
Mean (SD)	3.969 (0.177)
Range	3.000 - 4.000
q8advisorynetwork	
Mean (SD)	3.875 (0.336)
Range	3.000 - 4.000
q8infocampaign	
Mean (SD)	3.875 (0.336)
Range	3.000 - 4.000
q8prompts	
Mean (SD)	3.812 (0.471)
Range	2.000 - 4.000
q8greennudges	
Mean (SD)	3.844 (0.574)
Range	1.000 - 4.000

Table A14: Summary statistics excluded policy preferences

Results of the coding and detailed results for criterion 4

Table A15 shows the results of criteria application based on the catalog illustrated in Table A12. In Table A16, we elaborate on the detailed results of coding criteria 4, or in other words, the conflictuality of the policy instruments observed in the 14 face-to-face interviews.

Instrument type	Instrument name	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Selected for analysis
Regulation	Ban importation and use of particular pesticides	1	1	1	1	Yes
Regulation	National use reduction plans	1	0	0	0	No
Regulation	Increase restrictions for the approval of chemical pesticides	1	1	0	0	No
Regulation	Reduce restrictions for the approval of alternative/non-chemical products	1	1	1	0	Yes, SD >0.75
Regulation	More strict registration and regular inspection of pesticide importers and distributors, including strengthened border control	1	1	0	0	No
Regulation	Regulation to establish a coherent system of displaying health and environmental risks on pesticide labels	1	1	0	0	No
Regulation	Establish standards and regular surveillance of pesticide residues in water, air and food	1	1	0	0	No
Regulation	Regulations through laws authoritatively put forward (e.g. maximum dosage or restrictions/setting of pesticide)	1	1	1	1	Yes
Regulation	Zoning to spatially divide and restrict inputs depending on the surrounding environment (e.g. proximity to nature reserves)	1	1	1	0	Yes, SD >0.75
Regulation	Monitoring to ensure appropriate actions are occurring (e.g. farm inspections to monitor correct spraying material or health provisions)	1	1	0	0	No
Regulation	Covenants, a gentlemen's agreement on how and where pesticides are used	1	0	0	0	No
Regulation	Mandatory spraying certificates and spraying journals	1	0	0	0	No
Regulation	Promote precision farming to reduce the amount of pesticides used (e.g., use injection technology)	1	0	0	0	No
Economic	Tax to charge for the purchase of pesticides (tax money can be used to fund extension services)	1	1	1	1	Yes
Economic	Subsidies to incentivize alternative farming practices (e.g. organic farming or pesticide-free farming)	1	1	0	1	No
Economic	Tax to impose effluent or emission charge (e.g. a tax for polluters when pesticides are emitted into environment)	1	1	1	1	Yes
Economic	Taxes to charge for the purchase of pesticide units	1	1	1	1	Yes
Information	Information campaigns to increase awareness across all sectors of society	1	1	1	0	No, SD <0.75
Information	Reduction targets and objectives via agreements with the private sector (industry agreements) or between different sectors (public-public partnership)	1	1	1	1	Yes
Information	Research and knowledge generation to enhance scientific evidence, formation of expert groups/information platforms	1	1	0	0	No
Information	Voluntary measures by industry and civil society (e.g. to set specific targets, collection of empty containers or make advertising more comprehensive)	1	1	1	1	Yes
Information	Education and training to share and impart knowledge and practices to promote safe pesticide use	1	1	0	0	No
Information	Information campaigns to provide information to change opinions on pesticide use.	1	1	0	0	No
Information	Certifications to communicate about chemical use for a product	1	1	0	0	No
Information	Advisory networks close to the farm to share of information and support to aid and improve decisions on pesticide use	1	1	0	0	No
Nudge	Green nudges to provide warning signs on product containers	1	1	0	0	No
Nudge	Prompts to remind (via SMS/social media channels/radio) about safe pesticide use practices (e.g. wear PPE or disposal of containers)	1	1	0	0	No

