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ANALYSIS

Landscape features on farms: Evidence on factors influencing their quantity and ecological value

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ABSTRACT

Intensive agriculture and increasingly homogeneous agricultural landscapes are major drivers of biodiversity loss. The implementation of landscape features (e.g. hedges, trees, and field margins) as part of ecological focus areas on farms is a promising approach. This study aims to fill the gaps in understanding the influence of factors related to farmers' willingness and ability on their implementation of landscape features. We combine survey data on socio-psychological, economic, and sociodemographic factors collected in 2023 from 882 Swiss farmers with agricultural census data on registered landscape features and with biodiversity scores. Using regression analysis and various robustness checks, we estimate the influence of the above-mentioned factors on the farm area covered by landscape features and the ecological value of these features. Our findings indicate that both farmers' willingness (personal norms and self-efficacy to conserve biodiversity) and ability (biodiversity payments, education, and farm type) to preserve biodiversity affect the area of landscape features. The ecological value provided by landscape features is more influenced by farmers' ability than by their willingness. However, we also find that for landscape features that are not supported by biodiversity payments, farmers' willingness (i.e. personal norms) plays a decisive role, while ability is not important.

1. Introduction

Since the mid-twentieth century, the richness and diversity of biodiversity-enhancing landscape features[1] such as hedges, trees, ruderal areas, rock piles, ponds, and field margins have declined significantly (Guntern et al., 2020; Robinson and Sutherland, 2002; Czúcz et al., 2022). With the modernisation and intensification of agriculture, the landscape features of agricultural land have been steadily removed (Lanz et al., 2018; Guntern et al., 2020). Diversifying the composition and configuration of agricultural landscapes plays an essential role in providing the benefits of agrobiodiversity, such as resilience to climate change, improved nutrition, and improved livelihoods for smallholder farmers (Kahane et al., 2013). In this context, landscape features have traditionally been important components of agricultural landscapes and are closely linked to traditional agricultural management practices, which have historically modified existing features or actively created new ones (Poschlod and Braun-Reichert, 2017). The ongoing decline in landscape features contributes significantly to the loss of biodiversity in agricultural areas (Kleijn et al., 2011; Tscharntke et al., 2021).

The loss of biodiversity highlights the importance of taking a holistic approach to biodiversity conservation by considering the wider landscape diversity. This is particularly important for species that are functional for agriculture, such as bees and other pollinators (Meyer et al., 2017; Mendoza-García et al., 2018). The holistic approach is a central characteristic of the agroecological transition which aims at scaling up on-farm to off-farm agrobiodiversity improvements. According to Gliesmann (2016), the final level[2] of agroecological transition will be

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[1] In research and policy documents, the term landscape elements is used synonymously.

[2] Gliesmann (2016) proposes five levels of agroecological transition. While the first three levels relate to actions that farmers can take on the farm to converting from industrial agroecosystems, the other two levels go beyond the farm to the broader food system and the societies in which they are embedded. A more detailed description of the 10 elements of agroecology can be found in FAO (2018).

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achieved when the changes are global in scope and reach beyond the food system to the nature of human culture, civilization, progress, and development. At the policy level, agricultural policies in both the European Union (EU) and Switzerland aim to halt the decline landscape features (Lanz et al., 2018; Somoncini et al., 2019). Therefore, certain types of landscape features, such as hedgerows or field margins, can be declared Ecological Focus Areas (EFA) in the EU and Switzerland and are supported by direct payments. In addition, several key strategies and directives of EU environmental policy, such as the Biodiversity Strategy, the Water Framework Directive, and the Nitrates Directive, recognise the important role of landscape features in agricultural areas for the conservation of biodiversity (Czúcz et al., 2022). However, the implementation of landscape features on farms remains low despite these policy incentives, limiting their ability to enhance on-farm biodiversity.

Landscape features on agricultural land are often considered to conflict with short-term agricultural production because they cannot be used directly for agricultural production.[3] Rather, landscape features are long-term investments in pollination, and pest and disease control. This may be one of the barriers to farmers establishing or maintaining them (Raatz et al., 2019; Scheper et al., 2023). Therefore, understanding farmers' decisions to establish or maintain landscape features is key to developing effective policy programmes that enhance the area and the ecological value of landscape features.

The aim of this paper is to investigate what factors influence farmers' decisions to establish or maintain landscape features on their agricultural land. We are also interested in the key factors that encourage farmers to provide landscape features of high ecological value. To shed light on this issue, we draw on the existing literature and outline a conceptual framework that is then applied to empirical data from Switzerland. We combine data from a survey of farmers ($N = 882$) with data from the Swiss agricultural information system (AGIS) on the area of landscape features registered as part of EFAs and life cycle assessment data to calculate their ecological value. Using regression analysis, we estimate the influence of a broad range of factors, including socio-psychological factors, economic factors (i.e. agri-environmental payments), and farm and farmer characteristics, on (i) the area covered by landscape features and (ii) the ecological value of this area. To account for heterogeneity among different landscape features, we also analyse whether the influencing factors are different for landscape features that are eligible for biodiversity payments compared to those that are not. In addition, we performed a series of robustness checks to test the reliability of our regression results.

Previous socioeconomic research on landscape features is scarce. The few existing studies have investigated the relationship between landscape features and management practices (Schmitzberger et al., 2005) and farmers' perceptions of landscape features (Busck, 2002; Włodarczyk-Marciniak et al., 2020). By contrast, there is a large body of literature that focuses more broadly on the adoption of agri-environmental schemes (AESs) and environmentally friendly production systems (e.g. Mack et al., 2020; Malek et al., 2019; Mann, 2018; Schaub et al., 2023; Scheper et al., 2023; Uthes and Matzdorf, 2013; Zimmermann and Britz, 2016). Recent reviews of this broader body of literature have highlighted that farmers' environmental decision-making is multifaceted and driven by a wide range of factors (Dessart et al., 2019; Thompson et al., 2024). Furthermore, the results provided for different production systems, AESs, or social and environmental contexts are difficult to generalise beyond their contexts (Knowler and Bradshaw, 2007). In particular, insights from the literature on AES and environmentally friendly production systems are not directly generalisable to the adoption of landscape features, because the latter rarely produce agricultural outputs (i.e., products resulting from agricultural activities). This may impose additional or different barriers to adoption. Overall, there is also a lack of information on the enablers and barriers for farmers to establish or maintain landscape features for biodiversity conservation.

This study contributes to the literature on farmer decision-making regarding EFAs by focusing on landscape features. It brings together two streams of literature—farmers' perceptions of landscape features and farmers' adoption of biodiversity-enhancing practices—by linking an array of socio-psychological and economic factors to farmers' adoption decisions. It aims to fill the research gap by (i) identifying factors that influence farmers' decisions to create or maintain landscape features and (ii) comparing factors that influence the quantity (i.e. the area covered by landscape features) with factors that influence the quality (i.e. the ecological value) of landscape features.

The remainder of the paper is structured as follows. In Section 2, we describe the biodiversity-enhancing landscape features that we focus on in this study and how they are embedded in the Swiss direct payment system. In Section 3, we present the conceptual framework of the study, and in Section 4, we describe the data and methods used. We present the results in Section 5 and discuss them in Section 6. Section 7 reports limitations and Section 8 offers our conclusions and the policy implications of our findings to highlight the interplay between farmers' willingness and ability to implement landscape features.

2. Background: Importance of landscape features and policy measures that promote them in Switzerland

Landscape features are often biodiversity hotspots within and between crops in cleared agricultural landscapes (Dormann et al., 2007; Guntern et al., 2020; Jeanneret et al., 2014, 2021). They can be described as punctual, linear, or flat landscape elements of different sizes, materials, and structures that mostly do not contribute directly to agricultural production (Guntern et al., 2020). Typically located at the edge of cultivated plots, landscape features provide habitats as well as stepping stones and corridors that connect species populations. They also provide breeding and nesting sites, foraging areas, perching and hunting grounds, warming areas, and hiding places and retreats as protection from predators or disturbances from agricultural activities (Guntern et al., 2020). In addition, landscape features often enhance the ecological value of other biodiversity-enhancing, low-intensity production systems (i.e. non-landscape features). For example, extensive meadows and pastures can only provide a habitat for amphibian and reptile species if they are combined with landscape features such as ruderal areas, rock piles, and ponds (Guntern et al., 2020).

To integrate biodiversity conservation into agriculture, agricultural policies in the EU and Switzerland incentivise farmers to provide environmental public goods through direct payments (e.g. Hasler et al., 2022; Uthes and Matzdorf, 2013). For over 30 years in Switzerland, the AES for biodiversity conservation has included various measures to promote landscape features, such as hedges and trees on agricultural land (Mack et al., 2020). Farms are eligible for biodiversity payments if they meet the relevant requirements (FOAG (Federal Office for Agriculture), 2025). Furthermore, a cross-compliance scheme introduced in 1999 required farmers to enrol at least 7 % (3.5 % for special crops) of their total agricultural land in EFAs to be eligible for any direct payments.

Since 2022, 10 types of small-scale landscape features in the utilised agricultural area (UAA) have been supported by AESs (Table 1). These features can also be declared EFAs and qualify for the required minimum EFA area of 7 %.[4] Based on their eligibility for biodiversity payments, the features can be divided into two groups. The first group of landscape features is directly supported by biodiversity payments. They are eligible for action- and result-based payments, as well as agglomeration payments. The second group is only indirectly supported. These features

[3] The exception are high trunked fruit trees that produce fruit and nut trees, as well as sweet chestnut trees.

[4] Trees count as 0.1 ha towards the minimum EFA area.

Table 1
Overview of landscape features covered by AESs and illustrative pictures.

Landscape features	Group 1: Eligible for biodiversity payments and count towards the minimum EFA	Group 2: Not eligible for payments but qualify for the minimum EFA	Illustrative picture
Field margins on arable land	✓		 © Agroscope, Gabriela Brändle
Litter meadow	✓		 © Fiona Marty
Hedges, fields, and riparian shrubs	✓		 © Agroscope, Carole Parodi
Hedges, fields, and riparian shrubs with buffer strips[1]	✓	✓	
High-trunked fruit trees	✓		 ©Agroscope, Gabriela Brändle
Nut trees	✓		 ©Agroscope, Alain Bütler
Sweet chestnut trees	✓		 © Agroscope, Sonja Kay
Site-specific single trees and avenues	✓		 © Agroscope, Gabriela Brändle
Distinctive individual trees		✓	
Other trees[1]	✓	✓	

Note: From the wide range of biodiversity-enhancing landscape elements registered as EFAs in Switzerland, we selected those that were considered to meet the requirement of being a small-scale feature and excluded large-scale EFAs such as extensive meadows and wooded pastures.

[1] The regional authorities determine specifically for their region the group to which hedges, fields, and riparian shrubs with buffer strips and other trees belong.

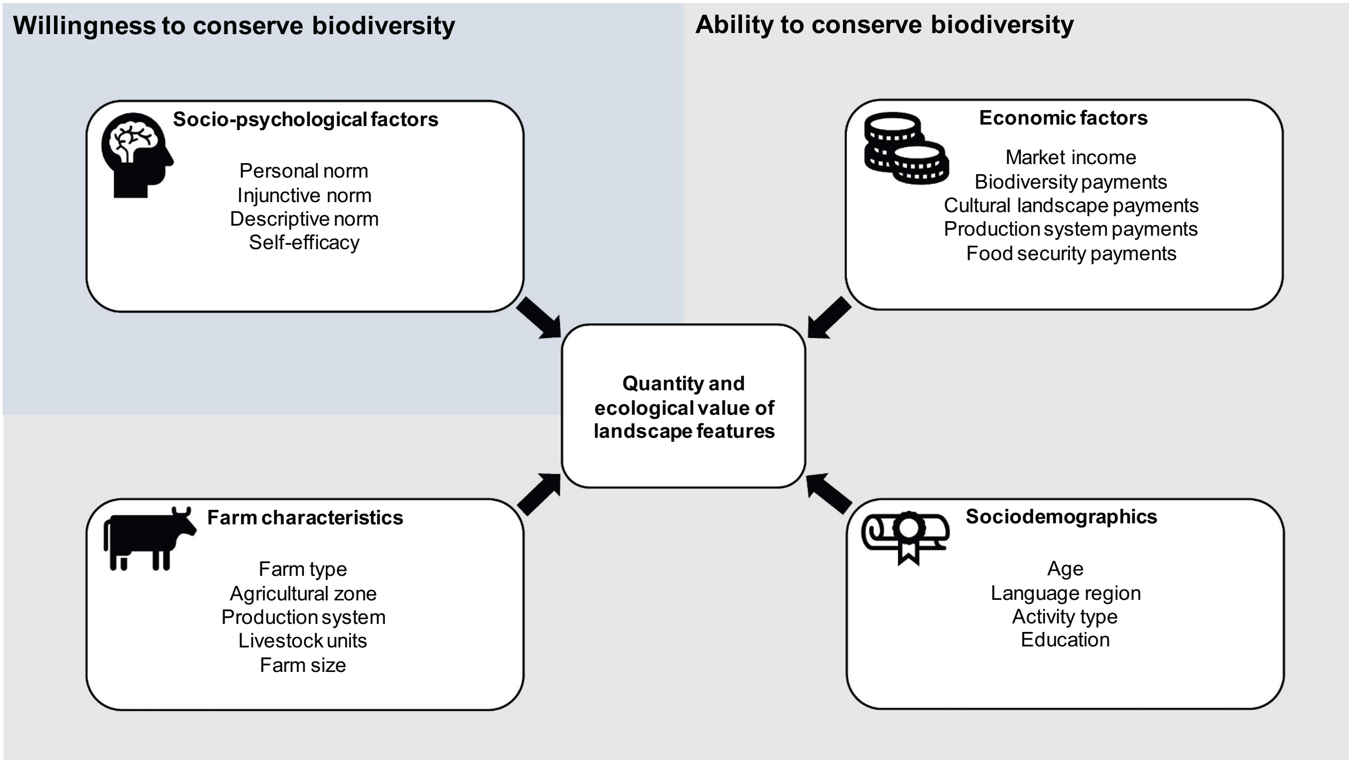

Fig. 1. Framework for analysing the factors affecting farmers' implementation of on-farm landscape features.

qualify for the required minimum EFA of 7 % but do not receive biodiversity payments. The payments for landscape features are defined in the Federal Ordinance on Direct Payments in Agriculture (FOAG (Federal Office for Agriculture), 2025). Farmers receive payments per hectare (e.g. for field margins on arable land) or per tree (e.g. high-trunked fruit trees). Biodiversity payments reflect the costs of providing the public good of biodiversity conservation including the forgone income (Opdenbosch et al., 2024). Some landscape features yield agricultural products, such as fruits from high-trunked fruit trees, while others do not, such as field margins on arable land. The latter, however, provide an important habitat for pollinators, for example.

3. Conceptual framework of factors influencing farmers' decisions to implement landscape features

Farmers' decisions to implement landscape features, like other environmental decisions, are complex and influenced by a variety of factors (Dessart et al., 2019; Thompson et al., 2024). Research on AES adoption has revealed that farmers' willingness to adopt (manifested in farmers' attitudes, beliefs, values, and norms) and their ability to adopt (co-determined, e.g. by the farm's economic status, the compatibility of the farming system with AES, and farmers' education)[5] are important (Mills et al., 2017). Fig. 1 presents the conceptual framework used in this paper. It builds on the existing literature on farmers' environmental management decisions, which is also relevant for farmers' decisions on landscape features and includes a range of different factors. These are grouped into the following four main categories: (1) socio-psychological factors, (2) economic factors, (3) farm characteristics, and (4) socio-demographic characteristics of farmers. Socio-psychological factors reflect the willingness to adopt, while economic factors and farm and farmer characteristics reflect the ability to adopt. These four categories can be located at different 'distances' from the decision to establish or maintain landscape features. Socio-psychological and a few economic factors can be assessed specifically in relation to biodiversity conservation, whereas farm and farmer characteristics are generic factors. Therefore, these generic factors are considered relatively distant from the specific decision-making situation (Dessart et al., 2019). By considering a variety of factors related to farmers' willingness and ability to conserve biodiversity, we are able to systematically disentangle the complexity of decisions in implementing landscape features. We can describe the complexity of decisions in implementing landscape features as a utility maximizing problem as follows:

$$\max_{L_i} E[U(\pi_i(L_i, A_i, u_i), W_i)] \quad (1)$$

Where subscript i depicts the farmer. U is the von-Neumann-Morgenstern utility function of the farmer and $W_i$denotes factors on farmers' willingness to conserve biodiversity (i.e., the socio-psychological factors), which does not influence profit but influences utility. Let $\pi_i(L_i, A_i, u_i)$ represent the random profit of farmer i,where L_i depicts the amount of landscape features and A_i the factors on farmers' ability to conserve biodiversity (i.e., economic factors, socio-demographic characteristics, and farm characteristics), both of which influence farmers' utility via the profit function. u_i denotes uncertainty related to profit.

