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Which policy instruments are more acceptable to farmers? The case of biodiversity-friendly pest control in the Flemish outdoor vegetable sector

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Abstract
Environmental degradation in agriculture remains a pressing issue, with key ecological indicators continuing to decline despite the longstanding policy objectives and public support for curbing environmental degradation. Biodiversity, particularly for natural pest control, is crucial for sustainable farming. The limited success of current policies to stimulate adoption of such practices can partly be attributed to a lack of attention to policy acceptability amongst farmers during ex-ante evaluations, leading to resistance or hesitance at the implementation stage. This paper tests the acceptability of different policy instrument types (categorized under the RESET framework) aimed at increasing the adoption of biodiversity-friendly practices through a survey among 99 outdoor vegetable farmers in Flanders. We explore variation in acceptability across different farmer profiles through a factor and cluster analysis. Policy instruments focused on education, advice, and knowledge exchange, including training courses, subsidised farm advice, demonstration farms, information sessions, and smart decision-support systems, received consistently high acceptability scores. In contrast, pull-based measures such as hybrid payments, voluntary labels, biodiversity monitoring tools, and collective efforts elicited mixed responses, while regulatory and penalising instruments (e.g. mandatory non-productive areas, pesticide taxes, bans) were generally less acceptable. Cluster analysis identified three farmer profiles; Sceptics, Moderates, and Enthusiasts; with Enthusiasts, typically younger, more educated and organic-oriented, showing high acceptability across most instruments. Based on our findings, we provide recommendations for policy design and for more targeted implementation strategies. The paper concludes by advocating for the systematic inclusion of acceptability assessments in the ex-ante design of agri-environmental policies.

Keywords Agroecology, Pesticide reduction, Organic agriculture, Adoption, Policy design, Europe

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Introduction

High use of insecticides and other plant protection products has significantly contributed to biodiversity decline in European agricultural landscapes. Increasing evidence points to the negative impact of pesticide use on non-target species such as bumblebees, and soil fauna, with cascading effects on ecosystem health and services (Nicholson et al. 2024; Beaumelle et al. 2023; Geiger et al. 2010). This dynamic creates a vicious cycle; low biodiversity weakens natural pest regulation, prompting greater pesticide reliance, which in turn further harms biodiversity (Geiger et al. 2010).

In this context, practices based on biodiversity-friendly crop protection offer a promising pathway. These agricultural practices aim to minimize environmental harm while enhancing biodiversity and associated ecosystem services. Examples include planting flower strips and hedgerows, adopting crop rotation or mixed cropping, and integrating agroforestry (Maskell et al. 2023; Bianchi et al. 2013; ELN-FAB 2012). Implementing these practices goes beyond merely reducing pesticide use; it requires a comprehensive effort to redesign and rethink the entire farm management system (Tscharntke et al. 2021; Landis 2017).

A growing body of literature stresses the need for policies that not only reduce pesticide use but also protect biodiversity (Finger et al. 2024; Schneider et al. 2023). In the European Union, there have been various policies addressing these issues. For example, the Sustainable Use of Pesticides Directive (SUD), adopted by the European Parliament and the Council of the European Union in 2009, establishes a framework to reduce the risks and impacts of pesticide use on human health and the environment, while promoting the uptake of Integrated Pest Management (IPM) and alternative crop protection methods (Directive 2009/128/EC). Complementary strategies, such as the EU Biodiversity Strategy, introduces the Nature Restoration Law which is operationalised through the Nature Restoration Regulation by setting continent-wide binding targets to restore ecosystems, with specific targets to reverse pollinator decline and restoring agricultural land biodiversity (European Commission 2020). The Common Agricultural Policy (CAP) 2023–2027 operationalizes the objectives of the European Green Deal and the Farm to Fork Strategy through eco-schemes, Agri-Environment Climate Measures (AECMs) and reinforced conditionality (European Commission 2023).

However, recent events point to a lower policy prioritisation to pesticide reduction and biodiversity protection. The strong pesticide reduction targets set out in the Farm to Fork Strategy are no longer reflected in the European Commission's 2025 Vision for Agriculture and Food, and the proposed Sustainable Use of Pesticides Regulation (SUR) was withdrawn in 2024, removing binding targets for Member States. This was partly driven by the large-scale farmer protests in various European countries in 2024, which were used to advocate for less environmental regulation (Läpple et al. 2026). Recent evaluations confirm that current policies fall short in protecting non-target species and broader ecosystems (Möhring et al. 2020; Guyomard et al. 2024). The uptake of biodiversity-friendly practices remains limited, and pesticide use across the EU continues to be high (Bianchi et al. 2013; Maskell et al. 2023).

Against this background, it becomes paramount to better understand how to design policies that promote an uptake of biodiversity-friendly practices. While much research has focused on the economic, social, and technical drivers (Zhang et al. 2018; Dessart et al. 2019; Klebl et al. 2024), policy related factors remain underexplored. Some studies have begun to identify features that contribute to effective agricultural policy, such as clear objectives, appropriate targeting, stakeholder involvement, and efficient resource use (Lee et al. 2019; Barzman and Dachbrodt-Saaydeh 2011). However, acceptability of policy instruments from the farmer's perspective remains insufficiently addressed in these frameworks. Although the concept of acceptability has been studied in other domains, e.g. energy (Liu et al. 2020), transport (Eriksson et al. 2006, 2008; Schade and Schlag 2003), health (Scheidmeir et al. 2022; Andreas et al. 2025; Diepeveen et al. 2013) and environment (de Groot and Schuitema 2012; Baranzini and Carattini 2017; Bicket and Vanner 2016; Drews and van den Bergh 2016; Van Der Cam et al. 2023), it has received limited attention in the agricultural policy context.

We contribute to the literature by addressing this research gap. The aim of this paper is to identify which types of policy instruments are most acceptable to farmers when it comes to adopting biodiversity-friendly practices for natural pest control[1]. We provide empirical evidence for the outdoor vegetable sector in Flanders, Belgium. This sector is associated with a particularly high pesticide use due to strong pest and fungal pressures, making it a relevant setting for investigating sustainability challenges caused by pesticide use in agriculture (Platteau and Van Bogaert 2024). At the same time, a wide array of policy instruments promoting biodiversity-friendly practices, ranging from regulations and subsidies to advisory services and cooperative initiatives, are already in place or being piloted. For example, biodiversity-friendly practices are supported through voluntary one-year eco-schemes and multi-year AECMs under the Flemish CAP Strategic Plan. Yet, their adoption rates are typically very low, with about 5% of Flemish farmers enrolled in eco-schemes in 2025, such as application of buffer strips and crop rotation with legumes. To regulate pesticide use, the Belgian National Action Plan for Pesticides (NAPAN) aims at safeguarding pollinators, and conserving and restoring biodiversity in line with the European biodiversity strategy and the Nature Restoration Law. Biodiversity objectives are further supported through mandatory training and certification of Plant Protection Products, advisory systems and monitoring, demonstration farms and experimental sites, and professional training initiatives.

We address two specific objectives. First, we evaluate the acceptability of different instrument types categorized under the RESET framework (Rules, Education, Support, Engagement, Tools), through a workshop with six stakeholders, representing different actors in the value chain, and a survey among 99 farmers. Acceptability is defined as people's attitude, which is the extent to which individuals are in favour of or opposed to policy instruments that have not yet been implemented (Schade and Schlag 2003; Liu et al. 2020). It is strongly linked to but not the same as adoption, which is the decision or action to uptake a practice that the policy instrument supports (Proctor et al. 2011). While acceptability is typically measured as a perception and does not guarantee actual adoption, several studies have shown that it plays a key role in determining policy outcomes (Schade and Schlag 2003; Andreas et al. 2025). Highly acceptable instruments may not be adopted due to feasibility constraints, while instruments with lower acceptability, such as strict regulations, might still be implemented and eventually adopted because

[1] This paper focuses primarily on pesticides affecting biodiversity relevant for natural pest control. This pertains mostly to insecticides, but herbicides and fungicides can pose risks as well, often indirectly.

of their effectiveness[2]. Therefore, a better understanding of acceptability towards different policy instruments helps to study and inform ex-ante policy evaluation. Second, we explore heterogeneity in acceptability across different farmer profiles using a factor and cluster analysis. This approach reveals whether certain types of farmers are more receptive to specific types of instruments than others. Our overall goal is to help design more targeted and acceptable policy instruments that effectively promote agrobiodiversity.

Literature review

Acceptability of policy instruments

Measuring policy acceptability before implementation (*ex-ante*) can help reduce farmer resistance and hesitation, enabling a smoother transition and implementation process. It can also lower transitional costs for governments by enhancing trust and increasing compliance with regulations (Andreas et al. 2025). From a policymaker's perspective, insights into farmers' acceptability can be used in political discourse to support or challenge policy proposals. Recent studies also highlight the importance of a hybrid approach in agricultural policy design, one that actively involves farmers in shaping policies (Conti et al. 2025). Assessing acceptability provides a way to integrate farmers' perspectives early in the design phase, which ultimately influences policy adoption and successful implementation.

Moreover, with the CAP post-2027 and the failure of several EU-level initiatives (such as the SUR) (European Commission 2022), increasing responsibility is shifting to Member States. In this context, and in the absence of binding top-down directives, farmers' bottom-up acceptability is no longer an ancillary factor but becomes a primary feasibility constraint for future policy. In addition, farmer acceptability has become more salient for national policymakers, who are often reluctant to "gold-plate" environmental standards beyond EU minimum requirements, due to competitiveness concerns within the EU single market. These dynamics make non-mandatory and incentive-based measures more politically attractive, but their effectiveness depends strongly on farmer uptake. This is precisely where ex ante analysis of farmer acceptability becomes policy-relevant.

Research from fields such as environment, energy, transport, and nutrition (de Groot and Schuitema 2012; Schade and Schlag 2003; Eriksson et al. 2008; Jakobsson et al. 2000; Eriksson et al. 2006) highlights three main categories of factors that influence acceptability towards policy instruments: (1) policy-specific characteristics, such as complexity, cost, flexibility, and level of coerciveness; (2) policy-specific beliefs, including perceived effectiveness, fairness, and trust in the implementing institution; and (3) socio-demographic characteristics, such as age and education level. Interactions also exist between farmers' beliefs that are not policy-specific, such as (but not limited to) their attitudes including perceived costs and benefits, risk and feasibility toward the sustainable farming practices that policies aim to stimulate and their compatibility with overall farmer goals. These factors influence policy-specific beliefs, contributing to heterogeneity in policy acceptability. Furthermore, it is difficult to draw a sharp distinction between policy characteristics and policy-specific beliefs, as the structure and design of a policy also shape the beliefs held about it.