Table A15: Coding results

	Interview number															
Instrument name	**1**	**3**	**4**	**5**	**6**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**17**	**Total**	**Value**
Ban importation and use of particular pesticides	x	x	x	x		x	x	x	x	x	x	x	x	x	13	0.92
Increase restrictions for the approval of chemical pesticides	x			x											2	0.14
Reduce restrictions for the approval of alternative/non-chemical products	x			x			x		x						4	0.29
Stricter registration and regular inspection of pesticide importers and distributors, including strengthened border control	x	x							x			x			4	0.29
Regulation to establish a coherent system of displaying health and environmental risks on pesticide labels	x			x				x				x			4	0.29
Establish standards and regular surveillance of pesticide residues in water, air and food	x												x		2	0.14
Regulations through laws authoritatively put forward (e.g. maximum dosage or restrictions/setting of pesticide)	x	x	x	x			x		x				x	x	8	0.57
Zoning to spatially divide and restrict inputs depending on the surrounding environment (e.g. proximity to nature reserves)	x						x	x			x	x			5	0.36
Monitoring to ensure appropriate actions are occurring (e.g. farm inspections to monitor correct spraying material or health provisions)	x							x							2	0.14
Tax to charge for the purchase of pesticides (tax money can be used to fund extension services)	x	x	x			x	x	x	x		x	x	x	x	11	0.79
Subsidies to incentivize alternative farming practices (e.g. organic farming or pesticide-free farming)	x	x				x	x	x	x				x	x	8	0.57
Tax to impose effluent or emission charge (e.g. a tax for polluters when pesticides are emitted into environment)	x	x		x		x		x			x	x	x	x	9	0.64
Taxes to charge for the purchase of pesticide units	x	x	x			x	x	x	x			x	x		9	0.64
Information campaigns to increase awareness across all sectors of society	x	x					x					x	x		5	0.36
Reduction targets and objectives via agreements with the private sector (industry agreements) or between different sectors (public-public partnership)	x	x					x	x	x			x	x		7	0.50
Research and knowledge generation to enhance scientific evidence, formation of expert groups/information platforms	x					x		x							3	0.21
Voluntary measures by industry and civil society (e.g. to set specific targets, collection of empty containers or make advertising more comprehensive)	x					x	x	x	x		x			x	7	0.50
Education and training to share and impart knowledge and practices to promote safe pesticide use	x														1	0.14
Certifications to communicate about chemical use for a product									x						1	0.14
Advisory networks close to the farm to share of information and support to aid and improve decisions on pesticide use	x	x						x			x				4	0.29
Green nudges to provide warning signs on product containers													x		1	0.14
Prompts to remind (via SMS/social media channels/radio) about safe pesticide use practices (e.g. wear PPE or disposal of containers)	x							x			x		x		4	0.29

Table A16: Coding of criterion 4

Identifying optimal clusters

Figure A8 shows the optimal clustering for the two beliefs and nine policy preferences. We also show the optimal clustering for beliefs (Figure A9) and policy preferences (Figure A10) separately. These two figures show, that looking at beliefs and preferences separately yields not a satisfactory amount of clusters to show tendencies for coalition building.

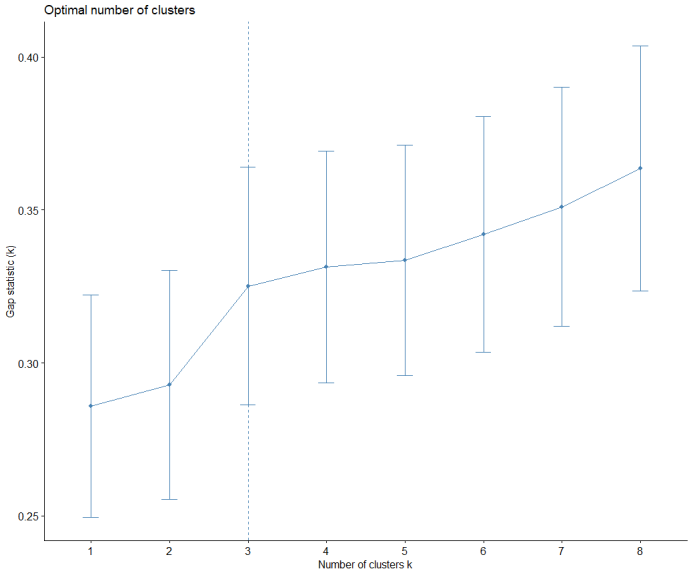

Figure A8: Optimal number of clusters for hierarchical clustering

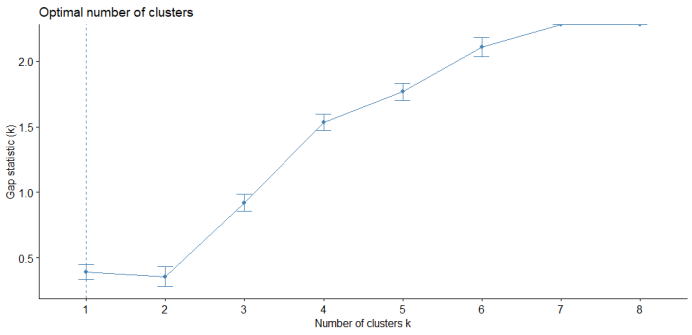

Figure A9: Optimal number of clusters for hierarchical clustering (only beliefs)