3.1. Socio-psychological factors

Socio-psychological factors include, for example, risk aversion, personal attitudes, beliefs, values, and norms. Norms are important in specific situations and can, therefore, be assessed close to the decision behaviour in question (Kaiser et al., 1999). Thus, they are considered to have a higher explanatory power than, for example, universal values, such as altruism or hedonism. In this study, we consider three different types of norms: (i) personal norms, (ii) injunctive norms, and (iii) descriptive norms.

[5] This interplay has also been described as one of individual and structural factors (Kaiser and Burger, 2022; Kaiser et al., 2024) or internal and external factors (Klebl et al., 2023).

Personal norms reflect an individual's intrinsic motivation (Calabuig et al., 2014), and thus describe a sense of moral obligation to do the right thing (Schwartz and Howard, 1981; Klöckner and Blöbaum, 2010). Studies reveal that organic farmers are much more concerned about doing 'the right thing'. They have stronger personal norms regarding environmentally friendly farming than conventional farmers (Mzoughi, 2011). In Switzerland, Kaiser et al. (2024) found that farmers have strong personal norms to reduce pesticide use.

Injunctive norms are defined as a person's perception of social pressure to act in a certain way (Klöckner and Blöbaum, 2010). Previous research has revealed that related conventions and expectations are important in agriculture (Burton, 2004a, 2004b) and influence farmers' decisions (Dessart et al., 2019; Kaiser et al., 2024; Kuhfuss et al., 2016).

Descriptive norms refer to the behaviour that an individual observes or attributes to peers. The effect of farmers being influenced by the behaviour of neighbouring farmers is well documented in the literature. For example, farmers with little experience with AES in the neighbourhood are less likely to adopt these schemes (Defrancesco et al., 2008; Läpple and van Rensburg, 2011; Vanslembrouck et al., 2002). However, these farmers could be positively influenced to apply conservation tillage, for example, if they know that other farmers in the area apply the scheme (D'Emden et al., 2008).

Schwartz (1973) argued that personal norms are internalized social norms that can be triggered by social norm interventions. Such interventions comprise, for example, the provision of information to farmers about the quantity and quality of landscape features implemented by other farmers and information about the extent to which society approves the implementation of landscape features (Howley and Ocean, 2021; Van Valkengoed et al., 2022). Therefore, we expect that the interplay between farmers' personal and social norms regarding biodiversity conservation to influence their decisions to implement landscape features.

We also include self-efficacy in our conceptual framework. Self-efficacy refers to a person's perception of the ease or difficulty of performing certain tasks (Bandura, 1977). Previous research suggests that organic farmers who rated their environmental knowledge as higher had more plant species on their farms than farmers with lower ratings (Power et al., 2013). Furthermore, farmers' self-efficacy drives their intention to adopt voluntary AES (van Dijk et al., 2016). Thus, we expect farmers' beliefs of knowing how to conserve biodiversity on their farms and being able to find solutions to potential difficulties to increase their implementation and maintenance of landscape features.

3.2. Economic factors

Economic motives are well documented in the literature as factors underlying farmers' decisions. First, market income (farm sales) is the main source of income for the majority of farms in Switzerland (Jan et al., 2023). Second, direct payments are crucial in encouraging agri-environmental decisions (Ingram et al., 2013; Lastra-Bravo et al., 2015; Pavlis et al., 2016). For example, Switzerland (and the EU) provides biodiversity payments for EFAs, to support the establishment or maintenance of landscape features. However, the EU and Switzerland also provide direct payments mainly for productive agricultural land to support food security. Therefore, these payments may provide an incentive for farmers to eliminate landscape features and increase food production. Furthermore, payments that support a reduction in the production intensity of productive land may also have a negative impact on landscape features, while payments for both the productive area and EFAs may not influence the establishment or maintenance of landscape features. Therefore, we identify the importance of four direct payments for farmers' incomes as relevant to their decision to establish or maintain landscape features. The first is biodiversity payments, which only support EFAs, including landscape features. Second, cultural landscape payments (i.e. payments for maintaining an open cultural landscape) support both the productive agricultural land and EFAs. Third, production system payments provide financial incentives to reduce the production intensity of the productive land (e.g. pesticide-free cropping systems; see Mack et al., 2023) and incentives for animal-friendly production systems. Fourth, there are food security payments that mainly support the productive land[6] to maintain a secure food supply for the population and are largely paid as a lump sum per cultivated hectare, without ecological requirements above the cross-compliance standards (see Möhring and Mann, 2020; FOAG (Federal Office for Agriculture), 2023a).

3.3. Farm characteristics

Farm characteristics that are among the general determinants of farmers' decisions are farm type, agricultural zone, production system (i.e. organic and non-organic), and farm size. Research has uncovered, for example, that biodiversity management on farms is strongly influenced by farm type (Mack et al., 2020), farm size, and agricultural zone (Mack et al., 2020; Zimmermann and Britz, 2016). Therefore, we expect that farmers' decisions to implement landscape features may be influenced by the above-mentioned farm characteristics.

3.4. Farmers' sociodemographic characteristics

The influence of sociodemographic characteristics is often considered in research on environmentally relevant farmer behaviour. With regard to the implementation of EFAs, the type of farm activity (i.e. full- and part-time farming), the farmers' age, and their educational level play a particularly important role (Calvet et al., 2019; Granado-Díaz et al., 2022; Karali et al., 2014; Mack et al., 2020). Furthermore, cultural differences, as reflected by different language regions within Switzerland, have been shown to influence farmers' biodiversity conservation behaviour (Wang et al., 2023). Therefore, we account for the potential influence of these two factors in our analysis.

4. Data and methods

Our analysis draws on three sources of data. First, in a 2023 survey, we collected data from 882 Swiss farmers on their willingness to adopt landscape features based on socio-psychological aspects, the importance of direct payments and market income for their total farm income, and sociodemographic characteristics. Second, we combined the survey data with agricultural census data on registered landscape features and other farm characteristics. Third, we added the ecological value, measured as biodiversity scores for the landscape features (aggregated for 11 indicator species groups), using the life cycle assessment tool SALCA-BD (for further description, see Jeanneret et al., 2014). To understand how different factors influence the quantity and ecological value of landscape features, we performed a regression analysis. The data and methods used are described in detail in the subsections below.

4.1. Survey design and sample

A survey of 2000 farmers was conducted between June 2023 and August 2023 in the German- and French-speaking parts of Switzerland. Farmers' contact details for the sample (stratified by agricultural zone and farm type) were provided by the Federal Office for Agriculture (FOAG). The FOAG maintains a database of all agricultural households that receive direct payments (42,125 in 2022 in the AGIS records). Farmers were sent a paper-and-pencil survey by post as well as a link to an online version of the survey programmed in the survey tool Tivian. The survey was available in French and German. The 2022 AGIS data on

[6] Food security payments provide payments for the productive area and a lower payment level for the EFA. Currently, the level of food security payments for EFAs is half of the rate for the productive area (FOAG, 2023a).

farm structure and landscape features registered as part of the EFA were linked to the survey data at the individual farm level.

The survey response rate was 44 % ($N = 882$). Our final sample is representative of the total Swiss farm population in 2022 (excluding the Italian-speaking part of the country) in terms of agricultural zone, farm type, production system (organic vs. non-organic), farm size, and activity type (full- vs. part-time farming). However, the following caveats apply: farmers from the valley zone (total population: 42.6 %, survey sample: 46.3 %), farm types of arable farming (total population: 5.9 %, survey sample: 7.0 %) and suckler cows (total population: 9.7 %, survey sample: 11 %), and organic farms (total population: 16.2 %, survey sample: 21.4 %) are slightly overrepresented. The farms in our sample are also slightly larger in terms of hectare UAA (total population: 21.6 ha, survey sample: 23.2 ha) and have fewer livestock units (LU) (total population: 29.0 LU; survey sample: 26.0) LU. There is a slightly higher number of full-time farms in the sample than in the farm population farms (total population: 71.0 %; survey sample: 75.7 %).

4.2. Description of variables

4.2.1. Dependent variables

For the empirical analysis, we used the following two dependent variables (Y):

$$\textit{Total area landscape features}\ (Y_{1i}) = \sum \textit{Area landscape features}_{ij}. \tag{2}$$

$$\textit{Ecological value landscape features}\ (Y_{2i}) = \left(\sum \textit{BD scores landscape features}_{j} \times \textit{Area landscape features}_{ij}\right) \Big/ \textit{Utilized agricultural area}_{i}. \tag{3}$$

To measure the quantity of landscape features, we calculated the first dependent variable Y_{1i} by summing up the area of all different landscape features j (in ha[7]) of farm i (hereafter referred to as the area of landscape features). To measure the ecological value (i.e. quality) of the landscape features, the dependent variable Y_{2i} was calculated according to Nishizawa et al. (2022) by weighting the sum of the registered landscape features j and biodiversity (BD) scores of farm i by the sum of the area of the registered landscape features of farm i divided by the total utilised agricultural area of farm i (hereafter referred to as the ecological value of landscape features). The SALCA-BD score can be considered a proxy for the ecological value of landscape features in Swiss agriculture (Jeanneret et al., 2014) (see Table 2). The summary statistics of the two dependent variables[8] are presented in Table 3.

4.2.2. Independent variables

Based on our conceptual framework, we grouped the independent variables into four main categories (see Fig. 1): (1) socio-psychological factors, (2) economic factors, (3) farm characteristics, and (4) sociodemographic characteristics. First, data on socio-psychological variables were collected in the survey and measured with norm items based on Cialdini et al. (1990) and self-efficacy items based on Bandura (1977), both on a seven-point Likert scale. Second, to collect economic variables, we asked farmers how important different income sources (i.e. market income and different categories of direct payments) are for their total farm income. Farmers rated these income sources on a seven-point Likert scale (*1 = Not important at all, 7 = Very important*). Third, the variables reflecting farm characteristics are farm type, agricultural zone, production system, and farm size, which were provided by the census data. The nominal scaled variable farm type has 11 levels, according to the official classification (see Renner et al., 2019). The variable agricultural zone takes one of six values based on the official classification of agricultural land into zones in Switzerland (FOAG (Federal Office for Agriculture), 2020). The production system is measured with a binary variable that reflects either organic production or non-organic production. Farm size was measured using two continuously scaled indicators: the UAA in hectares (as a control variable for the dependent variable Y_1 since this is not a weighted area) and livestock units. The farm's activity type was measured with a binary variable reflecting full- and part-time farming. Finally, we considered the sociodemographic characteristics of farmer age (continuous scale), education level, and language region. Table 3 presents descriptions of the independent variables, survey items, and summary statistics.

Table 2
Overview of the biodiversity scores attached to the landscape features aggregated for the analysis.

Landscape features	Biodiversity score
Field margin on arable land	18.50
Litter meadow	25.78
Hedges, fields, and riparian shrubs	25.01
High-trunked fruit trees, nut trees, sweet chestnut trees, site-specific single trees and avenues, distinctive individual trees, and other trees	11.44

Note: The biodiversity scores range from 0 (high impact of agricultural management on 11 indicator species groups) to 50 (low impact of agricultural management), with 50 representing an optimal situation for biodiversity. Additional information on the scores is provided in Appendix A, and a detailed description can be found in Jeanneret et al. (2014) and Nishizawa et al. (2022).

4.3. Regression analysis

4.3.1. Model specification

To identify factors that have a statistically significant effect on the quantity (i.e., area) and quality (i.e. ecological value) of landscape features on farms, we employed regression analysis. With regard to our conceptual framework, we included socio-psychological variables (X_1), economic factors (X_2), farm characteristics (X_3), and farmers' sociodemographic characteristics (X_4) as independent variables in our model.[9] Accordingly, our regression model can be formalised in the

[7] Each tree is counted as 0.01 ha.

[8] Note that while the two dependent variables strongly correlate ($r = 0.689$), they are assumed to measure two different aspects—that is, a quantitative indicator (Y_1) and a qualitative indicator (Y_2) of biodiversity. Alternatively, we could have considered the share of area landscape features in the total utilised agricultural area as Y_1. In this case, however, the correlation with Y_2 (ecological value of landscape features) is $r = 0.927$.

[9] We control for many factors that, according to our conceptual framework, influence the decision to implement landscape features (see Fig. 1). Accordingly, we believe that endogeneity is not an issue in our case. Nevertheless, we acknowledge there could be other sources of endogeneity. However, our aim was not to estimate a causal effect, where omitted variables cause endogeneity and thus a biased estimate of the causal effect of x on y. Moreover, self-selection of farmers with a strong preference for biodiversity conservation into our sample is also not an issue, since our sample represents the total population with respect to agricultural zone, farm type and utilised agricultural area well (see Fig. A1 in Appendix A).

Table 3
Description and summary statistics of variables used in the analysis.

Variable name	Description/survey item	Unit (measurement scale)	Mean/ frequency	SD	N
Dependent variables					
Area of landscape features	Sum of UAA covered with landscape features	Hectares (continuous)	1.03	1.67	882
Ecological value of landscape features	Area weighted sum of the BD scores of the landscape features	Scores (continuous)	0.79	0.98	882
Independent variables					
Socio-psychological factors		(Likert scale)			
Personal norm	'I think it is important to take measures to promote biodiversity on my farm'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	4.84	1.76	870
Injunctive norm—family	'My family members expect me to take measures to promote biodiversity on my farm'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	3.50	1.96	869
Injunctive norm —acquaintances	'Most of my acquaintances expect me to take measures to promote biodiversity on my farm'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	3.38	1.81	867
Descriptive norm—other farmers	'Most of the farmers I personally know take measures to promote biodiversity on their farms'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	4.41	1.66	868
Self-efficacy—personal skills	'I possess the necessary skills and knowledge to enhance biodiversity on my farm'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	5.24	1.45	869
Self-efficacy—damage prevention	'I am confident that I can prevent damage to biodiversity caused by agricultural production'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	5.35	1.47	863
Self-efficacy—overcoming difficulties	'If difficulties arise when implementing measures to enhance biodiversity, I usually find a solution'.	From *1* = *Does not apply at all* to *7* = *Fully applies*	5.29	1.58	862
Economic factors	'Please indicate how important the different sources of income are for your farm's total income'.	(Likert scale)			
Importance of market income	Income from farm sales	From *1* = *Not important at all* to *7* = *Very important*	5.90	1.52	861
Importance of biodiversity payments	Payments for EFA	From *1* = *Not important at all* to *7* = *Very important*	5.06	1.87	867
Importance of cultural landscape payments	Payments for both EFA and productive areas (non-EFA)	From *1* = *Not important at all* to *7* = *Very important*	4.94	1.95	857
Importance of production system payments	Payments for less intensive productive areas and animal welfare	From *1* = *Not important at all* to *7* = *Very important*	5.46	1.73	865
Importance of food security payments	Payments for mainly productive areas	From *1* = *Not important at all* to *7* = *Very important*	5.71	1.58	862
Farm characteristics					
Farm type		(Nominal scale)			882
1 = Arable farming		Share in %	7.03		
2 = Special cultures		Share in %	7.37		
3 = Dairy cows		Share in %	25.17		
4 = Suckler cows		Share in %	11.00		
5 = Cattle mixed		Share in %	7.94		
6 = Horses/sheep/goats		Share in %	5.44		
7 = Processing		Share in %	1.59		
8 = Combined dairy cows/arable farming		Share in %	4.20		
9 = Combined suckler cows		Share in %	4.54		
10 = Combined processing		Share in %	9.86		
11 = Combined others		Share in %	15.87		
Agricultural zone		(Nominal scale)			882
1 = Valley		Share in %	46.26		
2 = Hill		Share in %	14.51		
3 = Mountain I		Share in %	12.24		
4 = Mountain II		Share in %	26.33		
5 = Mountain III		Share in %	6.80		
6 = Mountain IV		Share in %	3.85		
Production system	1 = Organic, 0 = non-organic	Share in % organic (binary)	21.4		882
Utilised agricultural area		Hectare (continuous)	23.2	15.1	882
Livestock units		Reference unit for livestock[a] (continuous)	26.0	24.9	882
Sociodemographic characteristics					
Activity type	1 = Full time, 0 = part time farming	Share in % full time farming	75.7		875
Farmer age		Years (continuous)	49.97	10.05	882
Education level		(Nominal scale)			842
1 = Practical experience		Share in %	5.82		
2 = Federal vocational certificate (EBA)		Share in %	4.63		
3 = Federal certificate of competence (EFZ)		Share in %	46.08		
4 = Professional examination		Share in %	12.35		
5 = Master's examination		Share in %	21.73		
6 = Higher college		Share in %	4.63		
7 = Bachelor's degree/master's degree or higher		Share in %	4.75		
8 = Other education		Share in %			
Language region	1 = German, 0 = French	Share in % German (binary)	83.67		

[a] The reference unit for the calculation of livestock units (= 1 LU) is the feed requirement (pasture equivalent) of an adult dairy cow with an annual milk yield of 3000 kg without the addition of concentrated feed (Eurostat, 2021).