[2] Effectiveness refers to the extent to which environmental policy interventions ultimately generate environmental improvements (Steinebach 2019).

Determinants of acceptability

Policy-specific characteristics

The design of a policy plays a central role in influencing how farmers perceive the effectiveness of a policy, which in turn influences its acceptability (de Groot and Schuitema 2012; Garling and Schuitema 2007). Several classification frameworks exist in the literature. A common distinction is between push and pull measures or the related carrot-and-stick metaphor. Push measures discourage undesired behaviour through penalties or restrictions, while pull measures encourage desired behaviour by offering rewards or improving alternatives (de Groot and Schuitema 2012). These approaches also relate to the level of policy intrusiveness or coerciveness. Highly intrusive and coercive measures eliminate or constrain choice (e.g., bans or fines), moderately intrusive measures steer behaviour via incentives or defaults (e.g., subsidies, nudges), and minimally intrusive policies simply provide information or enable choice (Diepeveen et al. 2013; Loukopoulos et al. 2005; Eriksson et al. 2006). Push policies are generally considered more coercive and less acceptable than pull policies (Garling and Schuitema 2007; Steg et al. 2006; Jakobsson et al. 2000; Eriksson et al. 2006, 2008; Schuitema et al. 2011), especially when they target behaviours that are perceived as high-cost or high-effort (de Groot and Schuitema 2012).

However, pesticide-reducing or biodiversity-enhancing policies often combine elements of both push and pull and cannot always be neatly placed into one category. In practice, policymakers often differentiate policy instruments by function, such as legislative (e.g., bans, mandates), financial (e.g., taxes, subsidies), or communicative (e.g., information campaigns). These dimensions are reflected in the RESET framework (Rules, Education, Social pressure, Economics, Tools), which provides a more comprehensive behavioural lens. For this reason, our analysis uses the RESET framework (Lam et al. 2017) as the primary categorisation, while also drawing on the push/pull or the carrot/stick typology. This combined approach allows us to capture not only the formal characteristics of policy design but also the behavioural mechanisms through which these instruments influence acceptability.

The RESET framework has been proposed as a categorisation of behavioural change approaches for reducing dependence on antimicrobials in livestock (Lam et al. 2017) and was an adaptation of an earlier framework from the field of communication sciences by Van Woerkum, published in Leeuwis (2004). According to the RESET framework, there are five main types of behavioural instruments. First, rules are typically designed to compel individuals to adopt certain behaviors. These behaviors are enforced through legal mandates and restrictive policies and often act through external motivation. Behavior driven solely by enforcement tends to persist only as long as the regulatory pressure exists. Second, education plays a powerful role in fostering internal motivation. Although internal motivation is difficult to instil, it tends to be stable once established, making it a valuable tool for lasting behavioral change. Third, social norms and the desire to belong to a group are often strong forces behind behavioral change and can act through internal or external motivation. Individuals are highly influenced by the expectations and actions of their peers and social circles. What becomes a “normal” practice is often guided by collective behavior, not formal instruction. Fourth, economic factors can be strong external motivators. Changes in financial conditions, whether through rewards or penalties. Technological or practical tools can make desired behaviors easier to adopt. These can include physical devices, system designs, or subtle environmental cues (nudges) that encourage specific actions, sometimes without conscious effort. Fifth, tools often reduce barriers to change and support behavior aligned with broader goals. As part of a broader strategy, tools can reinforce positive habits by simplifying processes or making the preferred behavior more convenient and attractive.

Policy-specific beliefs

In terms of policy-specific beliefs, studies have shown that perceived policy effectiveness is a key determinant of acceptability across domains (de Groot and Schuitema 2012; Eriksson et al. 2008; Schade and Schlag 2003; Baranzini and Carattini 2017; Jakobsson et al. 2000; Andreas et al. 2025; Bicket and Vanner 2016). In farming contexts, it relates both to the extent to which policies address farmers' perceived constraints and enablers, and to their alignment with farm-level goals. Acceptability often increases when policies have been piloted or successfully implemented (Carattini et al. 2018; Cherry et al. 2012). Trust in institutions, both in their competence and motives, is also critical, with distrust, often rooted in past negative experiences, acting as a barrier (Bicket and Vanner 2016; Karali et al. 2014; Drews and van den Bergh 2016). Fairness further shapes acceptability: procedural fairness (transparent, participatory processes) and distributive fairness (equitable allocation of costs and benefits) both enhance support (Eriksson et al. 2008; Andreas et al. 2025; Bicket and Vanner 2016; Schuitema et al. 2011). A strong social norm, where attitudes towards a policy are common knowledge can also influence acceptability (Drews and van den Bergh 2016; Schade and Schlag 2003).

Socio-demographic factors

Research suggests that individual characteristics are important when evaluating policy acceptability (Jakobsson et al. 2000; Schade and Schlag 2003; Lee et al. 2019; Andreas et al. 2025). Farmers' perceptions of policy characteristics and overall acceptability stands in relation to their understanding of their situation, and hence the conditions farmers find themselves in. While the relation between socio-demographic factors and farmer acceptability is complex and not deterministic, a number of empirical correlations have been identified in the literature.

Smaller or diversified farms may be more open to environmental or sustainability-related measures (Capitanio et al. 2011). However, given their limited farm size, they may also have less land available for low-intensive practices, which increases their opportunity costs (Canessa et al. 2024). Conventional farmers may show more resistance unless policies align with productivity goals or provide sufficient economic incentives (Canessa et al. 2024; Dessart et al. 2019). Younger farmers are likely to be more flexible in adopting new ideas and non-traditional policies (Canessa et al. 2024). Higher education is generally associated with greater understanding of environmental issues and higher likelihood of adopting agri-environmental schemes (Lastra-Bravo et al. 2015; Wilson and Hart 2000).

Data and methods

Study context: the Flemish outdoor vegetable sector

Outdoor vegetable production plays an important economic role in the agricultural sector of Flanders, the northern region in Belgium. In 2022, outdoor vegetable farming covered 26,230 hectares, representing 4.2% of the total Flemish agricultural area

(Statbel 2023). In total, 2,644 farms were active in outdoor vegetable cultivation in 2022, comprising 12% of all Flemish agricultural holdings. Production serves both fresh and processing markets: 35% of farms target the fresh market, 44% supply the processing industry, and 21% are active in both (DLV 2018). The sector is highly export-oriented, particularly in processed and frozen vegetables, with major international companies like Ardo and Greenyard dominating the market.

The sector has experienced significant structural changes. Between 2013 and 2022, the number of farms declined by 31%, while the average area under outdoor vegetables per farm increased by 54%, reaching 10.6 hectares in 2022. In 2021, the total production value of outdoor vegetables reached €463 million, with leeks, carrots, and cauliflower as the most valuable crops. That year, despite relatively high production value, average net operating income per farm dropped sharply to €500, highlighting economic volatility (Platteau and Van Bogaert 2024).

At the same time, pressure to decrease pesticide use is increasing. Stimulated by the EU SUD (2009/128/EC) (European Parliament, Council 2009) and the Belgian NAPAN (Belgian Federal Public Service Health, Food Chain Safety and Environment 2013), several policy instruments have been implemented or are in pilot stage. These range from innovation and advisory support systems over instruments linked to the Common Agricultural Policy (CAP), such as conditionality[3], eco-schemes and AECMs[4] (European Commission 2023), to requirements of phytosanitary certificates (Belgian Federal Public Service Health, Food Chain Safety and Environment 2013).

Identification of policy instruments

Stakeholder workshop to identify policy instruments

To identify promising instruments for enhancing agrobiodiversity in the Flemish open-air vegetable sector, we conducted a multi-stakeholder workshop with six participants in November 2023 (see details of the participants in Table 1). Participants were selected to ensure a diverse range of stakeholders who can consider different types of behaviour change instruments at different levels (e.g. market-level, policy-level, and local initiatives). We invited about 30 people, but a majority was not available or did not wish to participate. The workshop centered around the shared problem statement: *"How to*

Table 1 Details of workshop participants

Job title	Actor category	Gender
Director at a processing company	Value Chain	Male
University Professor	Research	Female
Research leader at a practical research centre	Research	Female
Rural Development: Land policy advisor	Policy	Male
Agricultural Policy Advisor	Policy	Female
Rural Development: Policy advisor	Policy	Female

[3] Conditionality under the Flemish CAP requires a minimum share of non-productive areas on arable land, with at least 4% devoted to fallow land and landscape features, or alternatively 7% when including catch crops or nitrogen-fixing crops without plant protection products, of which at least 3% must be non-productive features.

[4] Eco-schemes and AECMs for the promotion of biodiversity include cultivation of environmentally friendly, biodiversity-friendly and/or climate-resilient crops, continuation of organic farming, buffer lanes, mechanical weed control, cultivation techniques to control erosion, application of crop rotation with leguminous plants, maintenance of agroforestry systems, management agreements for buffering vulnerable natural elements or for creating ecological connections, maintenance of small woody landscape elements, and protection of fauna and flora associated with agricultural activities.

increase agrobiodiversity for biological pest control and reducing dependence on environmentally harmful pesticides in the open-air vegetable sector in Flanders."

The stakeholder co-design process consisted of a structured 180-minute online workshop conducted via Microsoft Teams. The workshop was facilitated by two moderators (one facilitator and one note-taker) and followed a two-stage procedure. In the first stage, participants were presented with the problem statement and key farmer targeted behaviours (e.g. crop rotation, agroforestry, installation of buffer strips). They were then asked to individually think about actions, strategies or instruments that could be used to help target these farmer behaviours across different instruments according to the RESET framework. Participants were first asked to group similar instrument ideas into broader themes, which were subsequently aligned with the RESET framework categories. In the second stage, participants discussed each instrument theme in breakout groups and assessed them against four predefined criteria: farmer acceptability (anticipated farmer support), practical feasibility (ease of implementation), expected effectiveness (environmental and social outcomes), and potential unintended consequences. Rankings and justifications were documented in real time.