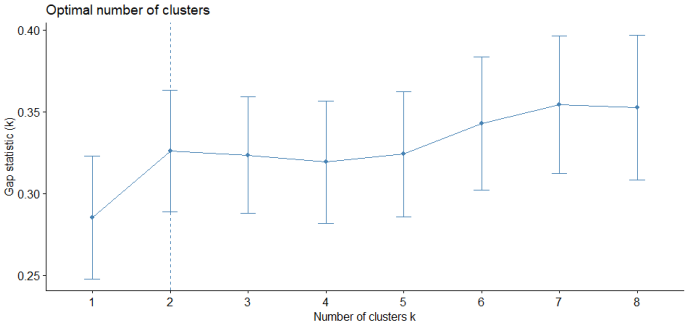

Figure A10: Optimal number of clusters for hierarchical clustering (only policy preferences)

Building the regression model (operationalization of variables)

Dependent variable

To construct the dependent variable (i.e. actors' co-occurence in one of the three belief clusters) we proceed in three steps. First, we transform the actor × cluster (two-mode affiliation in three clusters) matrix into an (one-mode adjacency) actor actor (32×32) matrix. Co-occurence in the clusters is coded with 1 (if two actors participated in the one of the three "belief and preference" cluster) or 0 (if two actors don't participate in either of the three "belief and preference" cluster). In the second step, we transform the adjacency matrix into a vector to create a dummy variable of all actor pairs resulting in a sample of 492 pairs. Within our analysis, we go beyond the investigation of co-membership in general (i.e., overall co-membership), but we also take a closer look at the likelihood of actors co-occurring in the two main clusters. For that reason, we constructed an additional dependent variable spanning over the 236 pairs of actors who co-occurred (145 in Cluster 1, 90 in Cluster 2 and 1 pair in Cluster 3).

Independent variable: Forum participation

A total of 49 different forums were mentioned by the surveyed actors, covering regulatory committees, roundtables, and networking events. The co-participation variable is a result of the three-step transformation (similar to dependent variable: from actor × forum affiliation to a weighted adjacency matrix to cleaned vector). Actor pairs co-participated in a maximum of three forums.

Independent variable: Collaboration

Based on the actors' answers about their cooperation with each other, we construct a one-mode non-symmetrized matrix in which 1s indicate that an actor collaborates with another actor, while 0s mean there is no collaboration between two actors. The data is subsequently transformed into a vector for the regression model.

Independent variable: Problem similarity

Their answers were transformed into a distance matrix (actors x problems) and subsequently, as with the other variables, transformed into a vector from the adjacency matrix. Values were subtracted from 1 to receive the problem similarity within the actor pairs under observation.

Control variables

We controlled for different actor attributes. First, we constructed an affiliation matrix between actor × value chain steps (nine steps, see Figure A11 below). Similar to the dependent and independent variables we extracted a vector for each actor pair indicating their co-occurrence along the pesticide value chain (maximum co-occurrence was 7, minimum 0) (CV1). Next, we constructed a variable to control for the actor type similarity (CV2). Actor pairs of the same actor type (six types: government ministry, government agency, research institution, association/interest group, CSO/NGO, pesticide

distributer) received 1s, otherwise they received 0s. To account for power structures among the actors, we introduced the control variable actors' reputation (CV 3). In the survey, we asked actors to indicate which actors they judge as highly important in the pesticide management in Uganda. Their answers were transformed into a distance matrix to control for the effect of reputational similarity (subtracting the values from 1 to get the similarity rather than the dissimilarity) on co-membership.