Table 4
Results of the three-step test for selecting the appropriate estimation technique.

Dependent variable	Overdispersion	Pearson goodness-of-fit test	LR test overdispersion parameter alpha	Choice of estimation technique
Y_1 (Area of landscape features)	Yes	$p = 0.951$	$p = 0.000$	Negative binomial regression
Y_2 (Ecological value of landscape features)	No	$p = 0.996$	$p = 0.499$	Poisson regression

following manner:

$$Y_i = \beta_0 + \delta X_{1i} + \lambda X_{2i} + \zeta X_{3i} + \theta X_{4i} + \varepsilon_i, \quad (4)$$

where Y denotes the dependent variable on farm level i. Eq. (4) was separately estimated for Y_1 (area of landscape features) and Y_2 (ecological value of landscape features). β_0 represents the intercept δ, λ, ζ, and θ each comprised a set of individual coefficients β. For block X_1, we obtained seven coefficients ($\beta_1 \ldots \beta_7$), for block X_2 five coefficients ($\beta_8 \ldots \beta_{12}$), for block X_3 six coefficients ($\beta_{13}, \ldots \beta_{18}$), and for block X_4 four coefficients ($\beta_{19}, \ldots \beta_{22}$). ε represents the error term for the unobserved characteristics of farm i.

4.3.2. Choice of estimation technique

The dependent variables Y_1 (area of landscape features) and Y_2 (ecological value of landscape features) have zero values, and the distributions are right-skewed (see Fig. B1 in Appendix B). Accordingly, for both dependent variables, ordinary least squares regression was not appropriate. In this case, the literature suggests using a Poisson or negative binomial model (Cameron and Trivedi, 2014). To select the appropriate estimation technique, we conducted the three-step test suggested by Ritzel and Mann (2021) for the two dependent variables:

- First, we tested whether a Poisson distribution was appropriate. The Poisson distribution would be appropriate in the absence of any signs of overdispersion (i.e. the mean and variance are the same).
- Second, we estimated a Poisson regression and conducted the Pearson goodness-of-fit test. A significant test statistic ($p < 0.1$) indicates that Poisson regression is the inappropriate estimation technique.
- Third, we ran a negative binomial regression. The LR test was performed to check whether the overdispersion parameter alpha was equal to zero. A significant test statistic ($p < 0.1$) indicates that a Poisson distribution is inappropriate and, therefore, a negative binomial regression should be applied.

The results of the three-step test for selecting the appropriate estimation technique are summarised in Table 4.

For Y_1 (mean = 1.0; variance = 2.8), we detected signs of overdispersion, whereas for Y_2 (mean = 0.8; variance = 1.0), we did not find overdispersion to be an issue. Even though in the case of Y_1, the Pearson goodness-of-fit test indicated that Poisson regression was the appropriate estimation technique, the LR test of the overdispersion parameter alpha revealed that the Poisson distribution was inappropriate. Therefore, we selected a negative binomial regression for Y_1. For Y_2, the two diagnostic tests revealed that the Poisson distribution was appropriate; accordingly, we selected Poisson regression for Y_2. By default, we report heteroskedasticity-robust standard errors for the full model (White, 1980).

Furthermore, to test for multicollinearity among the independent variables, we used the variance inflation factor and the collinearity diagnostics procedure developed by Hendrickx (2004). Both diagnostic tests for collinearity were applied to the full model that included four

Table 5
Results (average marginal effects) of the regression analysis for the dependent variable 'area of landscape features'.

Independent variables	Average marginal effects	Standard error
Socio-psychological factors (X_1)		
Personal norms	0.065**	0.026
Injunctive norm—family	0.046	0.028
Injunctive norm—acquaintances	−0.021	0.031
Descriptive norm—other farmers	−0.009	0.029
Self-efficacy—personal skills	0.084**	0.036
Self-efficacy—damage prevention	0.055*	0.031
Self-efficacy—overcoming difficulties	−0.008	0.032
Economic factors (X_2)		
Importance of market income	−0.029	0.029
Importance of biodiversity payments	0.149***	0.031
Importance of cultural landscape payments	−0.057**	0.027
Importance of production system payments	−0.132***	0.042
Importance of food security payments	0.008	0.032
Farm characteristics (X_3)		
Farm type (Reference: Arable farming)		
Special cultures	−0.038	0.166
Dairy cows	0.865***	0.209
Suckler cows	1.198***	0.378
Cattle mixed	0.484**	0.190
Horses/sheep/goats	0.577**	0.232
Processing	0.612**	0.252
Combined dairy cows/arable farming	0.130	0.147
Combined suckler cows	0.291*	0.168
Combined processing	0.263	0.177
Combined others	0.397***	0.143
Agricultural zone (Reference: Valley)		
Hill	−0.082	0.129
Mountain I	−0.351**	0.155
Mountain II	−0.642***	0.139
Mountain III	−0.773***	0.166
Mountain IV	−1.062***	0.158
Production system (1 = organic; 0 = non-organic)	0.190*	0.108
Utilised agricultural area	0.020***	0.004
Livestock units	0.001	0.002
Sociodemographic characteristics (X_4)		
Activity (1 = full time; 0 = part time)	0.276***	0.085
Farm manager age	0.002	0.004
Education (Reference: Practical experience)		
Federal vocational certificate	0.766**	0.347
Federal certificate of competence	0.384**	0.186
Professional examination	0.261	0.205
Master's examination	0.308	0.188
Higher college	0.145	0.206
Bachelor's degree/Master's degree, or higher	0.078	0.196
Other	0.268	0.274
Language region (1 = German; 0 = French)	0.084	0.125
Number of observations	815	

***, **, and * denote significance at 1 %, 5 %, and 10 % respectively. Standard errors are computed based on the delta method.

blocks of independent variables. For all independent variables, the variance inflation factor was below the recommended level of 10 (Chatterjee and Hadi, 2012), and the condition index computed by the collinearity diagnostic procedure was below the recommended level of 30 (Belsley et al., 1980). Consequently, multicollinearity was not an issue.

4.3.3. Robustness checks

To obtain reliable results, we performed a series of robustness checks based on Eq. (3).

First, we estimated four variants of Eq. (4). This means that we considered the four blocks of independent variables X_1 (socio-psychological factors), X_2 (economic factors), X_3 (farm characteristics), and X_4 (sociodemographic characteristics) individually. Accordingly, this robustness check tests whether the signs and significance levels of the coefficients remain consistent with those obtained from the full model (i.e. considering all four blocks of independent variables).

Second, we checked the robustness of our results by using different standard errors for the full model. As suggested by Abadie et al. (2023), we report cluster-robust standard errors, with clustering based on the geographic units of the canton and municipality. Additionally, we report bootstrapped standard errors (Guan, 2003). Accordingly, this robustness check tests whether the significance levels of the estimates remain consistent with those obtained from the full model with heteroskedasticity-robust standard errors.

Third, we accounted for the heterogeneity of the landscape features and analysed whether the drivers are different for landscape features that are eligible for biodiversity payments compared to those that are not. Therefore, we grouped them according to whether they were eligible for biodiversity payments or ineligible for biodiversity payments but qualifying for the minimum EFA (see Table 1). Accordingly, we obtained the four new dependent variables Y_3 (area eligible for biodiversity payments), Y_4 (area qualifying for minimum EFA), Y_5 (ecological value of area eligible for biodiversity payments), and Y_6 (ecological value of area qualifying for minimum EFA). Summary statistics of the four new dependent variables can be found in Table C1 in Appendix C. The new dependent variables also have zero values, and the distributions are right-skewed (see Fig. C1 in Appendix C).

5. Results

5.1. Factors influencing the area of landscape features

Table 5 presents the results (average marginal effects) of the regression analysis for the dependent variable 'area of landscape features'. The results with estimated (raw) coefficients and their standard errors can be found in Table B1 in Appendix B.

The variable reflecting farmers' personal norm towards on-farm biodiversity conservation indicates a statistically significant positive effect. A higher personal norm (i.e. an increase of one unit) leads to an increase in the area of landscape features by approximately 0.065 ha on average. The variable that captures farmer's self-efficacy regarding personal skills also has a statistically significant positive effect. Here, a one-unit increase in the variable 'self-efficacy—personal skills' is associated with an increase in the area of landscape features by an average of 0.08 ha. Furthermore, the higher the self-efficacy reported by farmers as able to prevent damage to biodiversity, the larger the area of landscape features.

Among the variables that reflect the importance of direct payments for farm income, the variable 'importance of biodiversity payments' shows a statistically significant positive effect on the area of landscape features. An increase of one unit in importance leads to an average increase of 0.15 ha in the area of landscape features. By contrast, the two variables 'importance of cultural landscape payments' and 'importance of production system payments' show negative effects. An increase by one unit in the variable 'importance of cultural landscape payments' is associated with a decrease in the area of landscape features by on average 0.06 ha. Furthermore, an increase by one unit in the 'importance of production system payments' leads to a decrease of 0.13 ha in the area of landscape features. The 'importance of food security payments' and the 'importance of market income' are not significant here.

The regression results further reveal that certain farm types—that is, dairy cows, suckler cows, cattle mixed, horses/sheep/goats, processing, combined suckler cows, and combined others—have higher areas of landscape features compared to the reference arable farming farm type. For example, the suckler cow farm type has, on average, an area of landscape features that is larger by 1.2 ha than the arable farming farm type. Compared to farms located in the valley region, farms located in the mountain zones I, II, III, and IV have statistically significant smaller areas of landscape features. The difference is most pronounced for farms located in mountain zone IV. Here, farms have, on average, a smaller area of landscape features by 1.06 ha than farms in the valley zone. The dummy variable reflecting the production system (i.e. organic vs. non-organic) reveals a statistically significantly positive impact, thereby implying that organic farms have, on average, areas with landscape features that are approximately 0.2 ha larger than non-organic farms. Moreover, the area of landscape features increases with increasing UAA. An increase in UAA by 10 ha increases the area of landscape features by

Table 6

Results (average marginal effects) of the regression analysis with the dependent variable 'ecological value of landscape features'.

Independent variables	Average marginal effect	Standard error
Socio-psychological factors (X_1)		
Personal norms	0.043*	0.024
Injunctive norm—family	0.011	0.022
Injunctive norm—acquaintances	−0.014	0.022
Descriptive norm—other farmers	−0.010	0.023
Self-efficacy—personal skills	0.053*	0.027
Self-efficacy—damage prevention	0.041	0.027
Self-efficacy—overcoming difficulties	0.002	0.029
Economic factors (X_2)		
Importance of market income	−0.023	0.024
Importance of biodiversity payments	0.122***	0.025
Importance of cultural landscape payments	−0.069***	0.021
Importance of production system payments	−0.066**	0.029
Importance of food security payments	0.002	0.021
Farm characteristics (X_3)		
Farm type (Reference: Arable farming)		
Special cultures	0.119	0.122
Dairy cows	0.655***	0.145
Suckler cows	0.744***	0.223
Cattle mixed	0.433***	0.139
Horses/sheep/goats	0.404***	0.152
Processing	0.453***	0.157
Combined dairy cows/arable farming	0.096	0.110
Combined suckler cows	0.140	0.099
Combined processing	0.277**	0.136
Combined others	0.327***	0.098
Agricultural zone (Reference: Valley)		
Hill	0.027	0.095
Mountain I	−0.165	0.112
Mountain II	−0.299***	0.108
Mountain III	−0.445***	0.138
Mountain IV	−0.563***	0.166
Production system (1 = organic; 0 = non-organic)	0.136	0.094
Utilised agricultural area	−0.005	0.004
Livestock units	0.000	0.002
Sociodemographic characteristics (X_4)		
Activity (1 = full time; 0 = part time)	−0.015	0.079
Farm manager age	0.003	0.003
Education (Reference: Practical experience)		
Federal vocational certificate	0.662*	0.332
Federal certificate of competence	0.245	0.161
Professional examination	0.090	0.174
Master's examination	0.192	0.167
Higher college	0.014	0.174
Bachelor's degree/Master's degree, or higher	0.021	0.170
Other	0.147	0.236
Language region (1 = German; 0 = French)	0.168*	0.090
Number of observations	815	

***, **, and * denote significance at 1 %, 5 %, and 10 % respectively. Standard errors are computed based on the delta method.

approximately 0.2 ha on average. Areas with landscape features are also positively affected when farms operate as full-time farms. They have, on average, areas of landscape features that are 0.28 ha larger than part-time farms.

Further, farmers with a federal vocational certificate have an area of landscape features that is, on average, 0.8 ha larger, and farmers with a federal certificate of competence have an area of landscape features that is 0.4 ha larger than that of farmers with only practical experience.

5.2. Factors influencing the ecological value of landscape features

Table 6 presents the regression results (average marginal effects) for the dependent variable 'ecological value of landscape features'. The results with estimated (raw) coefficients and their standard errors are presented in Table B2 in Appendix B.

As in the case of the regression results for the dependent variable 'area of landscape features', the variable reflecting farmers' personal norms is statistically significantly and positive. The variable 'self-efficacy—personal skills' is also significantly positive. We observe a statistically significant positive effect of the variable 'importance of biodiversity payments'. Here, an increase of one unit causes the ecological value of the landscape features to increase by an average of 0.12 points. By contrast, the effects of the variables 'importance of cultural landscape payments' and 'importance of production system payments' are significantly negative. Again, the 'importance of food security payments' and the 'importance of market income' have no significant effect.

Compared to the farm type 'arable farming', the ecological value of landscape features for the farm types 'dairy cows', 'suckler cows', 'cattle mixed', 'horses/sheep/goats', 'processing', 'combined processing', and 'combined others' is statistically significantly higher. For example, the ecological value of landscape features of the suckler cow farm type is, on average, 0.74 points higher than that of arable farms. Farms located in mountain zones II, III, and IV show a significantly lower ecological value of landscape features than farms in the valley region.

Compared to farmers with only practical experience, farmers with a federal vocational certificate exhibit significantly higher (on average, 0.67 points) ecological values of landscape features. Farmers located in the German-speaking part of Switzerland have an ecological value that is, on average, higher by 0.17 points than farmers located in the French-speaking part of the country.

5.3. Robustness checks

For the robustness check models considering single blocks of independent variables and for the robustness check models considering heterogeneity of landscape features, we performed the three-step test suggested in Subsection 4.3.2. The results of the three-step test for selecting the appropriate estimation technique for the robustness check models are presented in Table C2 in Appendix C.

The regression results with the blocks of independent variables X_1, X_2, X_3, and X_4 considered individually show that our results are stable (see Tables C3 and C4 in Appendix C). The signs of the significant coefficients do not change, and the coefficients remain statistically significant when comparing the full model with models considering the single blocks of independent variables.

The use of different standard errors (i.e., clustering based on the geographical units of canton and municipality, as well as bootstrapping) also proves the robustness of our main results. In most cases, the estimates remain statistically significant (see Tables C5 and C6 in Appendix C). Only for the variable 'self-efficacy damage prevention' does the use of bootstrapped standard errors (both model variants) or the use of municipality cluster standard errors (model variant with ecological value as the dependent variable) lead to a non-significant coefficient.

Taking into account the heterogeneity of landscape features (see Table C7 and Table C8 in Appendix C), the results of the model variants

Table 7
Summary and comparison of factors affecting the two outcome variables for landscape features that are not eligible for payments.

Factor*	*Quantity* Dependent variable 'area of landscape features'	*Quality* Dependent variable 'ecological value of landscape features'
Willingness		
Socio-psychological factors		
Personal norm	+	+
Self-efficacy—personal skills	n.s	n.s
Ability		
Economic factors		
Importance of biodiversity payments	n.s	n.s
Importance of cultural landscape payments	n.s	n.s
Importance of production system payments	n.s	n.s
Farm characteristics		
Farm type	n.s	n.s
Agricultural zone (mountain zones)	+	–
Organic farming	n.s	n.s.
Sociodemographic characteristics		
Full-time farming	n.s	n.s.
Education (federal vocational certificate and federal certificate of competence)	+	+
Language region (German)	n.s.	n.s

Notes: + indicates a positive and significant effect; − indicates a negative and significant effect; n.s. = non-significant effect.