Selection of instruments

The initial long list of measures was iteratively consolidated through moderated discussion and thematic aggregation, with convergence reached through group deliberation and formal voting. The final twelve policy instruments, grouped according to the RESET framework (Table 2) were selected based on thematic distinctiveness, relevance to the problem statement, and the collective assessment of feasibility and impact, ensuring that farmer-related considerations remained central throughout the process. The discussions held during the workshop were documented using templates attached in the Appendix C (Figure C1 and C2).

Some of the identified instruments are already partially in place, such as requirements for non-productive areas on farms or Value Added Tax (VAT) increases on inputs. However, the workshop participants proposed several modifications to improve their impact, for example, increasing the required share of non-productive area from 7% to 15%, or raising VAT on pesticides. Other instruments are hypothetical and were included to explore the acceptability of novel or more ambitious policy options.

Overall, during the workshop, participants emphasized the interplay between acceptability, effectiveness, and feasibility from an implementation perspective. They noted that effectiveness was often perceived as closely linked to acceptability. However, they distinguished between effectiveness in terms of changing farmer behaviour and effectiveness in achieving the intended goal, namely more biodiversity-friendly crop protection. Participants also highlighted that the perceived stringency of policies could strongly influence their acceptability, and that both acceptability and effectiveness were expected to depend on the specific design and calibration of the instruments.

Farmer survey

In a second phase, an online survey (see supplementary material) was distributed to the entire population of 2,700 registered outdoor vegetable farmers in Flanders to assess farmer acceptability of the 12 policy instruments identified during the stakeholder workshop. The population of 2,700 farmers includes all farmers who grow vegetables on at

Table 2 Policy instruments grouped according to the RESET framework identified during the stakeholder workshop

Type	Instrument	Explanation
Regulatory	**Ban on the most harmful plant protection products**	A ban on pesticides containing active substances such as chlorotoluron, ipconazole, or 8-hydroxyquinoline, substances already banned in the EU or listed for potential substitution. No exemptions to this ban will be allowed.
	Increase in non-productive area	10% of your land must consist of non-productive elements such as hedgerows or flower strips. Of this, 5% is legally required, and the remaining 5% is part of the conditionality for receiving direct payments under the CAP. You may choose not to implement the latter 5%, but this would reduce your CAP payments.
Economic	**VAT increase on pesticides**	The VAT on plant protection products will be raised from 12% to 21%.
	Weighted pesticide tax	Additional taxes (on top of VAT) on plant protection products. The tax would be higher for more harmful pesticides (e.g., 30–40% on insecticides and fungicides) and lower for less harmful ones (e.g., 10–15% on biocontrol products), potentially 0% for products with extremely low environmental impact.
	A voluntary consumer label	Introduce a voluntary consumer label that rewards farmers for implementing biodiversity-friendly practices (including organic farming). The label would enable farmers to receive a higher price for their products.
	Hybrid payments	A combination of action- and results-based payments, where you receive a basic subsidy for practices such as creating flower strips. You receive additional payments if you achieve extra, measurable outcomes, such as an increase in pollinating insects.
Social	**Information sessions and demonstration farms**	The government will organize more events at demonstration farms where you can learn about ecological pest control.
	Collective environmental efforts	Join a farming collective to improve spatial planning of biodiversity-friendly measures and receive bonuses for coordinated efforts.
Education	**Training courses**	The government will organize more training courses for farmers on ecological pest control, focusing on the use of biodiversity.
	Subsidized farm advisory services	Receive subsidized, independent advice on pest management.
Tools	**Biodiversity monitoring tools**	A tool to measure how your farm supports biodiversity and tracks improvements over time. It allows you to monitor the biodiversity benefits of your practices and show your positive impact to supply chain actors (such as supermarkets and processors), consumers, neighbours, friends, and family.
	Smart decision-support tools	The government will support the development of smart decision-support tools with integrated sensors to help determine when and how to use plant protection products. These tools can improve soil and biodiversity while lowering costs. They may also allow for timely monitoring of pest and beneficial insect populations.

least one plot and whose email addresses are registered with the Agency for Agriculture and Fisheries in Flanders. The initial invitation was sent on January 20, 2025, with two reminder emails sent in the weeks that followed. Of the recipients, 300 opened the survey (11.1%), and 99 completed it entirely (3.5%). While the response rate seems low, it is comparable to most other recent farm surveys in Europe, which are typically plagued by small samples (Slijper et al. 2026).

All responses were pseudonymised immediately after data collection by the organisation's data protection manager, who maintained the sole key linking farmer client numbers to email addresses. The research team had access only to pseudonymised analytical datasets, with all reported results fully anonymised. Survey responses were also linked to administrative parcel data from the Agency for Agriculture and Fisheries using anonymized client numbers[5]. This enabled the inclusion of farm-level variables such as total farm area and organic certification status. Informed consent was obtained from all participants prior to the start of the survey. Participants were informed about the purpose of the study, data processing procedures, and their rights under applicable data protection regulations. No formal pre-test was conducted, but the survey was reviewed internally for clarity and grammar by colleagues within the organisation prior to deployment.

The survey consisted of two parts. The first gathered socio-demographic information, including age, gender, and education. The second section assessed farmer perceptions of the acceptability of the proposed instruments. The 12 instruments were presented on a single page in a tabular format in the same order as in Table 2. Acceptability for each instrument was rated using a five-point Likert scale. A score of 5 indicated strong acceptability for the instrument while a score of 1 indicated zero acceptability.

Table 3 presents the summary statistics of the sample. Most farmers (90%) were male, aged between 36 and 65 (84%), and had at least secondary education. Approximately 15% of respondents were organically certified, while the majority of farms (87%) were under 10 hectares in size. To assess the representativeness of the sample, we compared it to the population of vegetable farmers as recorded by STATBEL and to administrative parcel data from the Agency for Agriculture and Fisheries (2023). The sample was found to be representative in terms of gender and farm size, but showed a slight overrepresentation of younger farmers and organically certified farms. Aware of the potential non-response bias, all conclusions pertain to the sample and not to the population.

Methods

We apply a cluster analysis to identify farmer groups based on their acceptability scores, preceded by a factor analysis to reduce the number of variables. This is necessary to reduce dimensionality and identify underlying latent constructs in the acceptability ratings. Since respondents evaluated multiple policy instruments, it is likely that some of these instruments reflect broader common dimensions (e.g. regulatory vs incentive-based approaches). Factor analysis helps to detect these latent structures, reduce noise,

Table 3 Socio-demographic and farm characteristics of survey respondents ($N=99$)[1]

Variable	Category	Sample	Population (vegetable farmers)
Age (years) (mean)		49.6 (11.4)	53
Farm size (ha) (mean)[2]		1.95 (5.51)	2.06
Gender (percentage)	Male	89.8	88.29
	Female	9.0	
	Rather not say	0.2	
Education level (percentage)[3]	Secondary degree	87.0	
	Tertiary degree	13.0	
	Other (e.g., horticulture training)	0.20	
Organic certification (percentage)	Yes	15.0	7.6

Notes: [1]$N=91$ for organic certification and farm size; [2]Farm size (ha) and age were recorded as continuous variables, SDs are in parentheses; [3]As no population (vegetable farmers) data on education were available, we cannot evaluate the representativeness of the sample in terms of educational level

[5] Eight out of 99 respondents did not provide their client number, so it was impossible to retrieve this information for them.

and avoid treating highly correlated measures as independent. It therefore improves construct validity and prevents redundancy in the cluster analysis, which uses the factor scores (rather than the raw items) to identify groups of respondents with similar acceptability profiles (Kaufman and Rousseeuw 1990; Shrestha 2021). Studies that used a similar approach in other contexts include Gebauer (1987), Davidova et al. (2009), Van den Broeck and Maertens (2017), Higuchi and Maehara (2021), Goswami et al. (2014) and Shrestha (2021).

Factor analysis

To reduce the number of individual policy instruments into broader underlying dimensions, an exploratory polychoric factor analysis (PFA) was conducted. Factor analysis (FA) is a multivariate statistical technique used to reduce data complexity by identifying latent factors that explain patterns of correlation among observed variables. The significant factors are extracted to explain the maximum variability of the variables under study. Since the acceptability scores for the different policy instruments were measured using ordinal Likert scales, polychoric correlations were used rather than Pearson correlations (see Fig. A1 in Appendix A).

To determine the optimal number of factors, we applied Kaiser's criterion and a scree plot to retain factors with eigenvalues greater than one. We then applied oblique rotation to aid interpretability of the factors (Brown 2009). The internal consistency is confirmed by calculating Cronbach's alpha to test the instrument accuracy and reliability, with a threshold value higher than 0.7. Finally, we computed standardized factor scores for each respondent, which represent the individual's position on each of the latent dimensions identified by the factor analysis. These were used as inputs for the subsequent cluster analysis.

Cluster analysis

We performed a cluster analysis to group farmers into distinct classes. Cluster analysis is an unsupervised classification method that seeks to identify internally homogeneous but externally heterogeneous groups by minimizing intra-cluster variance and maximizing inter-cluster variance. We applied a two-step clustering procedure. In the first step, Ward's method of agglomerative hierarchical clustering was used to identify the potential number and structure of clusters (Murtagh and Legendre 2014). In the second step, the centroids obtained from the hierarchical clustering were used as starting values for a K-means clustering procedure. Using K-means as a second step allows for refined cluster assignment, especially for observations near cluster boundaries, where K-means clustering alone may be suboptimal (Jain 2010).

To characterize the identified clusters and support the design of targeted instruments, we compared their socio-demographic characteristics, including age and gender, and farm characteristics. We used pairwise non-parametric Wilcoxon rank-sum tests for continuous variables or Fisher's exact tests for categorical variables. This allowed us to explore whether particular farmer profiles were associated with specific clusters, thereby providing practical insights for policy tailoring and stakeholder engagement strategies.

Results

Acceptability of policy instruments

Figure 1 shows the surveyed farmers' acceptability levels for the 12 policy instruments. Overall, the instruments that received most positive ratings focus on education and information provision, such as 'training courses' and 'subsidized farm advice', 'smart decision-support tools', and 'information sessions and demo farms'. A majority of respondents (70%) consider these measures acceptable or very acceptable. In contrast, responses to 'collective environmental efforts', 'hybrid payments', and 'biodiversity monitoring tools' are more mixed. Many respondents rate these instruments as neutral, resulting in an approximately equal split in acceptability and unacceptability. Regulatory and penalising economic instruments, which typically involve mandatory changes in agricultural practices, taxes, or financial penalties (for example, 'increasing non-productive area', 'raising VAT on pesticides', imposing 'a weighted pesticide tax', or 'banning the most harmful pesticides'), are generally rated less favorably. Among these, the proposed increase in the non-productive area requirement in Belgium is the least acceptable instrument overall. These findings suggest that farmers tend to prefer supportive and enabling policy measures over coercive or punitive ones.