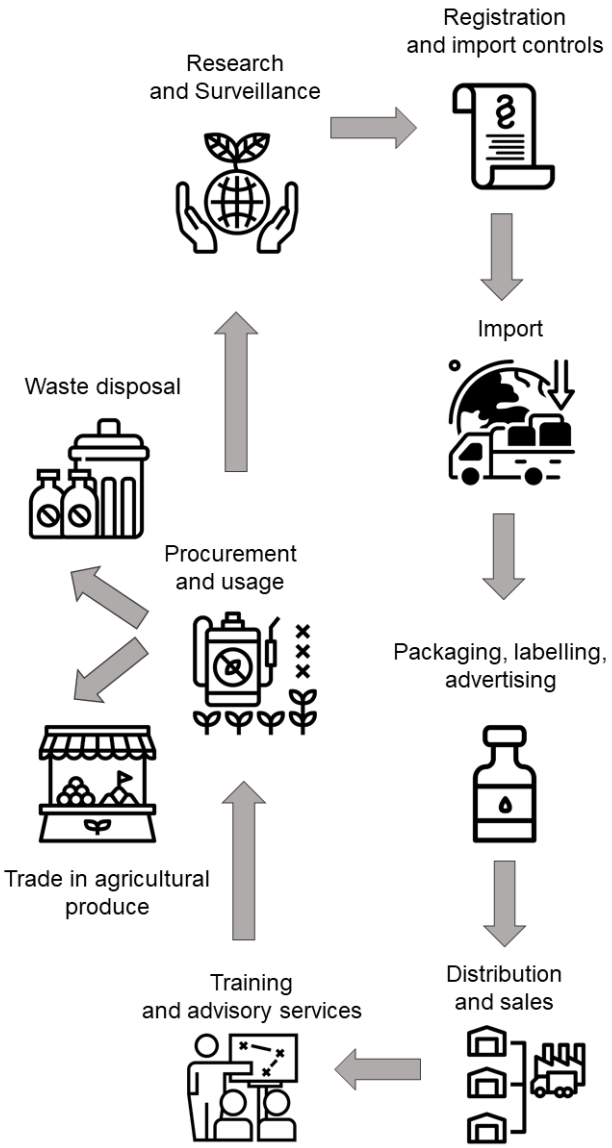

Figure A11: The different steps of the pesticide value chain)

Results: Detailed results for collaboration

cluster	id	Indegree.inf	Outdegree.inf	Betweenness.inf	Indegree.coll	Outdegree.coll	Betweenness.coll
1	MAAIF_DCP	0.87096774	0.90322581	0.06493464	0.74193548	0.61290323	0.19161251
1	MGLSD_DOHS	0.74193548	0.4516129	0.00843665	0.29032258	0.03225806	0.0008871
1	NARO	0.74193548	0.83870968	0.0233082	0.35483871	0.35483871	0.02241431
1	NEMA	0.83870968	0.93548387	0.05868734	0.61290323	0.06451613	0.00692479
1	UCDA	0.61290323	0.83870968	0.03137565	0.25806452	0.25806452	0.02601428
1	Econ_Policy_Research	0.5483871	0.03225806	0	0.12903226	0.03225806	0
1	Mak_Uni_Agri	0.64516129	0.51612903	0.00294873	0.38709677	0.29032258	0.00939818
1	Mak_Uni_Food	0.58064516	0.96774194	0.01248311	0.22580645	0.38709677	0.01693765
1	UNFF	0.80645161	0.70967742	0.01829952	0.51612903	0.70967742	0.25994892
1	CropLife_Uganda	0.64516129	0.96774194	0.02399729	0.32258065	0.38709677	0.01407306
1	UNADA	0.77419355	0.38709677	0.00461013	0.29032258	0.19354839	0.01903462
1	AUWPAE	0.38709677	0.61290323	0.00098266	0.06451613	0.09677419	0
1	UNFYA	0.4516129	0.32258065	0.00070068	0.03225806	0.77419355	0.09509092
1	CEFROHT	0.25806452	0.77419355	0.00249925	0.03225806	0.25806452	0.00016543
1	UFEA	0.67741935	0.35483871	0.00233994	0.12903226	0.22580645	0.00099797
1	UNACOH	0.67741935	0.90322581	0.02399248	0.5483871	0.41935484	0.11901336
1	NILE_Coffee	0.35483871	0.06451613	0.00010626	0.12903226	0.06451613	0.00129239
1	NAPE	0.4516129	0.61290323	0.00226511	0.22580645	0.16129032	0.0064908
1	BUKOOLA	0.64516129	0.61290323	0.00882143	0.29032258	0.16129032	0.00395379
1	Quality_Chem	0.61290323	0.22580645	0.00221724	0.09677419	0.19354839	0.00516393
2	MAAIF_DIC	0.80645161	0.87096774	0.04472006	0.58064516	0.41935484	0.09130598
2	MIA_DGAL	0.70967742	0.80645161	0.02542054	0.29032258	0.32258065	0.03855321
2	NDA	0.58064516	0.51612903	0.00712856	0.22580645	0.25806452	0.01405456
2	UMU	0.41935484	0.16129032	0.00034058	0.09677419	0.16129032	0.00210104
2	AFIRD	0.32258065	1	0.0061542	0.12903226	0.22580645	0.00360754
2	YOFACO	0.41935484	1	0.00852696	0.03225806	0.16129032	8.2713E-05
2	CIDI	0.41935484	0.51612903	0.00263713	0.09677419	0.25806452	0.00615266
2	NOGAMU	0.64516129	0.35483871	0.00280161	0.35483871	0.12903226	0.00684384
2	Agroline_Ext	0.19354839	0.61290323	0.00068109	0.06451613	0	0
2	Balton_Uganda	0.64516129	0.74193548	0.01826079	0.25806452	0.29032258	0.01876259
3	MoH_VCD	0.74193548	0.19354839	0.00322537	0.12903226	0	0
3	NWSC	0.58064516	0	0	0.09677419	0.12903226	0.00084229