Table 8
Summary and comparison of factors affecting the two outcome variables. Landscape features include types that are eligible for payments and types that are not eligible for payments.

Factor*	*Quantity* Dependent variable 'area of landscape features'	*Quality* Dependent variable 'ecological value of landscape features'
Willingness		
Socio-psychological factors		
Personal norm	+	n.s.
Self-efficacy—personal skills	+	+
Ability		
Economic factors		
Importance of biodiversity payments	+	+
Importance of cultural landscape payments	–	–
Importance of production system payments	–	–
Farm characteristics		
Farm type	+	+
Agricultural zone (mountain zones)	–	–
Organic farming	+	n.s.
Sociodemographic characteristics		
Full-time farming	+	n.s.
Education (federal vocational certificate and federal certificate of competence)	+	+
Language region (German)	n.s.	+

Notes: + indicates a positive and significant effect; − indicates a negative and significant effect; n.s. = non-significant effect.

with the dependent variables Y_3 (area eligible for direct payments) and Y_5 (ecological value of the area eligible for direct payments) are mostly consistent with our main results. For the models with the dependent variables Y_4 (area qualifying for minimum EFA but not eligible for direct payments) and Y_6 (ecological value of area qualifying for minimum EFA but not eligible for direct payments), we can observe that many coefficients are no longer significant. Interestingly, the quantity and quality of landscape features that are not eligible for biodiversity payments but qualifying for the minimum EFA are mainly influenced by farmers' personal norms. Moreover, in contrast to the area of landscape features eligible for direct payments, the area not eligible for payments is larger in mountain zones I and II than in the valley zone. Table 7 summarises the results of the analysis for landscape types that are not eligible for payments but qualify for the minimum EFA.

6. Discussion

With respect to the aim of this study, our analysis reveals which factors reflecting farmers' willingness and ability to conserve biodiversity influence the quantity (area covered by landscape features) and quality (ecological value of this area) of landscape features. Certain factors significantly influence both outcomes, while others influence only one. Table 8 summarises the results of the analysis for all landscape features (eligible and non-eligible for direct payments).

The variable measuring farmers' personal norms towards biodiversity conservation was found to significantly influence the quantity of landscape features. However, our results reveal no effect of farmers' personal norms on the ecological value of landscape features. These results suggest that farmers' willingness to conserve biodiversity affects the quantity of landscape features but that the ecological value provided by landscape features is determined by other factors. This is probably because landscape features with a high ecological value depend on natural site factors (e.g. litter meadows can only be implemented on wet and damp sites). In addition, farmers may focus more on implementing or maintaining landscape features and less on their ecological value, an aspect on which farmers are likely to have less knowledge. Previous studies on farmers' personal norms have focused on the adoption of AESs, thereby making them more comparable to our analysis in terms of quantity rather than quality. Whereas Mettepenningen et al. (2013) and Špur et al. (2018) found no significant effects of farmers' environmental values, Le Coent et al. (2018) revealed a positive relationship between personal norms and the likelihood of adopting AESs. Our results suggest that high personal norms positively influence the quantity of landscape features but are unlikely to influence their ecological value.

Our results reveal no significant effects of farmers' social norms on the quantity and quality of landscape features. This may imply that farmers are less concerned with the approval of others than when they decide to participate in AESs or to convert to organic farming (e.g. Khamzina et al., 2021; Kuhfuss et al., 2016; Läpple and Kelley, 2013).

Furthermore, our results show that the higher the farmers' self-efficacy regarding their personal ability to conserve biodiversity, the higher the area and the ecological value of landscape features. The role of self-efficacy in the adoption of biodiversity-enhancing AES appears to be widely neglected. In reference to other research on farmer behaviour, our finding is in line with that of McGinty et al. (2008), who found that the higher the farmers' self-efficacy, the stronger their intentions to adopt and maintain agroforestry systems, as well as Kaiser and Burger's (2022) typology, in which farmers' high self-efficacy is a relevant aspect of lower-input crop protection practices.

Economic considerations are relevant determinants of farmers' behaviour in general and with regard to EFAs and biodiversity conservation measures in particular (Klebl et al., 2023; Zinngrebe et al., 2017). Accordingly, the importance of biodiversity payments for farmers' income reveals a statistically significant positive effect for both outcomes, as expected. Our results support those of Karali et al. (2014), who found that Swiss farmers' decisions to participate in environmental management practices were, inter alia, driven by financial incentives, as well as those of Fleury et al. (2015), who demonstrated the benefits of different biodiversity payments.

Our results also demonstrate the negative effects of payments that do not target on-farm biodiversity conservation but less intensive productive areas and animal welfare. For example, the higher the importance of production system payments for farm income, the lower the area and ecological value of landscape features. This implies that if a farmer has a stronger focus on less intensive management practices (i.e. pesticide-free cropping systems) or animal welfare-friendly production methods, the incentive to implement landscape features of high ecological value is lower. Thus, it appears that farmers may perceive less intensive production systems and landscape features as mutual substitutes for environmentally friendly practices and are therefore less likely to adopt both. For the other economic factors tested—that is, market income and the importance of food security payments—we find no significant effects on landscape features. The finding that market income does not affect Swiss farmers' adoption decisions supports what Home et al. (2019) found for organic farming. However, this contrasts with studies in the EU that found a positive (Busse et al., 2021) or negative (Defrancesco et al., 2008) effect when market income is higher.

The farm characteristic that positively influences both outcomes is the farm type—particularly livestock farming compared to arable farming. This result is in line with several studies that have broadly investigated the determinants of the adoption of biodiversity-friendly farming measures (Barreiro-Hurlé et al., 2010; Defrancesco et al., 2008; Ducos et al., 2009; Zimmermann and Britz, 2016). On the contrary, our results reveal that higher altitudes (mountain zones) are negatively associated with both the area and the ecological value of landscape features. This is related to the choice of landscape features in this study, which excluded most grassland-related features. In Switzerland, the area in the higher mountain zones consists mainly of grasslands with high proportions of EFA (such as extensive meadows) and consequently lower proportions of other types of EFA, such as hedges and trees (FOAG (Federal Office for Agriculture), 2023b) (as covered in this study). Thus, our results can be explained by the greatly varying site-specific potential for creating different types of landscape features (van Herzele et al., 2013).

Further, organic farming is positively associated with the area covered with landscape features. This corroborates the findings of prior studies on conservation practices (Borsotto et al., 2008; Casagrande et al., 2016). Organic farming is not associated with the ecological value of the landscape features, which may be attributed to the reasons discussed regarding the findings on personal norms.

With regard to sociodemographic characteristics, our analysis reveals that full-time (versus part-time) farming is associated with larger areas of the landscape features. This may be explained by the fact that, on average, full-time farmers have larger farms (in hectares UAA); moreover, the maintenance of certain landscapes (e.g. high-trunk trees and hedges) is relatively labour-intensive. These features may therefore make them more suitable for full-time farming. Our finding contrasts with the broader literature on biodiversity-friendly farming measures, in which off-farm income (usually implying part-time farming) has been considered a factor that positively influences adoption (Granado-Díaz et al., 2022; Peerlings and Polman, 2009; Wossink and van Wenum, 2003). However, our results are in line with a study from Switzerland that found off-farm income to be lower with higher biodiversity payments (El Benni and Schmid, 2022). With regard to personal norms and organic farming, full-time farming has no effect on the ecological value of the landscape features in our study.

Furthermore, farmers' age has no significant effect on landscape features. This contrasts with the findings of numerous studies showing that younger farmers are more likely to adopt measures than older farmers (see Klebl et al., 2023). However, Mettepenningen et al. (2013) noted that this relationship may not be linear, as their results revealed an increase in the likelihood of engagement in AES up to the age of 42, followed by a decline. They explained this by older farmers' reluctance to introduce new practices.

We also found that the education level of farmers plays a significant role in both the area and the ecological value of landscape features. This is true for vocational education but not for higher levels, such as master's degree, higher college, and university education. Previous studies support the general finding that higher education levels, such as the vocational training of farmers, are beneficial for the adoption of biodiversity-enhancing farming measures (Calvet et al., 2019; Mack et al., 2020; Zhillima et al., 2021). These findings confirm that knowledge is a key factor for farmers in establishing or maintaining high ecological value landscape features.

Farmers in the German-speaking part of Switzerland have areas with a significantly higher ecological value, but these areas are not significantly larger than those of farmers in the French-speaking part. This seems to be due to the fact that German-speaking farmers have implemented landscape features with higher biodiversity scores (e.g. hedges and litter meadows). This finding is in line with the results of Wang et al. (2023), who found that German-speaking farmers provided higher ecological values than their French-speaking counterparts, as measured by the amount of payments received under biodiversity conservation AESs.

In summary, the revealed differences in factors influencing the two outcomes reflect the difference between measuring on-farm biodiversity with quantitative (area) versus qualitative (ecological value) indicators. They also support the idea that farmers' awareness of their farms' ecological potential may affect their implementation decisions (Canessa et al., 2023). This implies that policymakers should encourage farmers to implement more ecologically valuable landscape features by ensuring that agricultural extension provides tailored on-site advice.

However, a separate analysis of only those landscape features that are not supported by biodiversity payments reveals that farmers' willingness (i.e. personal norms) plays a decisive role, while ability is less important. Of the ability factors, only education has a significant effect. These results show that the relevance of willingness increases when landscape features are not supported by direct payments.

7. Limitations and directions for further research

This study has a few limitations with regard to the databases used. First, information on the area covered by landscape features per farm was entirely drawn from census data. This implies that the analysis was limited to landscape features that were actually registered by the farms (as EFAs), ignoring the much wider range of landscape diversity and land cover heterogeneity that needs to be addressed at the off-farm scale. Thus, it does not take into account the full range of landscape features present on and off the farms. Here, future research could extend our analysis—for example, by using geospatial data. Second, a proxy was used to measure the ecological value of the landscape features. In addition, the biodiversity score (extracted from SALCA-BD) used to calculate these measures generalises the effects on 11 indicator species. This ignores, for example, effects that may differ between species groups, effects that depend on the age of trees or the diversity of plants on field margins, and spatial effects, all of which are known to be important for biodiversity. Nevertheless, this study provides new insights by considering not only the area of landscape features but also an approximation of their ecological value.

8. Conclusions and policy implications

The aim of this study was to investigate the factors that influence the area and the ecological value of biodiversity-enhancing landscape features. Examining factors that influence farmers' decisions to establish or maintain landscape features with high ecological value yields additional information. The results suggest that farmers' willingness (e.g. as reflected in personal norms and self-efficacy) is conducive to on-farm biodiversity conservation through the implementation of landscape features, but it is not sufficient. Farmers' ability, which depends on structural factors—such as farm characteristics (e.g. site-specific ecological potential or natural conditions required for certain landscape features of high ecological value)—and on external drivers, also appears to be crucial for on-farm biodiversity conservation.

To attain the policy goal of enhancing both the quantity and ecological value of landscape features, both sets of factors need to be considered. Based on our findings, policymakers can engage farmers in biodiversity conservation through supportive direct payments, education, and tailored advice regarding the site-specific ecological potential of these landscape features. Further, direct payments with adverse effects on on-farm biodiversity may need to be better aligned with the sector's biodiversity targets.

The agricultural sector plays a major role in the global anthropogenic loss of biodiversity. Accordingly, on-farm efforts to conserve biodiversity are essential. However, if the landscape matrix remains a monoculture at the landscape scale, these efforts will yield only small improvements (Tscharntke et al., 2021). A holistic approach to biodiversity conservation would require a mix of on-farm and off-farm diversification and biodiversity conservation measures to take full advantage of spillovers between farmed and (semi-)natural areas (Tscharntke et al., 2024). To this end, a paradigm shift in environmental and agricultural policies is needed to promote biodiversity on a large scale (Pe'er et al., 2022), which implies that subsidies for biodiversity enhancement should not be limited to the on-farm scale.

CRediT authorship contribution statement

Antonia Kaiser: Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation, Data curation, Conceptualization. **Yanbing Wang:** Writing – review & editing, Writing – original draft, Validation, Investigation, Data curation, Conceptualization. **Noëlle Klein:** Writing – review & editing, Writing – original draft, Data curation. **Gabriele Mack:** Writing – review & editing, Writing – original draft, Validation, Project administration, Investigation, Funding acquisition, Conceptualization. **Christian Ritzel:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

A.1. Further explanation of biodiversity scores

SALCA-BD is a life cycle assessment tool that aims to assess the impact of agricultural management on 11 indicator species groups (flora of crops and grasslands, birds, mammals, amphibians, snails, spiders, carabids, butterflies, wild bees, and grasshoppers). Based on scientific literature and expert valuations, scores are attributed to the suitability of an agricultural crop or habitat for the indicator group as well as to the impact of all associated management options (including their timing) on the indicator group. The two elements are then aggregated to a biodiversity score that ranges between 0 (high impact) and 50 (low impact), with 50 representing an optimal situation for biodiversity. The scores are specific to each indicator species group, but can be spatially aggregated (field, farm, region) or in a trophic manner (individual species groups, overall biodiversity scores accounting for trophic relationships among the groups). In this study, only the aggregated biodiversity score was considered as an overall proxy for biodiversity. SALCA-BD is an established method for assessing the impacts of agricultural management on biodiversity (Curran et al., 2016) and has been validated with real-life field data for several indicator groups and spatial scales (Klein et al., 2023; Lüscher et al., 2017).

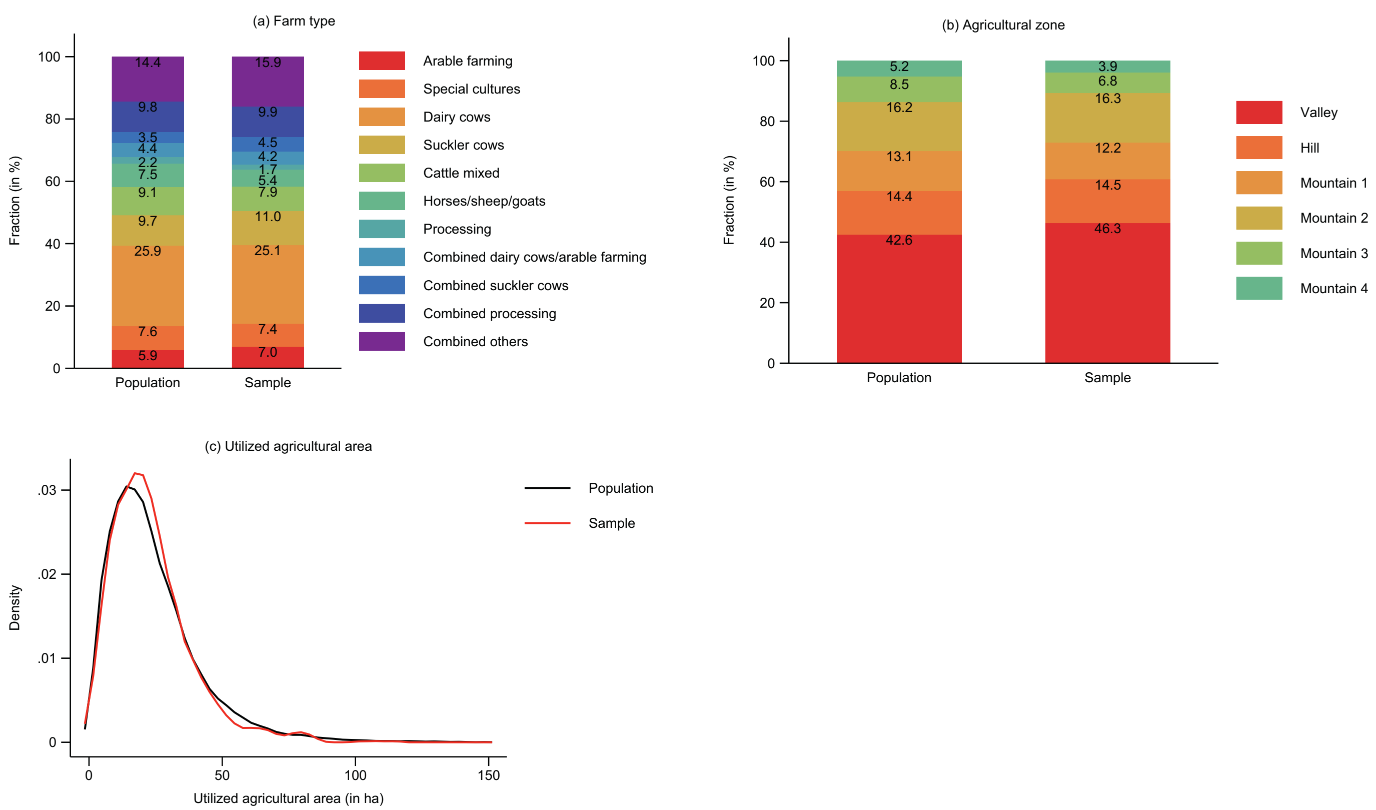

Fig. A1. Representativeness of sample compared to all Swiss farms in terms of a) agricultural zone, b) farm type, and c) farm size (total utilised agricultural area).