Factor and cluster analysis

Both Kaiser's criterion (see Table A1 in Appendix A) and the scree plot (see Fig. A2 in Appendix A) suggest that the acceptability scores for the 12 policy instruments can be analysed by three factors (See Fig. A3 in Appendix A). Factors with eigenvalue greater than 1 were retained, which explain 55.5% of the total variance and demonstrate good internal consistency, with Cronbach's alpha values of 0.75, 0.84 and 0.75.

Based on the factor scores, the optimal number of clusters is three according to the Calinski-Harabasz (CH) index (see Table A2 in Appendix A) and the elbow method (see Fig. A4 in Appendix A). The k-means clustering was employed with the centroids

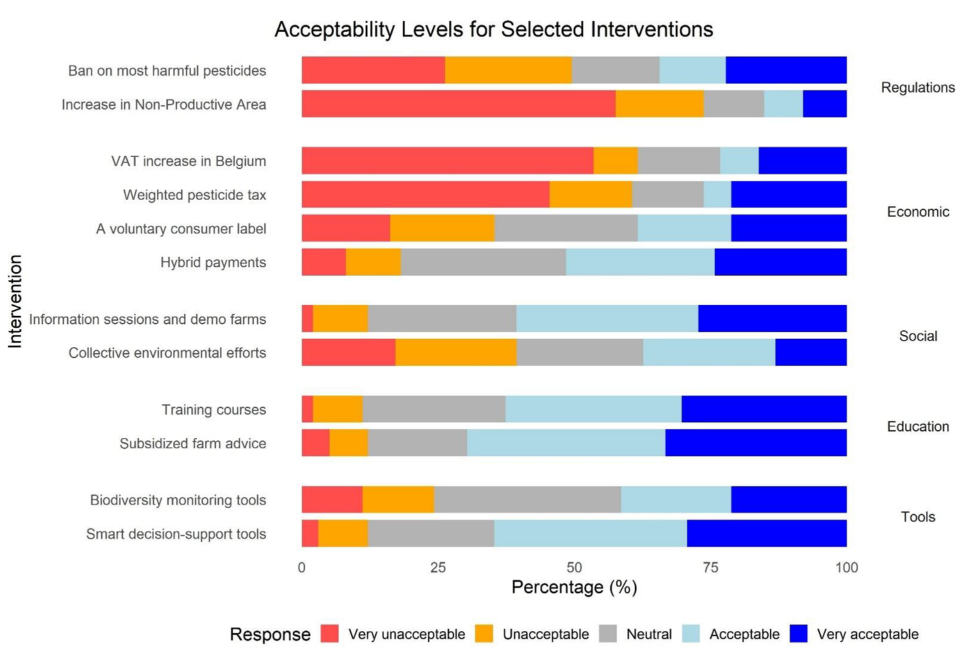

Fig. 1 Acceptability scores for 12 policy instruments on a Likert scale of 1–5

of three clusters (See Fig. A6 in Appendix A). We conduct several sensitivity checks to verify the number of clusters, which are explained in detail in Appendix B

Table 4 presents the mean acceptability scores for each instrument across the three identified clusters[6]. The first cluster, interpretatively labelled "Sceptics," shows consistently low mean acceptability scores across all instruments. The second cluster, called "Moderates," expresses moderate acceptability levels for most instruments. The third cluster, referred to as "Enthusiasts," exhibits high acceptability scores for nearly all instruments. The Sceptics represent 32.3% of the sample, the Moderates 42.4% and the Enthusiasts 25.3%. While the acceptability for the majority of instruments differs across clusters, some exceptions are observed. Clusters 1 and 2 do not differ significantly in their scores regarding 'VAT increase on pesticides', 'subsidized farm advice', and 'increase in non-productive area'. Furthermore, clusters 2 and 3 do not show significant differences in their scores for 'collective environmental efforts'. Despite the small sample size, we do find many statistically significant differences, indicating that a lack of statistical power is not a major issue[7].

Among the skeptics, most instruments are scored rather unacceptable, but some even less acceptable than others. 'Subsidised farm advice' receives the highest acceptability score, followed by 'training courses', 'information sessions and demo farms'. Intermediate levels of support are observed for 'hybrid payments' and 'biodiversity monitoring tools', whereas the 'weighted pesticide tax' is rated least acceptable, followed by 'an increase in non-productive area', a 'VAT increase on pesticides, and 'a ban on the harmful plant protection products'. 'Voluntary consumer labels' and 'collective environmental efforts' receive moderate ratings.

Among the Moderates, the most acceptable measures were 'information sessions demo farms', followed by 'training courses' and 'subsidised farm advice'. The least acceptable instrument was the 'Increase in non-productive area'. Other less acceptable measures included the 'VAT increase on pesticides', the 'weighted pesticide tax', and a 'ban on harmful plant protection products'. Other measures received moderate scores.

Table 4 Cluster means (±SD) and pairwise comparison of *p*-values between clusters

Policy instrument	Cluster 1: Sceptics (*n* = 32)	Cluster 2: Moderates (*n* = 42)	Cluster 3: Enthusiasts (*n* = 25)	C1 vs C2	C2 vs C3	C1 vs C3
Increase in non-productive areas	1.34 ± 0.70	1.67 ± 1.10	3.08 ± 1.53	0.47	<0.01	<0.01
Ban on the most harmful PPPs	1.63 ± 0.79	2.67 ± 1.26	4.56 ± 0.82	<0.01	<0.01	<0.01
Hybrid payments	2.91 ± 1.17	3.29 ± 1.04	4.60 ± 0.65	0.39	<0.01	<0.01
Voluntary consumer label	1.81 ± 0.78	3.14 ± 1.05	4.60 ± 0.65	<0.01	<0.01	<0.01
Weighted pesticide tax	1.09 ± 0.30	2.14 ± 1.16	4.56 ± 0.87	<0.01	<0.01	<0.01
VAT increase in Belgium	1.41 ± 0.95	1.76 ± 1.08	4.12 ± 1.27	0.20	<0.01	<0.01
Collective environmental efforts	2.06 ± 0.91	3.31 ± 1.12	3.44 ± 1.47	<0.01	1.00	<0.01
Information/demo farms	2.94 ± 0.98	3.88 ± 0.77	4.52 ± 0.77	<0.01	<0.01	<0.01
Subsidised farm advice	3.38 ± 1.26	3.81 ± 0.94	4.56 ± 0.82	0.28	<0.01	<0.01
Training courses	2.94 ± 0.91	3.86 ± 0.81	4.80 ± 0.41	<0.01	<0.01	<0.01
Biodiversity monitoring tools	2.40 ± 1.00	3.31 ± 0.98	4.28 ± 1.21	<0.01	<0.01	<0.01

[6] We prefer to use the average scores than the different categories for ease of interpretability.

[7] In addition to comparing mean Likert scores across clusters, we also treated the Likert responses as categorical variables. The results confirmed significant differences between clusters.

Table 5 Socio-demographic characteristics of the three clusters (means ±SD) and pairwise comparison of *p*-values between clusters

Variable	Cluster 1: Sceptics (*n* = 32)	Cluster 2: Moderates (*n* = 42)	Cluster 3: Enthusiasts (*n* = 25)	C1 vs C2	C2 vs C3	C1 vs C3
Age (years)	53.18 ± 11.81	47.00 ± 10.91	49.09 ± 10.09	<0.01	0.48	0.08
Male (%)	90.86	92.50	87.50	1.00	0.66	1.00
Tertiary education (%)	31.25	36.58	70.83	0.80	<0.01	<0.01
Organic (%)	7.14	5.00	47.83	1.00	<0.01	<0.01
Farm size (ha)	7.02 ± 26.11	7.50 ± 10.86	6.26 ± 10.53	<0.01	0.15	0.49

For the Enthusiasts, the highest-scoring instruments were 'training courses', followed by 'hybrid payments', 'voluntary consumer labels', and 'subsidised farm advice'. Interestingly, this group also rated the 'weighted pesticide tax' relatively high. By contrast, the 'increase in non-productive area' and 'collective environmental efforts' received the lowest scores. Other measures were rated moderately.

Socio-demographic characteristics of clusters

Table 5 describes the socio-demographic characteristics of the three clusters. Farmers in Cluster 1 "Sceptics" are older than Cluster 2 "Moderates", but not significantly different from Cluster 3 "Enthusiasts". Cluster 1 has smaller farms than Cluster 2, but a high standard deviation indicates heterogenous farm size within cluster 1. Cluster 3 has the highest proportion of organic farms and farmers with a tertiary degree compared to the other two clusters. Gender differences are not significant, although Cluster 3 has slightly more female farmers.

Discussion

Key findings

We find that the policy instruments of 'training courses', 'subsidised farm advice', 'information sessions and demonstration farms', and 'smart decision-support systems' receive the highest acceptability ratings, even among the most sceptic farmers. Although some of these measures are classified under different RESET categories (e.g. decision-support systems under "tools"; information events and demo farms under "social instruments"), they share a common feature, as they all facilitate learning and provide guidance in a non-intrusive way. This pattern suggests a clear interest in acquiring knowledge and skills needed to adopt biodiversity-friendly practices, possibly reflecting a perceived lack of capacity. Education and advice-based policy instruments have also been found to be highly acceptable in previous studies (Clayton 2018), although Eriksson et al. (2008) suggest that communicative policies elicit more neutral responses. In addition, these instruments can be tailored to local conditions, making them less likely to disrupt existing farm operations and allowing them to align to personal farm management goals. Since participation is voluntary and costs and benefits are perceived as evenly distributed, these instruments can be viewed as procedurally and distributively fair, especially when co-designed and adapted to local contexts.