Table A17: Descriptive results for the influence (.inf) and collaboration (.coll) network across the three clusters

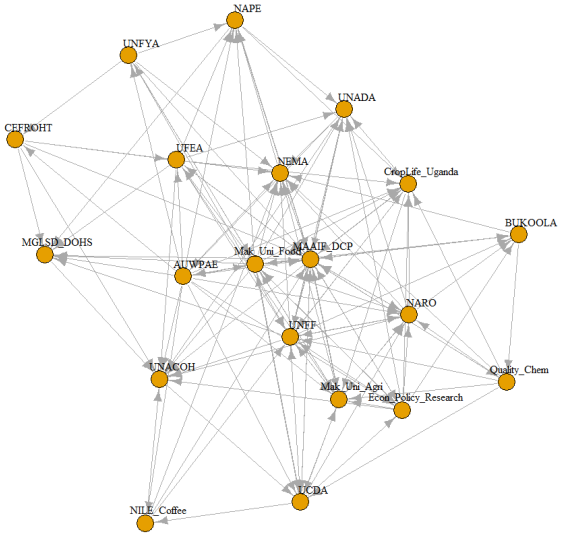

Figure A12: Collaboration network in Cluster 1 (density: 0.35)

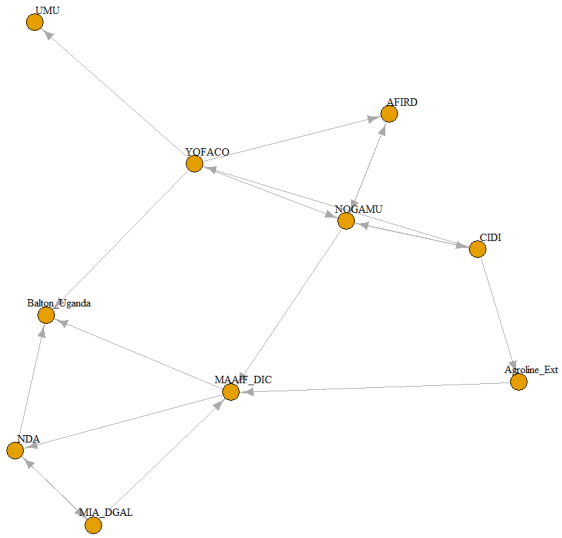

Figure A13: Collaboration network in Cluster 2 (density: 0.20)

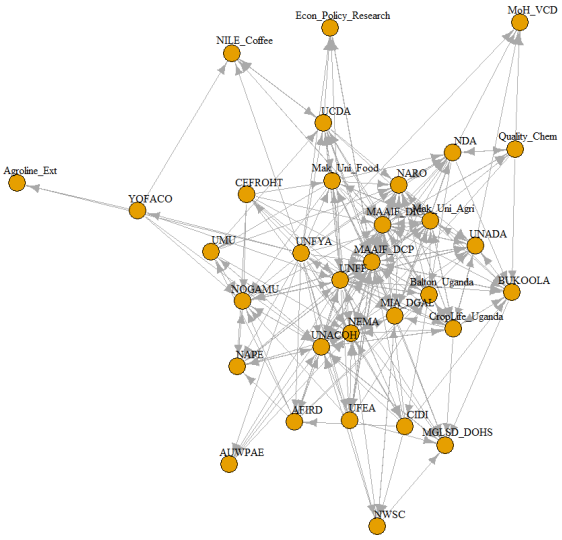

Figure A14: Collaboration network across clusters (density: 0.25)

Appendix D: Supplementary Material Online for

Solving cross-sectoral policy problems: adding a cross-sectoral dimension to assess policy performance

Documents selected for the coding

Table A18 and A19 provide a list of documents which have been gathered to evaluate policy performance.