Fig. A1 presents comparisons of the sample to the population of all farms in Switzerland in terms of farm type, agricultural zone, and farm size. Overall, the farms in our sample represent the population well. Farms in the valley zone are slightly overrepresented, and farms in mountain zones 3 and 4 are slightly underrepresented (Fig. A1(b)).

Appendix B

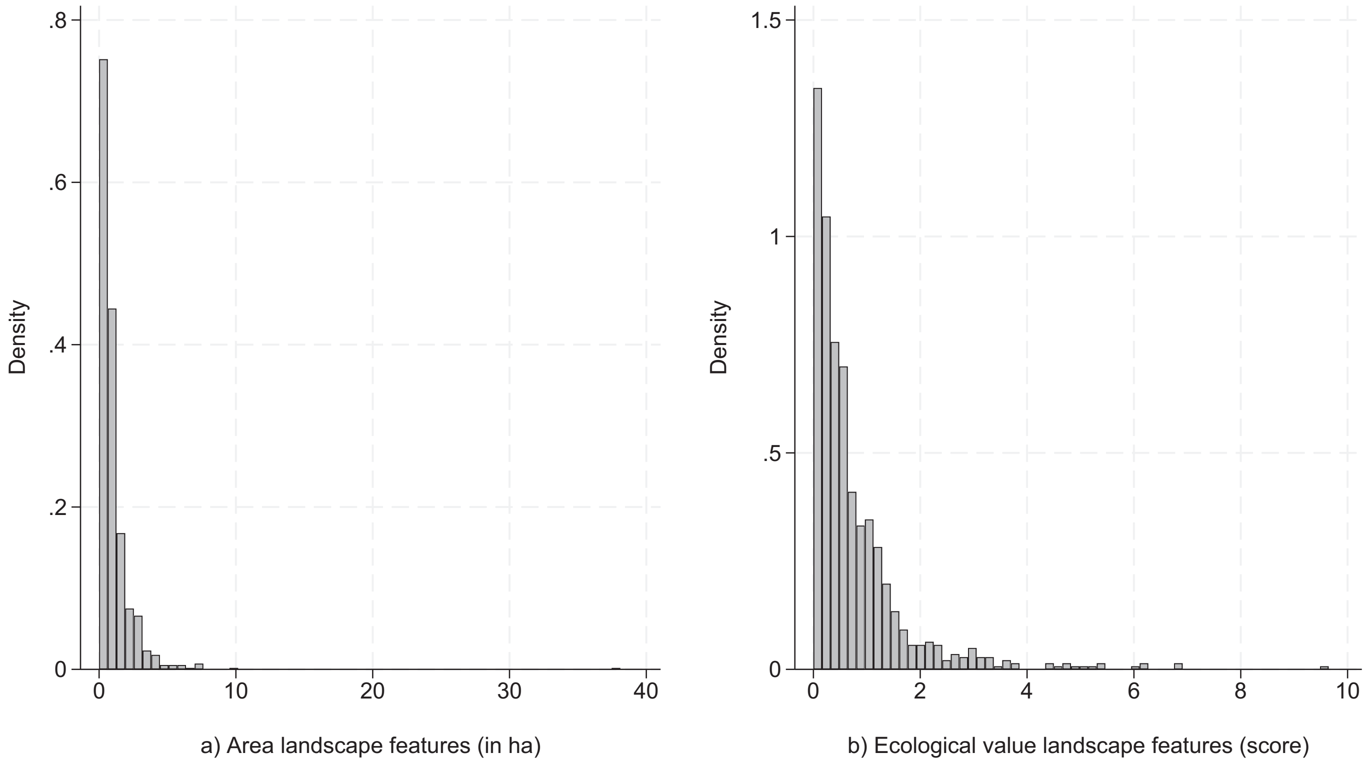

Fig. B1. Distribution of a) area landscape features (Y_1), and b) ecological value landscape features (Y_2).

Table B1
Results (estimates raw betas) of the regression analysis with the dependent variable 'area of landscape features'.

Independent variables	Full model *β*	Robust standard errors
Socio-psychological factors (X_1)		
Personal norms	0.062**	0.026
Injunctive norm—family	0.043	0.026
Injunctive norm—acquaintances	−0.020	0.030
Descriptive norm—other farmers	−0.009	0.028
Self-efficacy—personal skills	0.081**	0.034
Self-efficacy—damage prevention	0.053*	0.030
Self-efficacy—overcoming difficulties	−0.008	0.032
Economic factors (X_2)		
Importance of market income	−0.028	0.027
Importance of biodiversity payments	0.143***	0.027
Importance of cultural landscape payments	−0.055**	0.026
Importance of production system payments	−0.128***	0.038
Importance of food security payments	0.007	0.031
Farm characteristics (X_3)		
Farm type (Reference: Arable farming)		
Special cultures	−0.067	0.299
Dairy cows	0.916***	0.259
Suckler cows	1.123***	0.324
Cattle mixed	0.609**	0.262
Horses/sheep/goats	0.693***	0.278
Processing	0.723**	0.300
Combined dairy cows/arable farming	0.235	0.239
Combined suckler cows	0.408*	0.250
Combined processing	0.376	0.271
Combined others	0.523***	0.225
Agricultural zone (Reference: Valley)		
Hill	−0.063	0.098
Mountain I	−0.301**	0.132

(*continued on next page*)

Table B1 (*continued*)

Independent variables	Full model β	Robust standard errors
Mountain II	−0.645***	0.139
Mountain III	−0.849***	0.212
Mountain IV	−1.540***	0.360
Production system (1 = organic; 0 = non-organic)	0.175*	0.096
Utilised agricultural area	0.019***	0.004
Livestock units	0.001	0.002
Sociodemographic characteristics (X_4)		
Activity (1 = full time; 0 = part time)	0.292**	0.095
Farm manager age	0.002	0.004
Education (Reference: Practical experience)		
Federal vocational certificate	0.724***	0.319
Federal certificate of competence	0.428*	0.249
Professional examination	0.310	0.266
Master's examination	0.356	0.252
Higher college	0.183	0.274
Bachelor's degree/Master's degree, or higher	0.103	0.267
Other	0.317	0.324
Language region (1 = German; 0 = French)	0.083	0.128
Intercept	−2.422***	0.430
Number of observations	815	
AIC	2007	
BIC	2205	
Pseudo R^2	0.130	

***, ** and * denote significance at 1 %, 5 % and 10 % respectively.

Table B2
Results (estimates raw betas) of the regression analysis with the dependent variable ‘ecological value of landscape features’.

Independent variables	Full model β	Robust standard errors
Socio-psychological factors (X_1)		
Personal norms	0.054*	0.030
Injunctive norm—family	0.014	0.028
Injunctive norm—acquaintances	−0.017	0.028
Descriptive norm—other farmers	−0.013	0.029
Self-efficacy—personal skills	0.067*	0.034
Self-efficacy—damage prevention	0.052	0.034
Self-efficacy—overcoming difficulties	0.003	0.037
Economic factors (X_2)		
Importance of market income	−0.030	0.031
Importance of biodiversity payments	0.154***	0.030
Importance of cultural landscape payments	−0.087***	0.026
Importance of production system payments	−0.083**	0.036
Importance of food security payments	0.002	0.027
Farm characteristics (X_3)		
Farm type (Reference: Arable farming)		
Special cultures	0.262	0.270
Dairy cows	0.974***	0.260
Suckler cows	1.056***	0.310
Cattle mixed	0.737***	0.259
Horses/sheep/goats	0.702***	0.274
Processing	0.761***	0.283
Combined dairy cows/arable farming	0.217	0.250
Combined suckler cows	0.302	0.230
Combined processing	0.530*	0.273
Combined others	0.601***	0.219
Agricultural zone (Reference: Valley)		
Hill	0.028	0.100
Mountain I	−0.194	0.135
Mountain II	−0.386***	0.147
Mountain III	−0.648***	0.247
Mountain IV	−0.927**	0.415
Production system (1 = organic; 0 = non-organic)	0.165	0.109
Utilised agricultural area	−0.007	0.005
Livestock units	0.000	0.002

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Table B2 (*continued*)

Independent variables	Full model β	Robust standard errors
Sociodemographic characteristics (X_4)		
Activity (1 = full time; 0 = part time)	−0.018	0.099
Farm manager age	0.003	0.004
Education (Reference: Practical experience)		
Federal vocational certificate	0.747**	0.354
Federal certificate of competence	0.344	0.264
Professional examination	0.141	0.284
Master's examination	0.279	0.272
Higher college	0.023	0.290
Bachelor's degree/Master's degree, or higher	0.034	0.284
Other	0.220	0.357
Language region (1 = German; 0 = French)	0.232*	0.137
Intercept	−1.947***	0.480
Number of observations	815	
AIC	1783	
BIC	1976	
Pseudo R^2	0.089	

Table C1
Summary statistics of the four new dependent variables used for the robustness checks.

Variable name	Description	Unit (measurement scale)	Mean	SD	N
Area of landscape features eligible for direct payments	Sum of UAA covered with landscape features eligible for direct payments	Hectares (continuous)	1.01	1.66	882
Area of landscape features accountable for minimum EFA	Sum of UAA covered with landscape features accountable for minimum EFA	Hectares (continuous)	0.02	0.07	882
Ecological value of area landscape features eligible for direct payments	Area weighted sum of the BD scores of the landscape features eligible for direct payments	Scores (continuous)	0.77	0.98	882
Ecological value of area landscape features accountable for minimum EFA	Area weighted sum of the BD scores of the landscape features accountable for minimum EFA	Scores (continuous)	0.02	0.07	882

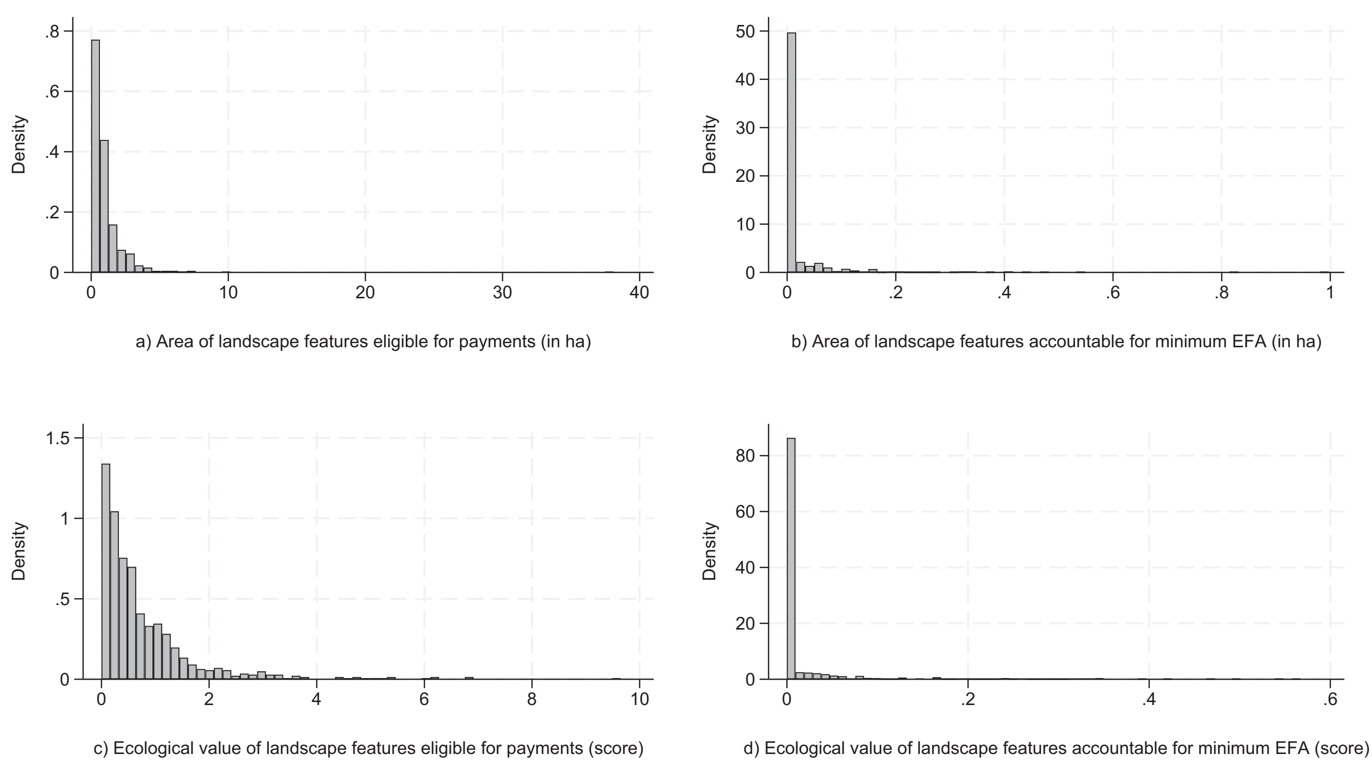

Fig. C1. Distribution Y3 (area eligible for direct payments), Y4 (area accountable minimum EFA), Y5 (ecological value of area eligible for direct payments), and Y6 (ecological value of area accountable minimum EFA).

Table C2
Results of the three-step test for selecting the appropriate estimation technique for the robustness check models.

Dependent variable	Overdispersion	Block independent variable	Pearson goodness-of-fit test	LR test overdispersion parameter alpha	Choice of estimation technique
Y_1 (Area)	Yes	X_1 socio-psychological	$p = 0.000$	$p = 0.000$	Negative binomial regression
Y_1 (Area)	Yes	X_2 economic	$p = 0.000$	$p = 0.000$	Negative binomial regression
Y_1 (Area)	Yes	X_3 farm characteristics	$p = 0.000$	$p = 0.000$	Negative binomial regression
Y_1 (Area)	Yes	X_4 socio-demographic characteristics	$p = 0.000$	$p = 0.000$	Negative binomial regression
Y_2 (Ecological value)	No	X_1 socio-psychological	$p = 0.018$	$p = 0.082$	Negative binomial regression
Y_2 (Ecological value)	No	X_2 economic	$p = 0.393$	$p = 0.130$	Poisson regression
Y_2 (Ecological value)	No	X_3 farm characteristics	$p = 0.171$	$p = 0.294$	Poisson regression
Y_2 (Ecological value)	No	X_4 socio-demographic characteristics	$p = 0.011$	$p = 0.073$	Negative binomial regression
Y_3 (Area eligible direct payments)	Yes	Full model	$p = 0.927$	$p = 0.000$	Negative binomial regression
Y_4 (Area minimum EFA)	No	Full model	$p = 1.000$	$p = 0.499$	Poisson regression
Y_5 (Ecological value eligible direct payments)	No	Full model	$p = 0.990$	$p = 0.500$	Poisson
Y_6 (Ecological value minimum EFA)	No	Full model	$p = 1.000$	$p = 1.00$	Poisson

Table C3
Results (estimates raw betas) of the regression analysis considering individual blocks of independent variables with the dependent variable 'area of landscape features'.