In contrast to the high and consistent support for education- and advice-based measures, responses to pull-based instruments, such as hybrid payments, voluntary consumer labels, biodiversity monitoring tools, and collective environmental efforts, are more mixed. These instruments receive a broad range of acceptability ratings, often clustering around neutrality, with approximately equal proportions of respondents viewing them positively and negatively. Although these measures fall under different RESET categories (e.g. Tools, Economic, Social), they share common design principles: they are incentive-based, voluntary, and dependent on farmers achieving observable results before receiving compensation. This qualifies them as pull measures that aim to reward rather than penalise. Research suggests that pull measures are perceived as fairer, more effective and more acceptable than push measures (de Groot Jim et al. 2012; Schuitema et al. 2011; Eriksson et al. 2006, 2008; Clayton 2018; Steg et al. 2006; Garling and Schuitema 2007). This holds particularly for farmers who perceive these measures and outcomes as realistic and more environmentally beneficial, such as organically certified, younger and higher educated farmers, who constitute the majority of the (moderately) enthusiast farmers in our sample, and which is in line with numerous other studies (e.g. Lastra-Bravo et al. 2015; Peerlings and Polman 2009; Wilson and Hart 2000; Hynes and Garvey 2009; Capitanio et al. 2011; Ducos et al. 2009). However, acceptability can decrease due to fairness concerns, especially when outcomes depend not only on own actions, but also on the actions or inaction of neighbouring farmers or by external outcomes such as weather and pests (Kuhfuss et al. 2016; Le Coent et al. 2021). Especially for collective efforts, subjective, injunctive norms and relational trust play an important role (Kuhfuss et al. 2016; Le Coent et al. 2021; Karali et al. 2014). In addition, trust in the development and data governance of monitoring tools can significantly influence farmers' acceptability. (Rose et al. 2016). Another reason for the neutral acceptability levels can be due to the novelty of these instruments, as most farmers do not have experience with these yet. Stakeholders at the workshop also expressed similar views on the acceptability of the proposed policy instruments from the farmers' perspective. Social pressure and collective schemes were thought to be received with mixed feelings: while peer influence could increase acceptability, concerns over fairness, power imbalances, and free riding could be a problem. Acceptability also hinged on clear, science-based standards, independent advice, and the potential for recognition or market rewards for sustainable practices for more economic based instruments. In many cases, acceptability was closely linked to feasibility and compensation levels, with insufficient support, monitoring, or alignment with existing standards identified as key barriers to wider uptake.

In the original RESET framework (Lam et al. 2017), the "S" component refers to social pressure, emphasizing peer or community influence on behavioural change. However, our results in the Flemish agricultural context suggest a more nuanced interpretation. Information sessions and demonstration farms are highly accepted, whereas collective environmental efforts receive mixed responses. This reflects the distinction between descriptive norms (observing others' behaviour, enabling social learning and imitation) and injunctive norms (perceived expectations or pressure to act in a certain way). Demonstration farms appear to operate mainly through social learning and support, while collective initiatives may generate feelings of pressure, concerns about free-riding, or risks to social capital, particularly among Skeptics.

The most negatively rated instruments are regulatory and penalising economic instruments, including mandatory 'increases in non-productive areas', 'bans on most harmful pesticides', 'VAT increases on pesticides', and 'weighted pesticide taxes'. These instruments require mandatory changes in farm practices and may directly affect farm income through higher costs or lower revenues. The acceptability is especially low among sceptic and moderate farmers, while comparable to other policy instruments for enthusiast farmers, indicating that acceptability can increase when farming systems are adapted to more biodiversity-friendly pest control. However, the increase in non-productive area is the most negatively rated across all clusters, probably because it entails substantial incomes foregone (Canessa et al. 2024). It can be viewed as unfair, particularly by smaller farms, as larger farms typically have more flexibility to set aside land without compromising viability (Canessa et al. 2024; Ducos et al. 2009). This reinforces perceptions of distributional unfairness, which can reduce legitimacy and willingness to comply. Negative experiences with previous iterations of non-productive area requirements, often characterised by rigid regulations and poor communication, may also contribute to the instrument's current unpopularity (Canessa et al. 2024).

On the other hand, the other regulatory instrument of banning most harmful pesticides receives somewhat higher acceptability scores, perhaps because farmers perceive such a ban as fairer and more justified. Particularly when both consumers' and farmers' health is protected, and long-term soil and ecosystem health are improved, this can be an important determinant in farmers' willingness to reduce pesticide use (Chèze et al. 2020; Damalas et al. 2024). Moreover, farmers may feel that bans targeting only the most harmful substances are less restrictive, as they retain access to less harmful alternatives, making the measure more manageable in practice.

A weighted pesticide tax, where tax rates are differentiated according to the toxicity and environmental impact of active substances, is rated less inacceptable than a general VAT increase. This is probably due to the higher flexibility of the weighted tax, allowing farmers to make cost-benefit decisions based on their own cropping systems and pest pressures (Nielsen et al. 2023). In general, differentiated environmental taxes are widely regarded as cost-effective instruments for reducing externalities, as they follow the polluter-pays principle where tax revenues can be used for public goods. The most sceptic farmers, however, rate this as the least acceptable policy instrument, even less than an increase in non-productive areas. A general VAT increase on pesticides is ranked as the second most unacceptable option across all farmer clusters. Farmers can perceive a uniform VAT increase as unfair and/or ineffective because it applies equally to all types of pesticides, regardless of their toxicity or environmental impact. This is particularly problematic for organic and low-input farmers, who often use less harmful or natural products. Penalising these equally with more hazardous substances is seen as disproportionate, undermining efforts to support more sustainable production systems. Enthusiast farmers, many of whom operate organically, are especially critical of this blanket approach. Moreover, no substitution effect is enabled, as all pesticide products are made more expensive uniformly. This limits the farmers' ability to shift to safer or more efficient alternatives. In addition, the high inelasticity of pesticide demand to price (ranging from −0.02 to −0.7 according to Skevas et al. 2013) would lead to higher costs but no substantial pesticide reductions, doubting the effectiveness of such a measure.

Policy recommendations

High acceptability for policy instruments is often a key condition for effective policy design and implementation. In the short term, priority should be given to the support of education-based policy instruments, such as training courses, subsidised farm advice, information sessions, demonstration farms, and decision-support systems.The CAP supports knowledge exchange, advisory services, and training through instruments such as the Farm Advisory System, Agriculture Knowledge and Innovation Systems (AKIS), and EIP-AGRI. Combined with specialised programmes on biodiversity-friendly agriculture, these instruments can strengthen farmers' skills and confidence in adopting such practices.

In the longer term, when farmers' education and experience have built confidence and control, focus should shift to the development of hybrid payments, biodiversity monitoring tools, collective environmental efforts and voluntary consumer labels. The post-2027 CAP will be more results-driven, with incentives linked to outcomes beyond mandatory requirements. It will be crucial for Member States to define and maintain indicators and monitoring systems that are based on hybrid payments and collective environmental efforts.

A ban on most harmful plant protection products and weighted pesticide taxes can gain support with suitable alternatives and adequate training, but a general VAT increase on all pesticides should be evaded. Recent negotiations for the Belgian federal budget 2026–2029 approved an increase in VAT on plant protection products from 12% to 21%, effective in 2026. This change is highly relevant for our study, as a large majority of our sample (75% comprising the Skeptics and Moderates) rejects such a measure. However, we also find that a weighted pesticide tax, differentiated by toxicity, is slightly less unacceptable, particularly for the Enthusiasts, who recognize the logic of internalizing externalities. By opting for a flat VAT increase, the government will overlook farmers' nuanced preference for instruments that target highly toxic pesticides, representing a missed opportunity. Similarly, increasing non-productive areas should either be avoided or targeted to areas where it would have the greatest ecological impact, such as ecologically sensitive zones using instruments such as AECMs, eco-schemes, or Natura 2000 incentives.

In addition, socio-demographic characteristics can inform better policy targeting. While a broad policy mix with flexible options can help engage all types of farmers, specific strategies could include training of younger, higher educated farmers as early adopters and peer influencers, and use trust-based, locally relevant, incremental approaches for older farmers. Communication campaigns could leverage "enthusiast" farmers as pioneers or demonstration cases. Situating this group within the framework of "communities of practice" and peer-to-peer learning can help with knowledge exchange and diffusion (Sutherland and Marchand 2021).

Limitations and suggestions for future research

We need to note that the focus of our study is on farmers' acceptability, and not on other factors that determine policy design or implementation, such as effectiveness or costs. While acceptability and effectiveness are closely linked, this is not always the case. The most acceptable policy instruments, such as education-based measures, are often less intrusive, which could hamper their effectiveness since it is possible to comply without changing anything in terms of on-farm practices. The high acceptability of education is often an artifact of its non-intrusive nature. Agreeing to "be informed" costs nothing and does not require immediate changes to agricultural practices, which often hides the pitfall labelled as the Knowledge action gap (Räsänen et al. 2024). To increase effectiveness, Lokhorst et al. (2010) propose smart educational approaches, where farmers publicly commit to achieve targets or indicate how this will affect their on-farm practices. Regarding implementation costs, education-based instruments can be rather expensive to design and deliver, whereas taxes could generate additional revenues for the government. At the same time a stricter monitoring of permitted products would come with its own regulatory challenges. For instance, Gensch et al. (2024) warn that banning specific active substances may not reduce overall pesticide risk if the substituted substances carry similar or even greater environmental and ecological risks.

In sum, other criterions need to be assessed to have a comprehensive understanding of policy design and impacts. The literature on behavioral change (including the COM-B model) suggests that Capacity (increased by education) is necessary but not sufficient without Opportunity (tools or economics) and Motivation (social pressure or rules) (Michie et al. 2011). The acceptable policy instruments should be part of a cohesive (adaptive) policy mix, in a way that instruments reinforce one another (Gottinger et al. 2025). Therefore, our study needs to be interpreted as a first step, where understanding acceptability (especially ex-ante) should be a prerequisite before the implementation of policy instruments, and should be complemented by pilot testing and evaluation of actual policy impacts. The results of this research should also be interpreted in light of limitations in the policy co-design process, particularly the selective inclusion and self-selection of participants, which may have influenced the range of perspectives represented (Grohmann et al. 2025). As the process mainly involved stakeholders from academia, research institutes, and implementing government organisations, the selected instruments may have leaned towards institutional or technical measures aligned with existing policy frameworks. A broader and more participatory co-design process involving more farmers and practice-oriented actors might have shifted the discussion towards more voluntary, incentive-based and knowledge-driven approaches, with greater emphasis on flexibility, lower opportunity and transaction costs, and farmer-led initiatives (Schulze et al. 2024; Irvine et al. 2025). For example, innovation transfer models such as FACOPA (factors–perception of complexity–adoption) and AKAIE (Awareness Knowledge Adoption Implementation Effectiveness) proposed in recent work (Vecchio et al. 2022, 2023) provide practical frameworks for operationalizing Responsible Research and Innovation (RRI) principles in policy design. By structuring innovation diffusion around farmer awareness and perceptions, contextual factors, and demonstrable outcomes, both models ensure that policies are not merely imposed top-down but are co-developed with stakeholders and proven effective in practice, possibly improving policy acceptability.