Name of the document	Sector	Year
El Plan de Acción para el Fortalecimiento de la Producción y Comercio Responsable de Piña en Costa Rica 2013-2017	Agriculture	2013
Plan Estratégico del Ministerio de Agricultura y Ganadería 2015-2018	Agriculture	2015
Plan Sectorial de Desarrollo Agropecuario y Rural 2015-2018	Agriculture	2015
Política de Estado para el Sector Agroalimentario y el Desarrollo Rural Costarricense, 2010-2021	Agriculture	2011
Política Nacional de Seguridad Alimentaria y Nutricional 2011-2021	Agriculture	2011
Política Nacional de Producción y Consumo Sostenible	Agriculture	2018
Plan Nacional de Desarrollo 2015-2018 “Alberto Cañas Escalante”	Development	2014
Plan de Acción de la Estrategia Nacional de Cambio Climático	Environment	2015
Plan Nacional de Salud 2016-2020	Health	2016
Política Nacional de Salud 2015	Health	2015
Plan de Acción de la Política Nacional de Salud Ocupacional	Occupational health	2015
Política Nacional de Salud Ocupacional	Occupational Health	2015
Agenda de Agua	Water	2013
Plan Nacional de Gestión Integrada de los Recursos Hídricos	Water	2008
Política Hídrica Nacional	Water	2009

Table A18: Documents gathered to evaluate the policy mix

Name of the document	Sector	Year
Ley de protección fitosanitaria	Agriculture	2008
Reglamento a la Ley de protección fitosanitaria	Agriculture	1998
Reglamento para la evaluación y clasificación de la calidad de cuerpos de agua superficiales	Aquatic ecosystem	2007
Ley general de agua potable	Drinking water	1953
Reglamento para la calidad del Agua Potable	Drinking water	2015
Ley de biodiversidad	Environment	1998
Reglamento a la Ley de biodiversidad	Environment	2008
Código Civil	General	1887
Código Penal	General	1970
Constitución Política de la República de Costa Rica	General	1949
Ley general de salud	Health	1973
Código de Trabajo	Labor	1943
Reglamento General de los Riesgos del Trabajo	Labor	1982
Reglamento de Salud Ocupacional en el Manejo y Uso de Agroquímicos	Occupational health	2019
Reglamento para regular la actividad de control de plagas mediante la aplicación de plaguicidas de uso doméstico y profesional	Occupational health	2014
Reglamento sobre disposiciones para personas ocupacionalmente expuestas a plaguicidas	Occupational health	2014
Ley de Aguas	Water	1942
Principios que regirán la política nacional en materia de gestión de los recursos hídricos	Water	2002
Reglamento de vertido y reúso de aguas residuales	Water	2007
Reglamento del canon ambiental por vertidos	Water	2008
Reglamento para el transporte y distribución de agua potable en camiones cisterna	Water	2017

Table A19: Documents gathered to evaluate the legislation

Coding scheme

The following tables provide the detailed coding for density, intensity and cross-sectoral performance of the instrument mix (Table A20) and of the cross-sectoral performance of the legislative texts (Table A21)

Criterion	Question for coder	Indicator
Density	To what extent is a regimes policy mix a part of the entire pesticide risk reduction mix?	*low*= The regime has no policy mix which is attributable to the overall pesticide reduction mix *medium*= Less than a third of the overall pesticide reduction mix is attributable to the regime under investigation *high*= A third or more of the overall pesticide reduction mix is attributable to the regime under investigation
Intensity	To what extent is the share between different policy instrument categories in the policy mix balanced?	*low*= One instrument category dominates the policy mix (more than half of all instruments) *medium*= Two instrument categories dominate the policy mix *high*= Each of the three instrument categories contributes in equal parts (less than 35%) to the policy mix
Source-directed versus end-of-pipe	To what extent are source-directed instruments part of the overall regimes' policy mix?	*low*= No source-directed instruments *medium*= Half of the instruments can be classified as source-directed *high*= A majority of the instruments can be classified as source-directed
Target group integration	To what extent are the pre-defined target-groups mentioned in the regime's policy mix?	*low*= No reference to a specific target group *medium*= Target groups are mentioned, but do not spread across all sectors and along the entire food value chain *high*= The target groups are spread across the sectors and along the food-value chain