Independent variables	Full model	X_1	X_2	X_3	X_4
Socio-psychological factors (X_1)					
Personal norms	0.062**	0.095***			
	(0.026)	(0.026)			
Injunctive norm—family	0.043	0.034			
	(0.026)	(0.033)			
Injunctive norm—acquaintances	−0.020	−0.006			
	(0.030)	(0.047)			
Descriptive norm—other farmers	−0.009	−0.034			
	(0.028)	(0.040)			
Self-efficacy—personal skills	0.081**	0.125***			
	(0.034)	(0.039)			
Self-efficacy—damage prevention	0.053*	0.061*			
	(0.030)	(0.036)			
Self-efficacy—overcoming difficulties	−0.008	−0.010			
	(0.032)	(0.045)			
Economic factors (X_2)					
Importance of market income	−0.028		0.007		
	(0.027)		(0.026)		
Importance of biodiversity payments	0.143***		0.173***		
	(0.027)		(0.029)		
Importance of cultural landscape payments	−0.055**		−0.044*		
	(0.026)		(0.026)		
Importance of production system payments	−0.128***		−0.109***		
	(0.038)		(0.027)		
Importance of food security payments	0.007		0.022		
	(0.031)		(0.030)		
Farm characteristics (X_3)					
Farm type (Reference: Arable farming)					
Special cultures	−0.067			0.147	
	(0.299)			(0.339)	
Dairy cows	0.916***			1.185***	
	(0.259)			(0.332)	
Suckler cows	1.123***			1.388***	
	(0.324)			(0.483)	
Cattle mixed	0.609**			0.972***	
	(0.262)			(0.349)	
Horses/sheep/goats	0.693***			0.963***	
	(0.278)			(0.339)	
Processing	0.723**			1.210***	
	(0.300)			(0.400)	
Combined dairy cows/arable farming	0.235			0.520*	
	(0.239)			(0.272)	

(continued on next page)

Table C3 (*continued*)

Independent variables	Full model	X_1	X_2	X_3	X_4
Combined suckler cows	0.408*			0.628**	
	(0.250)			(0.284)	
Combined processing	0.376			0.690**	
	(0.271)			(0.345)	
Combined others	0.523***			0.734***	
	(0.225)			(0.269)	
Agricultural zone (Reference: Valley)					
Hill	−0.063			−0.118	
	(0.098)			(0.116)	
Mountain I	−0.301**			−0.372**	
	(0.132)			(0.164)	
Mountain II	−0.645***			−0.770***	
	(0.139)			(0.180)	
Mountain III	−0.849***			−0.883***	
	(0.212)			(0.241)	
Mountain IV	−1.540***			−1.551***	
	(0.360)			(0.420)	
Production system (1 = organic; 0 = non-organic)	0.175*			0.285**	
	(0.096)			(0.115)	
Utilised agricultural area	0.019***			0.025***	
	(0.004)			(0.006)	
Livestock units	0.001			−0.004	
	(0.002)			(0.003)	
Socio-demographic characteristics (X_4)					
Activity (1 = full time; 0 = part time)	0.292**				0.583***
	(0.095)				(0.098)
Farm manager age	0.002				0.006
	(0.004)				(0.008)
Education (Reference: Practical experience)					
Federal vocational certificate	0.724***				0.773**
	(0.319)				(0.336)
Federal certificate of competence	0.428*				0.746**
	(0.249)				(0.298)
Professional examination	0.310				0.720**
	(0.266)				(0.289)
Master's examination	0.356				0.823***
	(0.252)				(0.274)
Higher college	0.183				0.566*
	(0.274)				(0.326)
Bachelor's degree/Master's degree, or higher	0.103				0.702**
	(0.267)				(0.303)
Other	0.317				0.426
	(0.324)				(0.321)
Language region (1 = German; 0 = French)	0.083				−0.133
	(0.128)				(0.230)
Intercept	−2.422***	−1.352***	−0.218	−1.169***	−1.342***
	(0.430)	(0.295)	(0.217)	(0.289)	(0.434)
Number of observations	815	815	815	815	815
AIC	2007	2159	2182	2074	2179
BIC	2205	2201	2214	2168	2235
Pseudo R^2	0.130	0.031	0.091	0.080	0.025

***, ** and * denote significance at 1 %, 5 % and 10 % respectively. Robust standard errors are in parentheses.

Table C4
Results (estimates raw betas) of the regression analysis considering individual blocks of independent variables with the dependent variable ‘ecological value of landscape features’.

Independent variables	Full model	X_1	X_2	X_3	X_4
Socio-psychological factors (X_1)					
Personal norms	0.054*	0.097***			
	(0.030)	(0.030)			
Injunctive norm—family	0.014	0.013			
	(0.028)	(0.029)			
Injunctive norm—acquaintances	−0.017	−0.024			
	(0.028)	(0.030)			
Descriptive norm—other farmers	−0.013	−0.026			
	(0.029)	(0.031)			
Self-efficacy—personal skills	0.067*	0.079**			
	(0.034)	(0.035)			
Self-efficacy—damage prevention	0.052	0.038			
	(0.034)	(0.034)			
Self-efficacy—overcoming difficulties	0.003	−0.003			

(*continued on next page*)

Table C4 (*continued*)

Independent variables	Full model	X_1	X_2	X_3	X_4
	(0.037)	(0.038)			
Economic factors (X_2)					
Importance of market income	−0.030		−0.012		
	(0.031)		(0.030)		
Importance of biodiversity payments	0.154***		0.200***		
	(0.030)		(0.034)		
Importance of cultural landscape payments	−0.087***		−0.080***		
	(0.026)		(0.027)		
Importance of production system payments	−0.083**		−0.059		
	(0.036)		(0.041)		
Importance of food security payments	0.002		−0.045		
	(0.027)		(0.029)		
Farm characteristics (X_3)					
Farm type (Reference: Arable farming)					
Special cultures	0.262			0.287	
	(0.270)			(0.292)	
Dairy cows	0.974***			1.130***	
	(0.260)			(0.276)	
Suckler cows	1.056***			1.193***	
	(0.310)			(0.351)	
Cattle mixed	0.737***			0.959***	
	(0.259)			(0.299)	
Horses/sheep/goats	0.702***			0.908***	
	(0.274)			(0.299)	
Processing	0.761***			1.166***	
	(0.283)			(0.321)	
Combined dairy cows/arable farming	0.217			0.443*	
	(0.250)			(0.252)	
Combined suckler cows	0.302			0.447*	
	(0.230)			(0.236)	
Combined processing	0.530*			0.731**	
	(0.273)			(0.290)	
Combined others	0.601***			0.759***	
	(0.219)			(0.232)	
Agricultural zone (Reference: Valley)					
Hill	0.028			−0.016	
	(0.100)			(0.105)	
Mountain I	−0.194			−0.239*	
	(0.135)			(0.138)	
Mountain II	−0.386***			−0.476***	
	(0.147)			(0.163)	
Mountain III	−0.648***			−0.649***	
	(0.247)			(0.250)	
Mountain IV	−0.927**			−0.895*	
	(0.415)			(0.464)	
Production system (1 = organic; 0 = non-organic)	0.165			0.277***	
	(0.109)			(0.107)	
Utilised agricultural area	−0.007			−0.006	
	(0.005)			(0.006)	
Livestock units	0.000			−0.004	
	(0.002)			(0.003)	
Socio-demographic characteristics (X_4)					
Activity (1 = full time; 0 = part time)	−0.018				−0.078
	(0.099)				(0.090)
Farm manager age	0.003				0.007
	(0.004)				(0.005)
Education (Reference: Practical experience)					
Federal vocational certificate	0.747**				0.662*
	(0.354)				(0.355)
Federal certificate of competence	0.344				0.347
	(0.264)				(0.272)
Professional examination	0.141				0.101
	(0.284)				(0.285)
Master's examination	0.279				0.272
	(0.272)				(0.277)
Higher college	0.023				0.157
	(0.290)				(0.307)
Bachelor's degree/Master's degree, or higher	0.034				0.229
	(0.284)				(0.292)
Other	0.220				0.044
	(0.357)				(0.330)

(*continued on next page*)

Table C4 (*continued*)

Independent variables	Full model	X_1	X_2	X_3	X_4
Language region (1 = German; 0 = French)	0.232*				0.468***
	(0.137)				(0.170)
Intercept	−1.947***	−1.187***	−0.243	−0.735***	−1.217***
	(0.480)	(0.246)	(0.212)	(0.250)	(0.350)
Number of observations	815	815	815	815	815
AIC	1783	1848	1831	1817	1855
BIC	1976	1890	1864	1906	1912
Pseudo R^2	0.089	0.018	0.025	0.047	0.017

***, ** and * denote significance at 1 %, 5 % and 10 % respectively. Robust standard errors are in parentheses.

Table C5
Results of the regression analysis considering different standard errors with the dependent variable 'area of landscape features'.

Independent variables	Coefficient full model	*p*-value bootstrap	*p*-value canton cluster	*p*-value municipality cluster
Socio-psychological factors (X_1)				
Personal norms	0.062	0.014	0.004	0.012
Injunctive norm—family	0.043	0.061	0.093	0.097
Injunctive norm—acquaintances	−0.020	0.571	0.538	0.488
Descriptive norm—other farmers	−0.009	0.766	0.642	0.753
Self-efficacy—personal skills	0.081	0.008	0.013	0.016
Self-efficacy—damage prevention	0.053	0.140	0.052	0.077
Self-efficacy—overcoming difficulties	−0.008	0.814	0.827	0.813
Economic factors (X_2)				
Importance of market income	−0.028	0.364	0.385	0.311
Importance of biodiversity payments	0.143	0.000	0.000	0.000
Importance of cultural landscape payments	−0.055	0.048	0.005	0.034
Importance of production system payments	−0.128	0.014	0.003	0.001
Importance of food security payments	0.007	0.843	0.726	0.809
Farm characteristics (X_3)				
Farm type (Reference: Arable farming)				
Special cultures	−0.067	0.826	0.834	0.816
Dairy cows	0.916	0.001	0.000	0.000
Suckler cows	1.123	0.002	0.000	0.001
Cattle mixed	0.609	0.039	0.008	0.020
Horses/sheep/goats	0.693	0.044	0.003	0.012
Processing	0.723	0.033	0.002	0.017
Combined dairy cows/arable farming	0.203	0.372	0.361	0.387
Combined suckler cows	0.408	0.114	0.020	0.105
Combined processing	0.376	0.188	0.061	0.167
Combined others	0.523	0.034	0.004	0.021
Agricultural zone (Reference: Valley)				
Hill	−0.063	0.592	0.579	0.547
Mountain I	−0.301	0.053	0.037	0.026
Mountain II	−0.645	0.000	0.001	0.000
Mountain III	−0.849	0.000	0.000	0.000
Mountain IV	−1.540	0.000	0.005	0.000
Production system (1 = organic; 0 = non-organic)	0.175	0.060	0.051	0.077
Utilised agricultural area	0.019	0.000	0.000	0.000
Livestock units	0.001	0.405	0.517	0.492
Socio-demographic characteristics (X_4)				
Activity (1 = full time; 0 = part time)	0.292	0.020	0.005	0.002
Farm manager age	0.002	0.599	0.395	0.583
Education (Reference: Practical experience)				
Federal vocational certificate	0.724	0.025	0.039	0.023
Federal certificate of competence	0.428	0.063	0.063	0.085
Professional examination	0.310	0.210	0.147	0.245
Master's examination	0.356	0.142	0.100	0.158
Higher college	0.183	0.416	0.453	0.508
Bachelor's degree/Master's degree, or higher	0.103	0.627	0.710	0.701
Other	0.317	0.326	0.310	0.330
Language region (1 = German; 0 = French)	0.083	0.512	0.435	0.514
Intercept	−2.422	0.000	0.000	0.000

Table C6
Results of the regression analysis considering different standard errors with the dependent variable 'ecological value of landscape features'.

Independent variables	Coefficient full model	*p*-value bootstrap	*p*-value canton cluster	*p*-value municipality cluster
Socio-psychological factors (X_1)				
Personal norms	0.054	0.076	0.073	0.066
Injunctive norm—family	0.014	0.629	0.598	0.620
Injunctive norm—acquaintances	−0.017	0.539	0.606	0.536
Descriptive norm—other farmers	−0.013	0.620	0.615	0.663
Self-efficacy—personal skills	0.067	0.041	0.089	0.057
Self-efficacy—damage prevention	0.052	0.106	0.086	0.109
Self-efficacy—overcoming difficulties	0.003	0.944	0.951	0.944
Economic factors (X_2)				
Importance of market income	−0.030	0.356	0.437	0.342
Importance of biodiversity payments	0.154	0.000	0.000	0.000
Importance of cultural landscape payments	−0.087	0.001	0.000	0.001
Importance of production system payments	−0.083	0.006	0.018	0.020
Importance of food security payments	0.002	0.939	0.921	0.945
Farm characteristics (X_3)				
Farm type (Reference: Arable farming)				
Special cultures	0.262	0.205	0.387	0.323
Dairy cows	0.974	0.000	0.000	0.000
Suckler cows	1.056	0.001	0.000	0.001
Cattle mixed	0.737	0.023	0.002	0.005
Horses/sheep/goats	0.702	0.010	0.001	0.008
Processing	0.761	0.010	0.000	0.007
Combined dairy cows/arable farming	0.217	0.466	0.400	0.377
Combined suckler cows	0.302	0.251	0.020	0.192
Combined processing	0.530	0.042	0.011	0.052
Combined others	0.601	0.015	0.003	0.006
Agricultural zone (Reference: Valley)				
Hill	0.028	0.758	0.801	0.791
Mountain I	−0.194	0.161	0.127	0.154
Mountain II	−0.386	0.008	0.060	0.011
Mountain III	−0.648	0.006	0.012	0.008
Mountain IV	−0.927	0.082	0.145	0.026
Production system (1 = organic; 0 = non-organic)	0.165	0.156	0.108	0.147
Utilised agricultural area	−0.007	0.141	0.148	0.144
Livestock units	−0.000	0.999	0.999	0.999
Socio-demographic characteristics (X_4)				
Activity (1 = full time; 0 = part time)	−0.018	0.878	0.862	0.858
Farm manager age	0.003	0.376	0.291	0.416
Education (Reference: Practical experience)				
Federal vocational certificate	0.747	0.057	0.051	0.035
Federal certificate of competence	0.344	0.258	0.120	0.191
Professional examination	0.141	0.663	0.569	0.619
Master's examination	0.279	0.401	0.238	0.311
Higher college	0.023	0.942	0.926	0.938
Bachelor's degree/Master's degree, or higher	0.034	0.914	0.890	0.904
Other	0.220	0.578	0.486	0.539
Language region (1 = German; 0 = French)	0.232	0.098	0.127	0.097
Intercept	−1.947	0.000	0.000	0.000

Table C7
Results of the regression analysis considering the heterogeneity of landscape features with the dependent variable 'area of landscape features'.

Independent variables	Landscape features eligible for biodiversity payments	Landscape features not eligible for biodiversity payments
Socio-psychological factors (X_1)		
Personal norms	0.057**	0.289***
	(0.026)	(0.093)
Injunctive norm—family	0.044	−0.012
	(0.027)	(0.072)
Injunctive norm—acquaintances	−0.018	−0.113
	(0.030)	(0.093)
Descriptive norm—other farmers	−0.006	−0.105
	(0.028)	(0.083)
Self-efficacy—personal skills	0.083**	−0.040
	(0.034)	(0.114)

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Table C7 (*continued*)

Independent variables	Landscape features eligible for biodiversity payments	Landscape features not eligible for biodiversity payments
Self-efficacy—damage prevention	0.057*	−0.110
	(0.030)	(0.092)
Self-efficacy—overcoming difficulties	−0.005	−0.148
	(0.032)	(0.114)
Economic factors (X_2)		
Importance of market income	−0.031	0.146*
	(0.027)	(0.080)
Importance of biodiversity payments	0.144***	0.104
	(0.028)	(0.075)
Importance of cultural landscape payments	−0.056**	−0.022
	(0.026)	(0.069)
Importance of production system payments	−0.127***	−0.071
	(0.038)	(0.092)
Importance of food security payments	0.007	−0.001
	(0.031)	(0.081)
Farm characteristics (X_3)		
Farm type (Reference: Arable farming)		
Special cultures	0.055	−1.305
	(0.300)	(0.829)
Dairy cows	0.921***	0.259
	(0.262)	(0.658)
Suckler cows	1.130***	0.422
	(0.327)	(0.675)
Cattle mixed	0.610**	0.208
	(0.265)	(0.667)
Horses/sheep/goats	0.701**	−0.015
	(0.279)	(0.883)
Processing	0.725**	−0.053
	(0.303)	(0.839)
Combined dairy cows/arable farming	0.214	−0.470
	(0.239)	(0.708)
Combined suckler cows	0.400	0.637
	(0.255)	(0.662)
Combined processing	0.368	0.407
	(0.275)	(0.762)
Combined others	0.530**	−0.066
	(0.228)	(0.603)
Agricultural zone (Reference: Valley)		
Hill	−0.073	0.673*
	(0.099)	(0.365)
Mountain I	−0.317**	0.749*
	(0.134)	(0.388)
Mountain II	−0.676***	0.764**
	(0.143)	(0.378)
Mountain III	−0.860***	0.025
	(0.210)	(0.714)
Mountain IV	−1.534***	−2.421***
	(0.360)	(0.760)
Production system (1 = organic; 0 = non-organic)	0.176*	0.155
	(0.097)	(0.282)
Utilised agricultural area	0.019***	0.031***
	(0.004)	(0.009)
Livestock units	0.001	0.001
	(0.002)	(0.005)
Socio-demographic characteristics (X_4)		
Activity (1 = full time; 0 = part time)	0.303***	−0.400
	(0.096)	(0.323)
Farm manager age	0.002	0.000
	(0.004)	(0.012)
Education (Reference: Practical experience)		
Federal vocational certificate	0.733**	−0.418
	(0.324)	(0.847)
Federal certificate of competence	0.426*	0.397
	(0.254)	(0.527)
Professional examination	0.288	1.122*
	(0.273)	(0.602)
Master's examination	0.342	0.995*
	(0.258)	(0.585)
Higher college	0.180	0.201
	(0.278)	(0.716)
Bachelor's degree/Master's degree, or higher	0.098	0.342

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Table C7 (*continued*)

Independent variables	Landscape features eligible for biodiversity payments	Landscape features not eligible for biodiversity payments
	(0.272)	(0.742)
Other	0.320	−0.025
	(0.331)	(0.749)
Language region (1 = German; 0 = French)	0.100	−0.443
	(0.130)	(0.334)
Intercept	−2.469***	−5.161***
	(0.435)	(1.170)
Number of observations	815	815
AIC	1993	215
BIC	2191	408
Pseudo R^2	0.130	0.101

***, ** and * denote significance at 1 %, 5 % and 10 % respectively. Robust standard errors are in parentheses.

Table C8
Results of the regression analysis considering the heterogeneity of landscape features with the dependent variable 'ecological value of landscape features'.