In addition, our framing of acceptability has some limitations when viewed through a critical social science lens. Acceptability concerns should always be considered in relation to the systemic realities in which farmers operate. In reality, what counts as "acceptable" policy is often shaped by pre-existing institutional norms and discursive formations that reflect the interests of more powerful actors, whereas a purely preference-based framing tends to assume that all stakeholders have relatively equal opportunities to influence policy outcomes. Related to this, we suggest that future research could conceptualize acceptability as a multi-dimensional construct, including compatibility with farmer goals, perceived efficacy and fairness.

A methodological limitation of this study is the relatively small sample size, illustrative of a wider phenomenon of increasing difficulty to obtain large sample sizes in European farmer surveys due to stakeholder fatigue (Slijper et al. 2026). Researchers should take this trend into account when designing data collection efforts to ensure robust and meaningful insights. While our sample is representative in terms of farm size, response rates are higher among organically certified farmers, which needs to be considered when interpreting and extrapolating our findings. Another limitation is that we do not have data on socio-psychological factors and policy-specific beliefs linked to the policy instruments. While these factors are undoubtedly important, including them in the survey would have increased its length, potentially further reducing the number of respondents. A trade-off is always necessary between survey depth and sample size. Future research could explore these aspects in greater detail, either by designing more targeted surveys or by complementing quantitative analysis with qualitative methods.

Conclusion

This study analyses farmers' acceptability towards different policy instruments aiming at strengthening the uptake of biodiversity-friendly pest control practices. We focus on the open-air vegetable sector in Flanders, where pesticide use is intensive but policy efforts to reduce pesticide use are increasing. Through a stakeholder workshop, we identify twelve policy instruments that could support the transition towards more biodiversity-friendly crop protection. We categorize them using the RESET framework and test their acceptability through an online farmer survey. Overall, information-based and decision-support tools are viewed most positively. Training programs, subsidized farm advice, information sessions and smart decision-support systems providing tailored information are rated as highly acceptable. In contrast, perceptions of collective schemes, hybrid payments, and biodiversity monitoring tools are more mixed, often resulting in a neutral or divided response. Regulatory and penalising economic instruments, which typically involve mandatory changes in agricultural practices, taxes, or financial penalties (for example, increasing non-productive area, raising VAT on pesticides, imposing a weighted pesticide tax, or banning the most harmful pesticides), are generally rated less favourably. Among these, the proposed increase in the non-productive area requirement in Belgium is the least acceptable instrument overall. Farmers show a clear preference for supportive and enabling instruments over coercive ones. Using factor and cluster analysis, we identify three farmer groups based on acceptability profiles; Sceptics, who express low acceptability across most instruments; Moderates, with mixed but moderate levels of support; and Enthusiasts, who rate nearly all instruments positively. Socio-demographic differences are apparent across these clusters, with Enthusiasts more likely to be younger, higher educated, and organically certified, pointing to opportunities for better targeting of instruments. While acknowledging that acceptability is not the only criterion for policy design and implementation and acceptability of instruments does not necessarily imply their adoption or effectiveness in practice, we argue that including acceptability assessments in ex-ante policy design can strengthen farmer agency and promote meaningful participation.

Appendix A

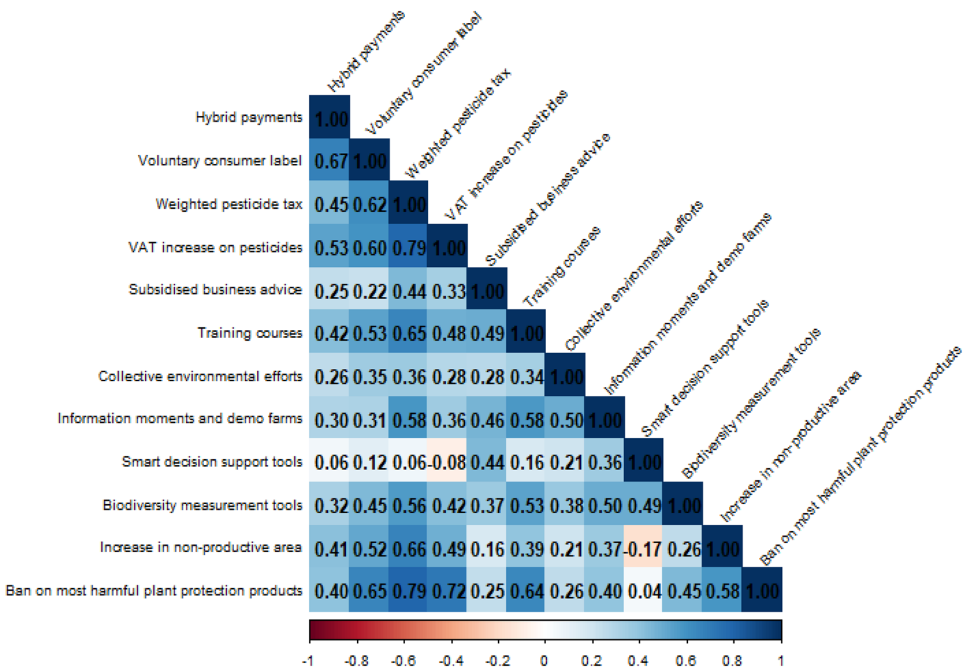

Fig. A1 Polychoric correlation matrix showing the correlation between the acceptability scores of the selected 12 instrument

To determine the suitability of the dataset for factor analysis, both sample size and the strength of relationships among items must be considered (Tabachnick and Fidell 2013; Stevens 1996). A larger sample is generally recommended, with a common rule of thumb being ten cases per item. However, smaller samples may also be adequate when the solution contains several strongly loading marker variables (loadings > 0.80) (Stevens 1996). Two statistical measures are commonly used to evaluate the factorability of the data: the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The Kaiser–Meyer–Olkin (KMO) measure assesses the suitability of the data for factor analysis by evaluating sampling adequacy for individual variables and for the overall model. KMO values between 0.80 and 1.00 indicate adequate sampling, values between 0.70 and 0.79 are considered middling, and values between 0.60 and 0.69 are considered mediocre. For sample sizes below 100, an average KMO value above 0.60 is

Table A1 Eigenvalues from factor analysis

Component	1	2	3	4	5
Eigenvalue	5.53469	1.29448	0.87320	0.76120	0.61059

generally regarded as acceptable (Guttman 1954; Tabachnick and Fidell 2013). Bartlett's test of sphericity examines the null hypothesis that variables are orthogonal, meaning the correlation matrix is an identity matrix and the variables are unrelated, making them unsuitable for structure detection. The alternative hypothesis states that variables are sufficiently correlated for factor analysis. A significant result ($p < 0.05$) indicates that factor analysis may be appropriate for the dataset (Guttman 1954).

We find that the Bartlett's test of sphericity indicated that the correlation matrix was not an identity matrix, χ^2 (66) = 717.02, $p < 0.001$, supporting the suitability of the data for factor analysis, i.e. items are sufficiently correlated for factor analysis. The Kaiser-Meyer-Olkin measure indicated sampling adequacy for factor analysis, with an overall value of 0.85 > 0.6 and individual item values ranging from 0.78 to 0.92.