Table A20: Summary of the coding scheme for density, intensity and cross-sectoral performance (substantive)

Criterion	Question for coder	Indicator
Formulation of Cross-sectoral formulation of objectives	To what extent does the regime identify pesticide exposure or use are a cross-sectoral problem and does the regime set specific targets/objectives to counteract on this problem (e.g., an overall reduction target)?	*low*= Is (not) considered a political problem for the own sector *medium*= Is considered a cross-sectoral problem *high*= Considered cross-sectoral political problem setting specific targets
Target group integration	To what extent are the pre-defined target-groups mentioned in the regime's legislation?	*low*= No reference to a specific target group *medium*= Target groups are mentioned, but do not spread across all sectors and along the entire food value chain *high*= The target groups are spread across the sectors and along the food-value chain
Cross-sectoral institutional coordination	To what extent is cross-sectoral policy coordination among different agencies and administrative entities regulated?	*low*= To reference to a responsible body *medium*= Responsibilities are allocated but without cross-sectoral coordination *high*= Responsibilities are allocated explicitly among cross-sectoral agencies

Table A21: Summary of the coding scheme for cross-sectoral performance (institutional)

Density ratio

Figure A15 illustrates the density ratio of each regime's instruments (drinking water, aquatic ecosystem and occupational health) compared to the total share of instruments addressing pesticide risk reduction.

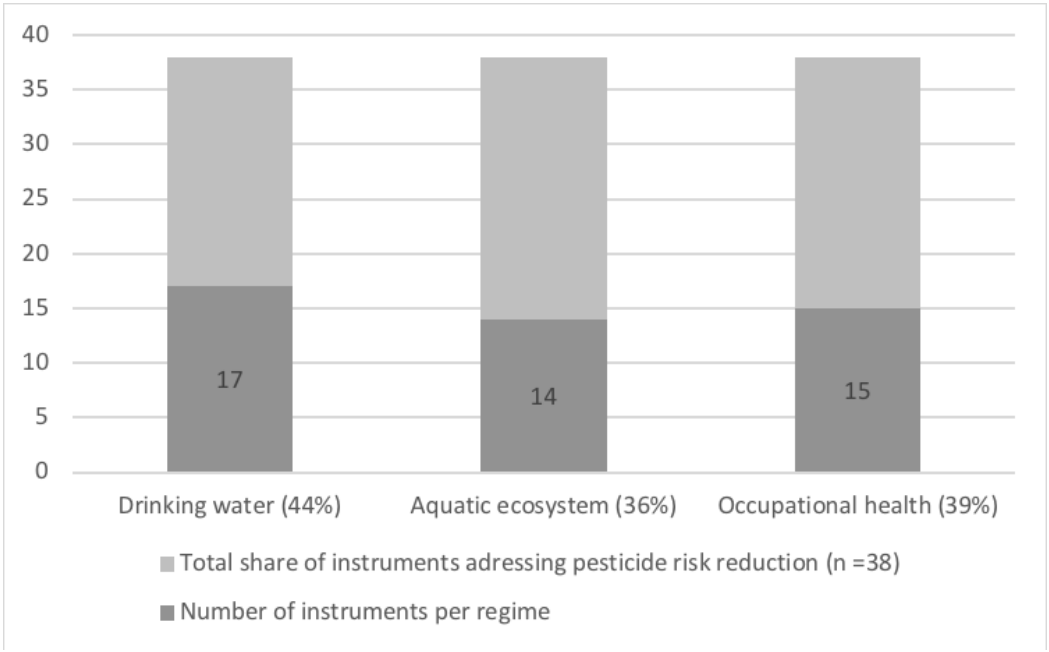

Figure A15: Density ratio

Selbständigkeitserklärung

Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Koautorenschaften sowie alle Stelle, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet. Mir ist bekannt, dass allenfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe o des Gesetzes vom 5. September 1996 über die Universität zum Entzug des aufgrund dieser Arbeit verliehenen Titels berechtigt ist.

Bern, 12. April 2022

Ruth Wiedemann