Independent variables	Landscape features eligible for biodiversity payments	Landscape features not eligible for biodiversity payments
Socio-psychological factors (X_1)		
Personal norms	0.051*	0.202**
	(0.031)	(0.103)
Injunctive norm—family	0.015	−0.032
	(0.029)	(0.093)
Injunctive norm—acquaintances	−0.017	−0.039
	(0.029)	(0.100)
Descriptive norm—other farmers	−0.011	−0.083
	(0.030)	(0.080)
Self-efficacy—personal skills	0.070**	−0.034
	(0.034)	(0.101)
Self-efficacy—damage prevention	0.056	−0.059
	(0.035)	(0.091)
Self-efficacy—overcoming difficulties	0.007	−0.149
	(0.038)	(0.080)
Economic factors (X_2)		
Importance of market income	−0.033	0.114
	(0.031)	(0.080)
Importance of biodiversity payments	0.156***	0.094
	(0.031)	(0.070)
Importance of cultural landscape payments	−0.088***	−0.041
	(0.026)	(0.068)
Importance of production system payments	−0.086**	0.043
	(0.036)	(0.093)
Importance of food security payments	0.003	−0.059
	(0.027)	(0.083)
Farm characteristics (X_3)		
Farm type (Reference: Arable farming)		
Special cultures	0.253	0.351
	(0.278)	(0.785)
Dairy cows	0.987***	0.289
	(0.265)	(0.717)
Suckler cows	1.073***	0.234
	(0.316)	(0.727)
Cattle mixed	0.732***	0.617
	(0.265)	(0.760)
Horses/sheep/goats	0.732***	−1.033
	(0.279)	(0.807)
Processing	0.767***	0.103
	(0.290)	(0.833)
Combined dairy cows/arable farming	0.230	−0.454
	(0.257)	(0.773)
Combined suckler cows	0.291	0.429
	(0.238)	(0.715)
Combined processing	0.538	0.128
	(0.279)	(0.869)
Combined others	0.617***	−0.178
	(0.224)	(0.678)
Agricultural zone (Reference: Valley)		
Hill	0.018	0.476
	(0.103)	(0.374)
Mountain I	−0.213	0.587
	(0.138)	(0.383)
Mountain II	−0.413***	0.599

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Table C8 (*continued*)

Independent variables	Landscape features eligible for biodiversity payments	Landscape features not eligible for biodiversity payments
	(0.152)	(0.365)
Mountain III	−0.648***	−0.700
	(0.250)	(0.558)
Mountain IV	−0.917***	−2.875***
	(0.415)	(0.966)
Production system (1 = organic; 0 = non-organic)	0.159	0.415
	(0.112)	(0.374)
Utilised agricultural area	−0.007	0.003
	(0.005)	(0.011)
Livestock units	−0.000	0.003
	(0.002)	(0.006)
Socio-demographic characteristics (X_4)		
Activity (1 = full time; 0 = part time)	−0.008	−0.462
	(0.100)	(0.315)
Farm manager age	0.003	0.009
	(0.004)	(0.011)
Education (Reference: Practical experience)		
Federal vocational certificate	0.767**	−0.631
	(0.362)	(0.831)
Federal certificate of competence	0.350	0.061
	(0.273)	(0.502)
Professional examination	0.118	0.794
	(0.293)	(0.601)
Master's examination	0.274	0.466
	(0.281)	(0.586)
Higher college	0.024	−0.040
	(0.298)	(0.671)
Bachelor's degree/Master's degree, or higher	0.013	0.647
	(0.292)	(0.664)
Other	0.202	0.539
	(0.370)	(0.660)
Language region (1 = German; 0 = French)	0.242*	−0.048
	(0.141)	(0.374)
Intercept	−2.002***	−4.896***
	(0.492)	(1.184)
Number of observations	815	815
AIC	1764	220
BIC	1957	412
Pseudo R^2	0.091	0.059

Data availability

The data that has been used is confidential.

References

Abadie, A., Athey, S., Imbens, G.W., Wooldridge, J.M., 2023. When should you adjust standard errors for clustering? Q. J. Econ. 138 (1), 1–35. https://doi.org/10.1093/qje/qjac038.

Bandura, A., 1977. Self-efficacy: toward a unifying theory of behavioral change. Psychol. Rev. 84, 191–215. https://doi.org/10.1037/0033-295X.84.2.191.

Barreiro-Hurlé, J., Espinosa-Goded, M., Dupraz, P., 2010. Does intensity of change matter? Factors affecting adoption of Agri-environmental schemes in Spain. J. Environ. Plan. Manag. 53, 891–905. https://doi.org/10.1080/09640568.2010.490058.

Belsley, D., Kuh, E., Welsch, R., 1980. Regression Diagnostics. Wiley, New York.

Borsotto, P., Henke, R., Macrì, M.C., Salvioni, C., 2008. Participation in rural landscape conservation schemes in Italy. Landsc. Res. 33, 347–363. https://doi.org/10.1080/01426390802046044.

Burton, R.J., 2004a. Reconceptualising the 'behavioural approach' in agricultural studies: a socio-psychological perspective. J. Rural. Stud. 20, 359–371. https://doi.org/10.1016/j.jrurstud.2003.12.001.

Burton, R.J., 2004b. Seeing through the 'good farmer's' eyes: towards developing an understanding of the social symbolic value of 'productivist' behaviour. Sociol. Rural. 44, 195–215. https://doi.org/10.1111/j.1467-9523.2004.00270.x.

Busck, A.G., 2002. Farmers' landscape decisions: relationships between farmers' values and landscape practices. Sociol. Rural. 42, 233–249. https://doi.org/10.1111/1467-9523.00213.

Busse, M., Zoll, F., Siebert, R., Bartels, A., Bokelmann, A., Scharschmidt, P., 2021. How farmers think about insects: perceptions of biodiversity, biodiversity loss and attitudes towards insect-friendly farming practices. Biodivers. Conserv. 30 (11), 3045–3066. https://doi.org/10.1007/s10531-021-02235-2.

Calabuig, V., Olcina, G., Panebianco, F., 2014. The dynamics of personal norms and the emergence of cultural diversity. In: Discussion Papers in Economic Behaviour 05/14. https://www.uv.es/erices/RePEc/WP/2014/0514.pdf.

Calvet, C., Le Coent, P., Napoleone, C., Quétier, F., 2019. Challenges of achieving biodiversity offset outcomes through Agri-environmental schemes: evidence from an empirical study in southern France. Ecol. Econ. 163, 113–125. https://doi.org/10.1016/j.ecolecon.2019.03.026.

Cameron, A.C., Trivedi, P.K., 2014. Regression Analysis of Count Data. Cambridge University Press, Cambridge, UK.

Canessa, C., Venus, T.E., Wiesmeier, M., Mennig, P., Sauer, J., 2023. Incentives, rewards or both in payments for ecosystem services: drawing a link between farmers' preferences and biodiversity levels. Ecol. Econ. 213, 107954. https://doi.org/10.1016/j.ecolecon.2023.107954.

Casagrande, M., Peigné, J., Payet, V., Mäder, P., Sans, F.X., Blanco-Moreno, J.M., Antichi, D., Bàrberi, P., Beeckman, A., Bigongiali, F., Cooper, J., Dierauer, H., Gascoyne, K., Grosse, M., Heß, J., Kranzler, A., Luik, A., Peetsmann, E., Surböck, A., Willekens, K., David, C., 2016. Organic farmers' motivations and challenges for adopting conservation agriculture in Europe. Org. Agric. 6, 281–295. https://doi.org/10.1007/s13165-015-0136-0.

Chatterjee, S., Hadi, A.S., 2012. Regression Analysis by Example, 5th Edition. Wiley, New York, p. 98.

Cialdini, R.B., Reno, R.R., Kallgren, C.A., 1990. A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. J. Pers. Soc. Psychol. 58, 1015–1026. https://doi.org/10.1037/0022-3514.58.6.1015.

Curran, M., de Souza, D.M., Antón, A., Teixeira, R.F.M., Michelsen, O., Vidal-Legaz, B., Sala, S., Milài Canals, L., 2016. How well does LCA model land use impacts on biodiversity? A comparison with approaches from ecology and conservation. Environ. Sci. Technol. 50, 2782–2795. https://doi.org/10.1021/acs.est.5b04681.

Czúcz, B., Baruth, B., Angileri, V., Prieto Lopez, A., Hagyo, A., Terres, J.M., 2022. Landscape Features in the EU Member States: A Review of Existing Data and Approaches. Publications Office of the European Union, Luxembourg. https://doi.org/10.2760/101979, JRC128876.

Defrancesco, E., Gatto, P., Runge, F., Trestini, S., 2008. Factors affecting farmers' participation in Agri-environmental measures: a northern Italian perspective. Aust. J. Agric. Econ. 59, 114–131. https://doi.org/10.1111/j.1477-9552.2007.00134.x.

D'Emden, F.H., Llewellyn, R.S., Burton, M.P., 2008. Factors influencing adoption of conservation tillage in Australian cropping regions. J. Agric. Resour. Econ. 52, 169–182. https://doi.org/10.1111/j.1467-8489.2008.00409.x.

Dessart, F.J., Barreiro-Hurlé, J., van Bavel, R., 2019. Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. Eur. Rev. Agric. Econ. 46, 417–471. https://doi.org/10.1093/erae/jbz019.

Dormann, C.F., Schweiger, O., Augenstein, I., Bailey, D., Billeter, R., de Blust, G., DeFilippi, R., Frenzel, M., Hendrickx, F., Herzog, F., Klotz, S., Liira, J., Maelfait, J.-P., Schmidt, T., Speelmans, M., van Wingerden, W.K.R.E., Zobel, M., 2007. Effects of landscape structure and land-use intensity on similarity of plant and animal communities. Glob. Ecol. Biogeogr. 16, 774–787. https://doi.org/10.1111/j.1466-8238.2007.00344.x.

Ducos, G., Dupraz, P., Bonnieux, F., 2009. Agri-environment contract adoption under fixed and variable compliance costs. J. Environ. Plan. Manag. 52, 669–687. https://doi.org/10.1080/09640560902958248.

El Benni, N., Schmid, D., 2022. Off-farm income and direct payments—an indispensable diversification strategy of Swiss farmers. Q Open 2, qoab019.

Eurostat, 2021. Glossar: Großvieheinheit (GVE) Online. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_(LSU)/de.

Fleury, P., Seres, C., Dobremez, L., Nettier, B., Pauthenet, Y., 2015. 'Flowering meadows', a result-oriented Agri-environmental measure: technical and value changes in favour of biodiversity. Land Use Policy 46, 103–114. https://doi.org/10.1016/j.landusepol.2015.02.007.

FOAG (Federal Office for Agriculture), 2020. Weisungen und Erläuterungen 2020 zur Verordnung über den landwirtschaftlichen Produktionskataster und die Ausscheidung von Zonen (Landwirtschaftliche Zonen-Verordnung; SR 912.1). Bundesamt für Landwirtschaft, Bern, Switzerland.

FOAG (Federal Office for Agriculture), 2023a. Direktzahlungen. Online. https://www.blw.admin.ch/blw/de/home/instrumente/direktzahlungen.html.

FOAG (Federal Office for Agriculture), 2023b. Landwirtschaftliche Zonen. Online. https://www.blw.admin.ch/blw/de/home/instrumente/grundlagen-und-querschnittsthemen/landwirtschaftliche-zonen.html.

FOAG (Federal Office for Agriculture), 2025. Verordnungüber die Direktzahlungen an die Landwirtschaft. Direktzahlungsverordnung, DZV. https://www.fedlex.admin.ch/eli/cc/2013/765/de.

Gliesmann, S., 2016. Transforming food systems with agroecology. Agroecol. Sustain. Food Syst. 40 (3), 187–189. https://doi.org/10.1080/21683565.2015.1130765.

Granado-Díaz, R., Villanueva, A.J., Gómez-Limón, J.A., 2022. Willingness to accept for rewilding farmland in environmentally sensitive areas. Land Use Policy 116, 106052. https://doi.org/10.1016/j.landusepol.2022.106052.

Guan, W., 2003. From the help desk: bootstrapped standard errors. Stata J. 3, 71–80. https://doi.org/10.1177/1536867X0300300105.

Guntern, J., Pauli, D., Klaus, G., 2020. Biodiversitätsfördernde Strukturen im Landwirtschaftsgebiet. In: Bedeutung, Entwicklung und Stossrichtungen für die Förderung. Forum Biodiversität Schweiz (SCNAT), Bern.

Hasler, B., Termansen, M., Nielsen, H.Ø., Daugbjerg, C., Wunder, S., Latacz-Lohmann, U., 2022. European Agri-environmental policy: evolution, effectiveness, and challenges. Rev. Environ. Econ. Policy 16, 105–125. https://doi.org/10.1086/718212.

Hendrickx, J., 2004. COLDIAG2: Stata Module to Evaluate Collinearity in Linear Regression, Statistical Software Components S445202. Boston College Department of Economics. Revised 09 Dec 2004. Online. https://ideas.repec.org/c/boc/bocode/s445202.html.

Home, R., Indermuehle, A., Tschanz, A., Ries, E., Stolze, M., 2019. Factors in the decision by Swiss farmers to convert to organic farming. Renew. Agric. Food Syst. 34, 571–581. https://doi.org/10.1017/S1742170518000121.

Howley, P., Ocean, N., 2021. Doing more with less: leveraging social norms and status con-cerns in encouraging conservation farm practices. Land Econ. 97 (2), 372–387. https://doi.org/10.3368/le.97.2.372.

Ingram, J., Gaskell, P., Mills, J., Short, C., 2013. Incorporating Agri-environment schemes into farm development pathways: a temporal analysis of farmer motivations. Land Use Policy 31, 267–279. https://doi.org/10.1016/j.landusepol.2012.07.007.

Jan, P., Schmid, D., Renner, S., Schiltknecht, P., Hoop, D., 2023. Die wirtschaftliche Entwicklung der schweizerischen Landwirtschaft 2022. Agroscope Sci. 506, 1–8. Online: https://www.newsd.admin.ch/newsd/message/attachments/84186.pdf.

Jeanneret, P., Baumgartner, D.U., Freiermuth Knuchel, R., Koch, B., Gaillard, G., 2014. An expert system for integrating biodiversity into agricultural life-cycle assessment. Ecol. Indic. 46, 224–231. https://doi.org/10.1016/j.ecolind.2014.06.030.

Jeanneret, P., Lüscher, G., Schneider, M.K., Pointereau, P., Arndorfer, M., Bailey, D., Balázs, K., Báldi, A., Choisis, J.-P., Dennis, P., Diaz, M., Eiter, S., Elek, Z., Fjellstad, W., Frank, T., Friedel, J.K., Geijzendorffer, I.R., Gillingham, P., Gomiero, T., Jerkovich, G., Jongman, R.H.G., Kainz, M., Kovács-Hostyánszki, A., Moreno, G., Nascimbene, J., Oschatz, M.-L., Paoletti, M.G., Sarthou, J.-P., Siebrecht, N., Sommaggio, D., Wolfrum, S., Herzog, F., 2021. An increase in food production in Europe could dramatically affect farmland biodiversity. Commun. Earth Environ. 2. https://doi.org/10.1038/s43247-021-00256-x.