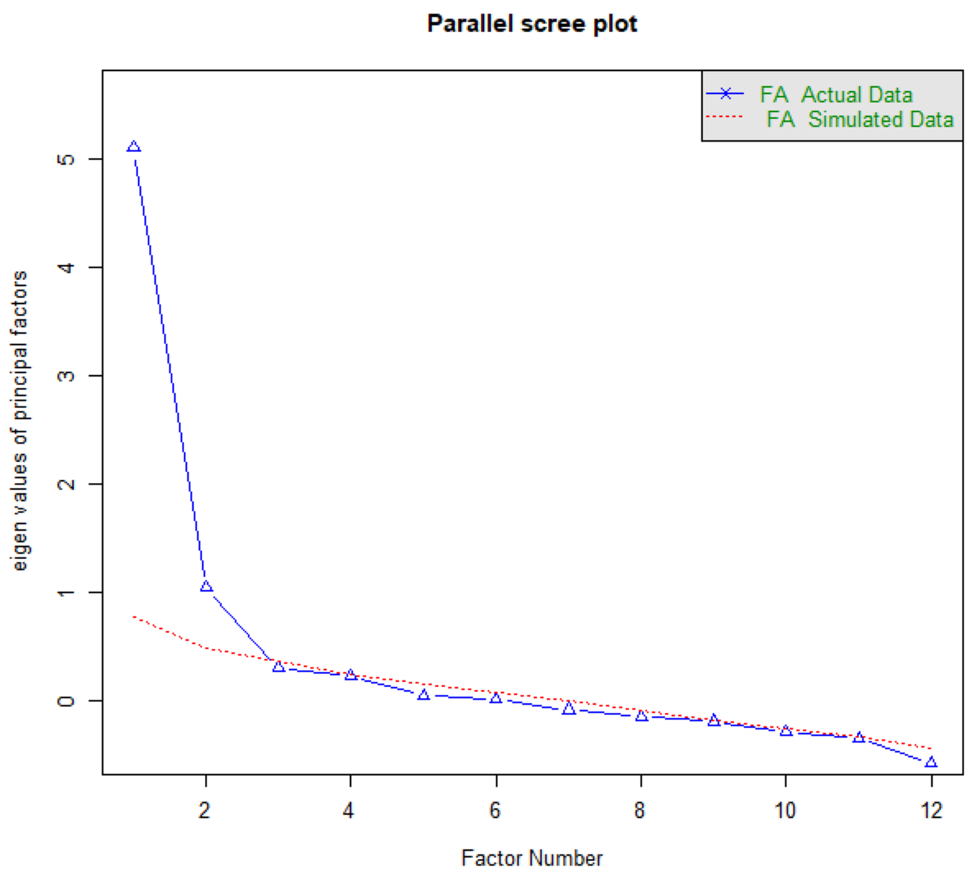

Fig. A2 Scree plot to identify the optimum numbers of factors

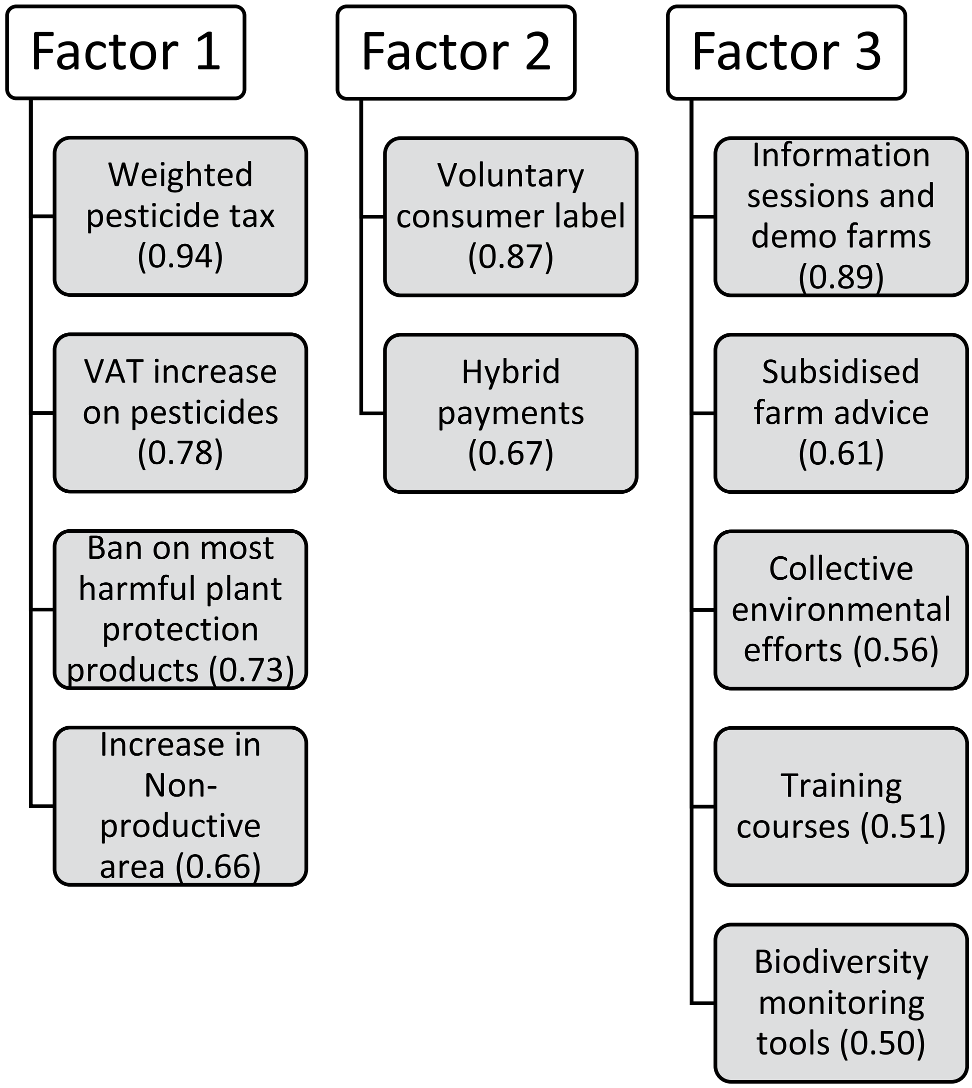

Fig. A3 Grouping of policy instruments according to three identified factors, with factor loadings presented in brackets. The variable "Smart decision tools" had the lowest individual Measure of Sampling Adequacy (MSA) (0.38), confirming its weak relationship with other variables as suggested by the polychoric correlation matrix. Therefore, this instrument was removed from further analysis.

Factor 1 groups regulatory and punitive economic instruments, including 'a weighted pesticide tax', 'VAT increase', 'ban on harmful plant protection products', and an 'increase in non-productive area'. Common characteristics of these policies are their restrictive, top-down nature and their potential negative impacts on farm income or autonomy. Factor 2 consists of market- and incentive-based instruments, specifically the 'voluntary consumer label' and 'hybrid payments'. These reflect voluntary, supportive measures combining consumer demand and flexible financial incentives. Factor 3 includes a broad range of enabling and participatory instruments such as 'information sessions', subsidized farm advice', 'collective environmental efforts', and 'training courses'. This factor captures instruments aimed at providing knowledge, support, and opportunities for collaboration.

Table A2 Calinski-Harabasz index (Ch_index) for different numbers of clusters (**k**)

k	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
CH_Index	131	128	104	92	86	83	82	81	80

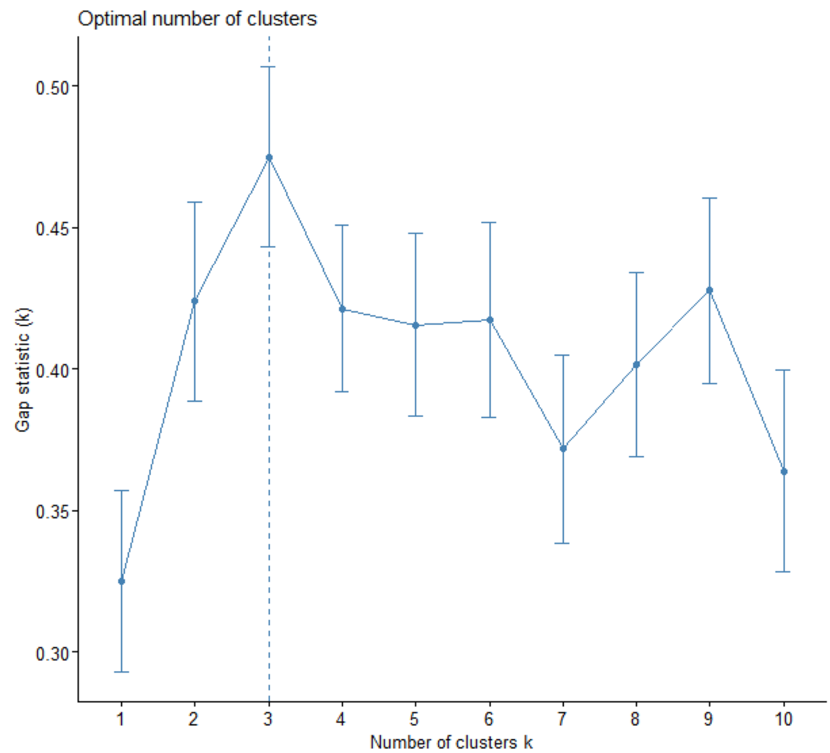

Fig. A4 Elbow method to identify the optimum number of clusters for Ward's clustering

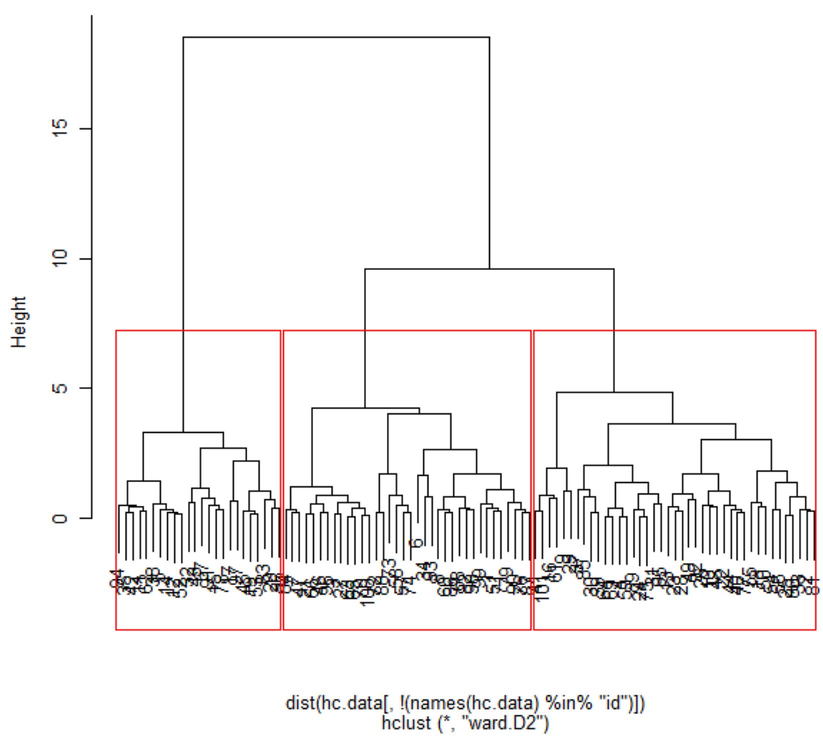

Fig. A5 Dendrogram from hierarchical agglomerative clustering using Ward's minimum variance method (Ward.D2) based on Euclidean distances. The red boxes indicate the three-cluster solution selected based on the fusion height criterion

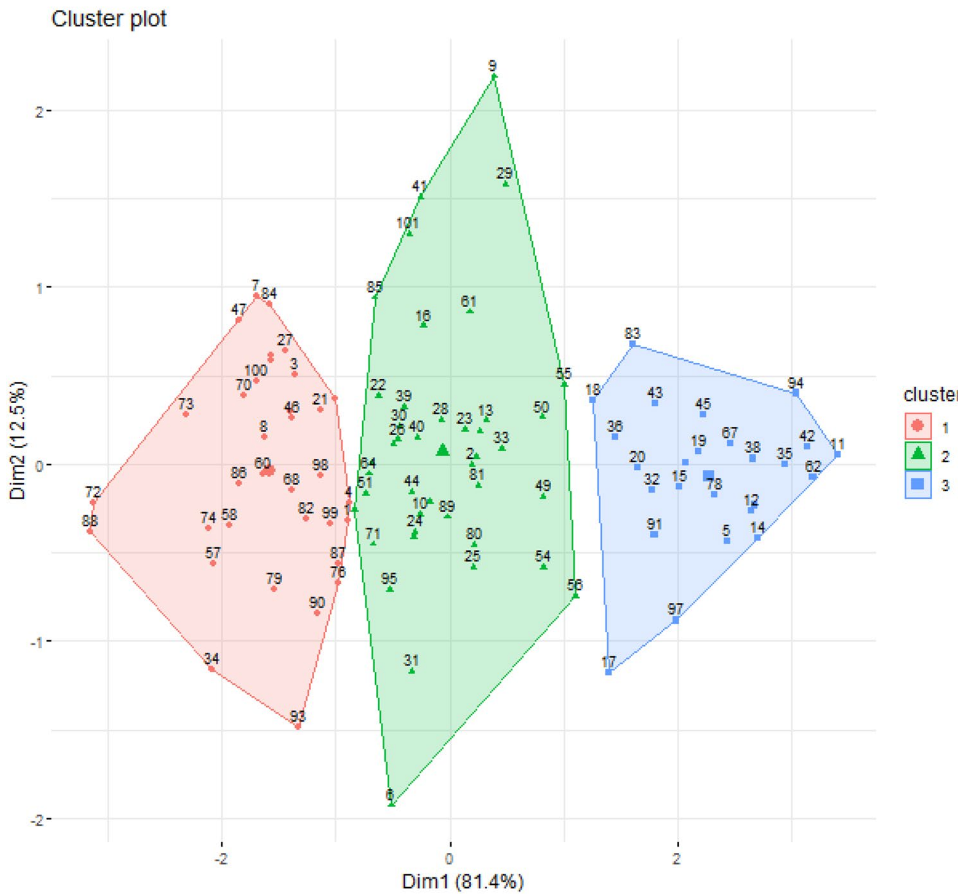

Fig. A6 Cluster solution obtained using k-means clustering with initial centroids derived from Ward's hierarchical method. The three clusters are clearly separated mainly along the first dimension (Dim1), which explains most of the variance (81.4%)

Appendix B

Euclidean distances between cluster centroids in factor score space indicated clear graded separation (C1–C2 = 1.53; C2–C3 = 2.38; C1–C3 = 3.87), supporting a three-cluster solution in which Enthusiasts were clearly distinct and Moderates occupied an intermediate position. The maximum centroid separation ($\Delta = 3.87$) closely approaches simulation-based thresholds ($\Delta \approx 4$) suggested as sufficient for reliable subgroup detection with approximately 20–30 observations per group (Dalmaijer et al 2022). Although separation between Sceptics and Moderates was smaller ($\Delta = 1.53$), the overall graded pattern of centroid distances suggests meaningful structure rather than random clustering, supporting the stability of the three-cluster solution. With three factors and within-cluster standard deviations ranging from 0.30 to 1.53 (typically around 0.8–1.2), inter-centroid distances of 1.53–3.87 are substantial. These distances are approximately 1.5 to 5 times larger than typical within-cluster variation, indicating clear seperation.

Appendix C

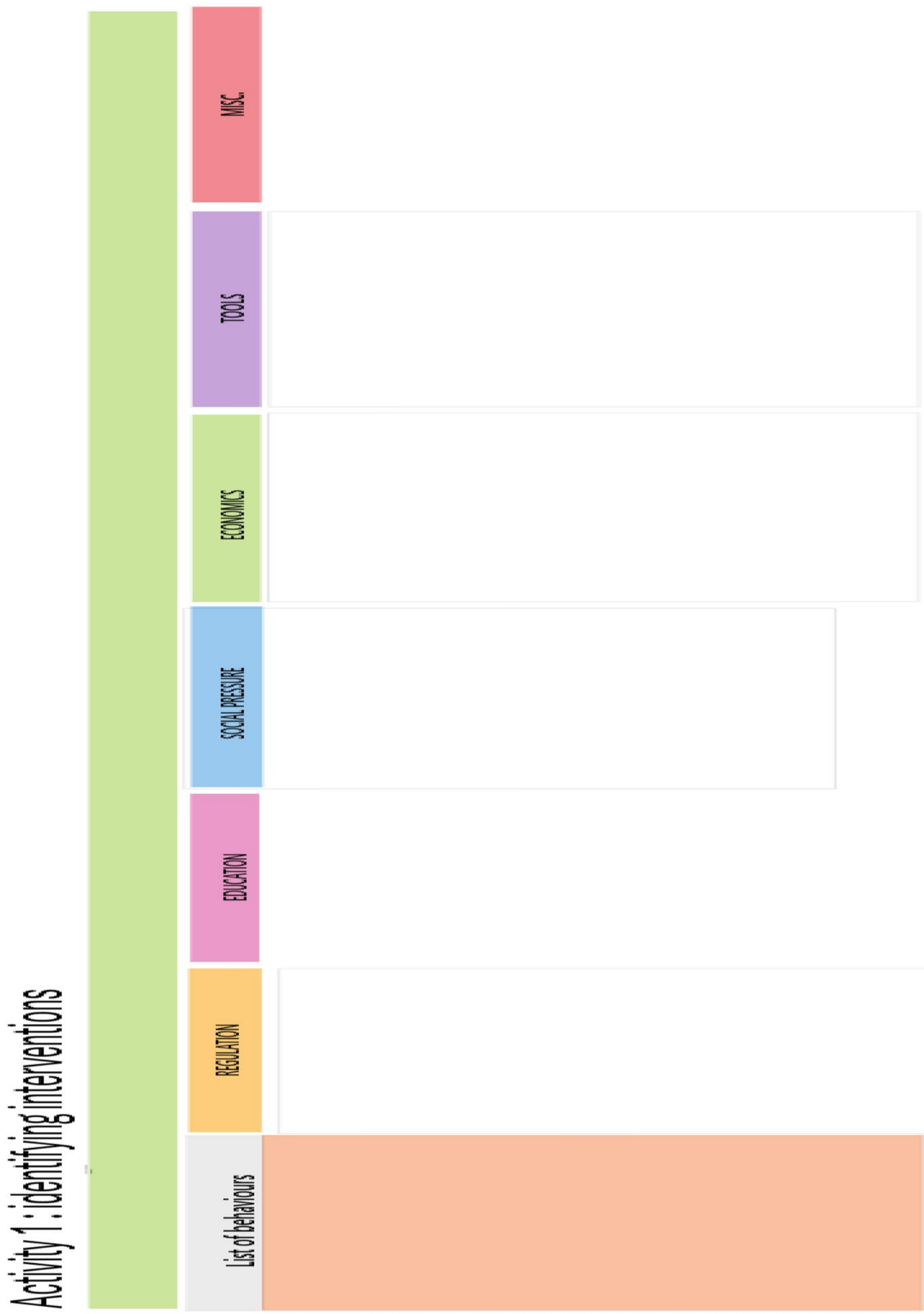

Fig. C1 Template used during the workshop, where participants listed key farmer behaviours and grouped proposed instruments into thematic categories

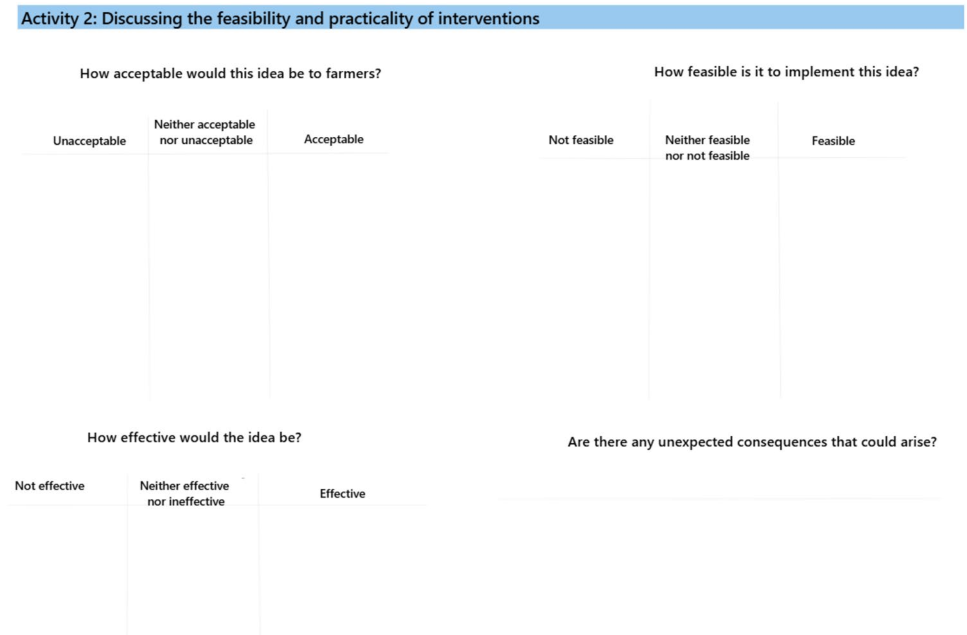

Fig. C2 Template used during the workshop to assess the feasibility, acceptability and effectiveness of proposed instruments

Abbreviations

RESET	Rules, Education, Social pressure, Economics, Tools
IPM	Integrated Pest Management
SUD	Sustainable Use of Pesticides Directive
CAP	Common Agriculture Policy
AECMs	Agri-Environment Climate Measures
KMO	Kaiser–Meyer–Olkin
AKIS	Agriculture Knowledge and Innovation Systems
COM-B	Capability, Opportunity, Motivation, and Behaviour
NAPAN	National Action Plan on Sustainable Pesticide Use
PFA	Polychoric Factor Analysis
FA	Factor Analysis
VAT	Value Added Tax
FACOPA	factors–perception of complexity–adoption
AKAIE	Awareness Knowledge Adoption Implementation Effectiveness

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40100-026-00489-4.

Supplementary material 1

Author contributions

AV conceptualized the study, conducted the formal analysis, investigation, visualization, and prepared the original draft of the manuscript. LT validated the results and contributed to funding acquisition, and review and editing. MT contributed to formal analysis and review and editing. EW contributed to the conceptualization, supervision, funding acquisition, and review and editing. GVDB contributed to the conceptualization, supervision, and review and editing. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The research was approved by the Committee for Ethics in Social Science and Humanities of the Flanders Research Institute of Agricultural, Fisheries and Food (ILVO). Ethical clearance number: ComESSH_2024_05

Declaration of generative AI and AI-assisted technologies in the writing process
During the preparation of this work the author(s) used ChatGPT-4 developed by Open AI in order to enhance the readability and check spelling and grammar. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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The authors declare no competing interests.

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