Kahane, R., Hodgkin, T., Jaenicke, H., Hoogendoorn, C., Hermann, M., Keatinge, J.D.H., d'Arros Hughes, J., Padulosi, S., Looney, N., 2013. Agrobiodiversity for food security, health and income. Agron. Sustain. Dev. 33, 671–693. https://doi.org/10.1007/s13593-013-0147-8.

Kaiser, A., Burger, P., 2022. Understanding diversity in farmers' routinized crop protection practices. J. Rural. Stud. 89, 149–160. https://doi.org/10.1016/j.jrurstud.2021.12.002.

Kaiser, F.G., Wölfing, S., Fuhrer, U., 1999. Environmental attitude and ecological behaviour. J. Environ. Psychol. 19, 1–19. https://doi.org/10.1006/jevp.1998.0107.

Kaiser, A., Samuel, R., Burger, P., 2024. Toward a low-pesticide agriculture: bridging practice theory and social-psychological concepts to analyse farmers' routines. Sustain. Sci. Pract. Policy 20. https://doi.org/10.1080/15487733.2024.2306731.

Karali, E., Brunner, B., Doherty, R., Hersperger, A., Rounsevell, M., 2014. Identifying the factors that influence farmer participation in environmental management practices in Switzerland. Human Ecology 42, 951–963. https://doi.org/10.1007/s10745-014-9701-5.

Khamzina, K., Huet, S., Deffuant, G., Streith, M., Guimond, S., 2021. Making the planet green again: the interplay of attitudes and group norms in the conversion to organic farming. J. Appl. Soc. Psychol. 51 (11), 1073–1088. https://doi.org/10.1111/jasp.12825.

Klebl, F., Feindt, P.H., Piorr, A., 2023. Farmers' behavioural determinants of on-farm biodiversity management in Europe: a systematic review. Agric. Hum. Values. https://doi.org/10.1007/s10460-023-10505-8.

Kleijn, D., Rundlöf, M., Scheper, J., Smith, H.G., Tscharntke, T., 2011. Does conservation on farmland contribute to halting the biodiversity decline? Trends Ecol. Evol. 26, 474–481. https://doi.org/10.1016/j.tree.2011.05.009.

Klein, N., Herzog, F., Jeanneret, P., Kay, S., 2023. Validating farmland biodiversity life cycle assessment at the landscape scale. Environ. Sci. Technol. 57, 9184–9193. https://doi.org/10.1021/acs.est.2c09677.

Klöckner, C.A., Blöbaum, A., 2010. A comprehensive action determination model: toward a broader understanding of ecological behaviour using the example of travel mode choice. J. Environ. Psychol. 30, 574–586. https://doi.org/10.1016/j.jenvp.2010.03.001.

Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. Food Policy 32, 25–48. https://doi.org/10.1016/j.foodpol.2006.01.003.

Kuhfuss, L., Préget, R., Thoyer, S., Hanley, N., Le Coent, P., Désolé, M., 2016. Nudges, social norms, and permanence in Agri-environmental schemes. Land Econ. 92, 641–655. https://doi.org/10.3368/le.92.4.641.

Lanz, B., Dietz, S., Swanson, T., 2018. The expansion of modern agriculture and global biodiversity decline: an integrated assessment. Ecol. Econ. 144, 260–277. https://doi.org/10.1016/j.ecolecon.2017.07.018.

Läpple, D., Kelley, H., 2013. Understanding the uptake of organic farming: accounting for heterogeneities among Irish farmers. Ecol. Econ. 88, 11–19. https://doi.org/10.1016/j.ecolecon.2012.12.025.

Läpple, D., van Rensburg, T., 2011. Adoption of organic farming: are there differences between early and late adoption? Ecol. Econ. 70, 1406–1414. https://doi.org/10.1016/j.ecolecon.2011.03.002.

Lastra-Bravo, X.B., Hubbard, C., Garrod, G., Tolón-Becerra, A., 2015. What drives farmers' participation in EU agri-environmental schemes? Results from a qualitative meta-analysis. Environ. Sci. Pol. 54, 1–9. https://doi.org/10.1016/j.envsci.2015.06.002.

Le Coent, P., Preget, R., Thoyer, S.S., 2018. Do farmers follow the herd? The influence of social norms in the participation to Agri-environmental schemes. Online: ffhalshs-01936004f.

Lüscher, G., Nemecek, T., Arndorfer, M., Balázs, K., Dennis, P., Fjellstad, W., Friedel, J.K., Gaillard, G., Herzog, F., Sarthou, J.-P., Stoyanova, S., Wolfrum, S., Jeanneret, P., 2017. Biodiversity assessment in LCA: a validation at field and farm scale in eight European regions. Int. J. Life Cycle Assess. 22, 1483–1492. https://doi.org/10.1007/s11367-017-1278-y.

Mack, G., Ritzel, C., Jan, P., 2020. Determinants for the implementation of action-, result- and multi-actor-oriented Agri-environment schemes in Switzerland. Ecol. Econ. 176, 106715. https://doi.org/10.1016/j.ecolecon.2020.106715.

Mack, G., Finger, R., Ammann, J., El Benni, N., 2023. Modelling policies towards pesticide-free agricultural production systems. Agric. Syst. 207, 103642. https://doi.org/10.1016/j.agsy.2023.103642.

Malek, Ž., Douw, B., Van Vliet, J., Van Der Zanden, E.H., Verburg, P.H., 2019. Local land-use decision-making in a global context. Environ. Res. Lett. 14, 083006. https://doi.org/10.1088/1748-9326/ab309e.

Mann, S., 2018. Conservation by innovation: what are the triggers for participation among Swiss farmers? Ecol. Econ. 146, 10–16.

McGinty, M.M., Swisher, M.E., Alavalapati, J., 2008. Agroforestry adoption and maintenance: self-efficacy, attitudes and socio-economic factors. Agrofor. Syst. 73, 99–108. https://doi.org/10.1007/s10457-008-9114-9.

Mendoza-García, M., Blanco-Moreno, J.M., Chamorro, L., José-María, L., Sans, F.X., 2018. Patterns of flower visitor abundance and fruit set in a highly intensified cereal cropping system in a Mediterranean landscape. Agriculture, Ecosystems & Environment 254, 255–263. https://doi.org/10.1016/j.agee.2017.12.001.

Mettepenningen, E., Vandermeulen, V., Delaet, K., van Huylenbroeck, G., Wailes, E.J., 2013. Investigating the influence of the institutional organisation of Agri-environmental schemes on scheme adoption. Land Use Policy 33, 20–30. https://doi.org/10.1016/j.landusepol.2012.12.004.

Meyer, S., Unternährer, D., Arlettaz, R., Humbert, J.-Y., Menz, M.H.M., 2017. Promoting diverse communities of wild bees and hoverflies requires a landscape approach to managing meadows. Agriculture, Ecosystems & Environment 239, 376–384. https://doi.org/10.1016/j.agee.2017.01.037.

Mills, J., Gaskell, P., Ingram, J., Dwyer, J., Reed, M., Short, C., 2017. Engaging farmers in environmental management through a better understanding of behaviour. Agric. Hum. Values 34, 283–299. https://doi.org/10.1007/s10460-016-9705-4.

Möhring, A., Mann, S., 2020. Causes and impacts of the mis-representation of agricultural policy—the case of food supply security payments in Switzerland. J. Policy Model 42, 466–482. https://doi.org/10.1016/j.jpolmod.2020.01.002.

Mzoughi, N., 2011. Farmers adoption of integrated crop protection and organic farming: Do moral and social concerns matter? Ecol. Econ. 70, 1536–1545. https://doi.org/10.1016/j.ecolecon.2011.03.016.

Nishizawa, T., Kay, S., Schuler, J., Klein, N., Herzog, F., Aurbacher, J., Zander, P., 2022. Ecological–economic modelling of traditional agroforestry to promote farmland biodiversity with cost-effective payments. Sustainability 14, 5615. https://doi.org/10.3390/su14095615.

Opdenbosch, H., Brady, M.V., Bimbilovski, I., Swärd, R., Manevska-Tasevska, G., 2024. Farm-level aaceptability of contract attributes in Agri-environment-climate measures for biodiversity. J. Rural. Stud. 112, 103448. https://doi.org/10.1016/j.jrurstud.2024.103448.

Pavlis, E.S., Terkenli, T.S., Kristensen, S.B., Busck, A.G., Cosor, G.L., 2016. Patterns of Agri-environmental scheme participation in Europe: indicative trends from selected case studies. Land Use Policy 57, 800–812. https://doi.org/10.1016/j.landusepol.2015.09.024.

Pe'er, G., Finn, J.A., Díaz, M., Birkenstock, M., Lakner, S., Röder, N., Kazakova, Y., Šumrada, T., Bezák, P., Concepción, E.D., Dänhardt, J., Morales, M.B., Rac, I., Špulerová, J., Schindler, S., Stavrinides, M., Targetti, S., Viaggi, D., Vogiatzakis, I.N., Guyomard, H., 2022. Conserv. Lett. 15 (6), e12901. https://doi.org/10.1111/conl.12901.

Peerlings, J., Polman, N., 2009. Farm choice between Agri-environmental contracts in the European Union. J. Environ. Plan. Manag. 52, 593–612. https://doi.org/10.1080/09640560902958131.

Poschlod, P., Braun-Reichert, R., 2017. Small natural features with large ecological roles in ancient agricultural landscapes of Central Europe-history, value, status, and conservation. Biol. Conserv. 211, 60–68.

Power, E.F., Kelly, D.L., Stout, J.C., 2013. Impacts of organic and conventional dairy farmer attitude, behaviour and knowledge on farm biodiversity in Ireland. J. Nat. Conserv. 21, 272–278. https://doi.org/10.1016/j.jnc.2013.02.002.

Raatz, L., Bacchi, N., Pirhofer Walzl, K., Glemnitz, M., Müller, M.E.H., Joshi, J., Scherber, C., 2019. How much do we really lose? Yield losses in the proximity of natural landscape elements in agricultural landscapes. Ecol. Evol. 9, 7838–7848. https://doi.org/10.1002/ece3.5370.

Renner, S., Jan, P., Hoop, D., Schmid, D., Dux-Bruggmann, D., Weber, A., Lips, M., 2019. Survey system of the Swiss farm accountancy data network with two samples: income situation sample and farm management sample. Agroscope Sci. 68, 1–76.

Ritzel, C., Mann, S., 2021. The old man and the meat: on gender differences in meat consumption across stages of human life. Foods (Basel, Switzerland) 10. https://doi.org/10.3390/foods10112809.

Robinson, R.A., Sutherland, W.J., 2002. Post-war changes in arable farming and biodiversity in Great Britain. J. Appl. Ecol. 39, 157–176. https://doi.org/10.1046/j.1365-2664.2002.00695.x.

Schaub, S., Ghazoul, J., Huber, R., Zhang, W., Sander, A., Rees, C., Banerjee, S., Finger, R., 2023. The role of behavioural factors and opportunity costs in farmers' participation in voluntary Agri-environmental schemes: a systematic review. J. Agric. Econ. 74 (3), 617–660.

Scheper, J., Badenhausser, I., Kantelhardt, J., Kirchweger, S., Bartomeus, I., Bretagnolle, V., Clough, Y., Gross, N., Raemakers, I., Vilà, M., Zaragoza-Trello, C., Kleijn, D., 2023. Biodiversity and pollination benefits trade off against profit in an intensive farming system. Proc. Natl. Acad. Sci. USA 120, e2212124120. https://doi.org/10.1073/pnas.2212124120.

Schmitzberger, I., Wrbka, T., Steurer, B., Aschenbrenner, G., Peterseil, J., Zechmeister, H. G., 2005. How farming styles influence biodiversity maintenance in Austrian agricultural landscapes. Agric. Ecosyst. Environ. 108, 274–290. https://doi.org/10.1016/j.agee.2005.02.009.

Schwartz, S.H., 1973. Normative explanations of helping behavior: a critique proposal and empirical test. J. Exp. Soc. Psychol. 9, 349–364. https://doi.org/10.1016/0022-1031(73)90071-1.

Schwartz, S.H., Howard, J.A., 1981. A normative decision-making model of altruism. In: Rishton, J.P., Sorrentino, R.M. (Eds.), Altruism and helping behavior. Lawrence Erlbaum, Hillsdale, N.J, pp. 189–211.

Somoncini, R., Ring, I., Sandström, C., Albert, C., Kasymov, U., Arlettaz, R., 2019. Constraints and opportunities for mainstreaming biodiversity and ecosystem services in the EU'S common agricultural policy: insights from the IPBES assessment for Europe and Central Asia. Land Use Policy 88, 104099. https://doi.org/10.1016/j.landusepol.2019.104099.

Špur, N., Šorgo, A., Škornik, S., 2018. Predictive model for meadow owners' participation in Agri-environmental climate schemes in Natura 2000 areas. Land Use Policy 73, 115–124. https://doi.org/10.1016/j.landusepol.2018.01.014.

Thompson, B., Leduc, G., Manevska-Tasevska, G., Toma, L., Hansson, H., 2024. Farmers' adoption of ecological practices: a systematic literature map. Aust. J. Agric. Econ. 75, 84–107. https://doi.org/10.1111/1477-9552.12545.

Tscharntke, T., Grass, I., Wanger, T.C., Westphal, C., Batáry, P., 2021. Beyond organic farming - harnessing biodiversity-friendly landscapes. Trends Ecol. Evol. 36, 919–930. https://doi.org/10.1016/j.tree.2021.06.010.

Tscharntke, T., Batáry, P., Grass, I., 2024. Mixing on- and off-field measures for biodiversity conservation. Trends Ecol. Evol. 39 (8), 726–733. https://doi.org/10.1016/j.tree.2024.04.003.

Uthes, S., Matzdorf, B., 2013. Studies on Agri-environmental measures: a survey of the literature. Environ. Manag. 51, 251–266. https://doi.org/10.1007/s00267-012-9959-6.

van Dijk, W.F., Lokhorst, A.M., Berendse, F., de Snoo, G.R., 2016. Factors underlying farmers' intentions to perform unsubsidised Agri-environmental measures. Land Use Policy 59, 207–216. https://doi.org/10.1016/j.landusepol.2016.09.003.

van Herzele, A., Gobin, A., van Gossum, P., Acosta, L., Waas, T., Dendoncker, N., Henry de Frahan, B., 2013. Effort for money? Farmers' rationale for participation in Agri-environment measures with different implementation complexity. J. Environ. Manag. 131, 110–120. https://doi.org/10.1016/j.jenvman.2013.09.030.

Van Valkengoed, A.M., Abrahamse, W., Steg, L., 2022. To select effective interventions for pro-environmental behaviour change, we need to consider determinants of behaviour. Nat. Hum. Behav. 6, 1482–1492. https://doi.org/10.1038/s41562-022-01473-w.

Vanslembrouck, I., van Huylenbroeck, G., Verbeke, W., 2002. Determinants of the willingness of Belgian farmers to participate in Agri-environmental measures. Aust. J. Agric. Econ. 53, 489–511. https://doi.org/10.1111/j.1477-9552.2002.tb00034.x.

Wang, Y., Schaub, S., Wuepper, D., Finger, R., 2023. Culture and agricultural biodiversity conservation. Food Policy 120, 102482. https://doi.org/10.1016/j.foodpol.2023.102482.

White, H., 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica 48, 817–838. https://doi.org/10.2307/1912934.

Włodarczyk-Marciniak, R., Frankiewicz, P., Krauze, K., 2020. Socio-cultural valuation of polish agricultural landscape components by farmers and its consequences. J. Rural. Stud. 74, 190–200. https://doi.org/10.1016/j.jrurstud.2020.01.017.

Wossink, G.A.A., van Wenum, J.H., 2003. Biodiversity conservation by farmers: analysis of actual and contingent participation. European Review of Agricultural Economics 30 (4), 461–485. https://doi.org/10.1093/erae/30.4.461.

Zhillima, E., Shahu, E., Xhoxhi, O., Gjika, I., 2021. Understanding farmers' intentions to adopt organic farming in Albania. New Medit. 20. https://doi.org/10.30682/nm2105g.

Zimmermann, A., Britz, W., 2016. European farms' participation in Agri-environmental measures. Land Use Policy 50, 214–228. https://doi.org/10.1016/j.landusepol.2015.09.019.

Zinngrebe, Y., Pe'er, G., Schueler, S., Schmitt, J., Schmidt, J., Lakner, S., 2017. The EU'S ecological focus areas—how experts explain farmers' choices in Germany. Land Use Policy 65, 93–108. https://doi.org/10.1016/j.landusepol.2017.03.027.