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Will Farmers Accept Lower Gross Margins for the Sustainable Cultivation Method of Mixed Cropping? First Insights from Germany

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Abstract: A decline in the legume cultivation has contributed to the biodiversity loss within the agricultural production across Europe. One possibility to include legumes into the production and promote sustainability is mixed cropping with legumes and non-legumes. However, the adoption of mixed cropping is challenging for farmers and information about the profitability is scarce. If mixed cropping should become a widely established production method, it is essential to gain an understanding of famers' evaluation of the profitability mixed cropping needs to reach. Therefore, this article provides first empirical insights into farmers stated willingness to accept gross margin changes compared to current production possibilities. Based on a survey with results from 134 German non-adopters conducted in 2018 we can distinguish conventional farmers with a positive, neutral and negative willingness to accept reductions in gross margins as the trade-off for ecological benefits. Using an ordered logistic model we find that risk attitude, risk perception, the number of measures performed for ecological focus areas, the farmer's age and being located in the south of Germany influence their willingness to accept gross margin changes compared to currently produced cereals.

Keywords: willingness to accept; gross margin; mixed cropping; ordered logistic regression

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1. Introduction

In accordance with the Sustainable Development Goals of the United Nations, restoring biodiversity and promoting sustainable production patterns are among some of the goals sustainable agriculture should achieve [1] Promoting changes towards a more ecologically beneficial production and reducing negative environmental externalities of current production patterns are therefore core challenges the agricultural sector has to address [2]. A substantial decline in the cultivation of legumes has reduced the provision of ecosystem services and contributed to the biodiversity loss within agricultural production patterns in the European Union (EU) [3,4]. Legumes are able to fixate atmospheric nitrogen (N) through symbiosis with rhizobia in their root system. They can thus reduce the need for mineral N fertilizers which in turn can decrease nitrate leaching and potentially ground water pollution [5]. However, conventional crop rotations in the EU are largely dominated by cereals nowadays. In 2019, around 121 Mio hectare (ha) of cereals were cultivated within the EU, whereas the cultivation of grain legumes amounted to approximately 5 Mio ha [6]. Enhancing legume production has therefore been a political objective. The EU's Common Agricultural Policy (CAP) regulations currently include legumes as part of the greening restrictions, in particular for the provision of Ecological Focus Areas (EFA), in order to encourage adoption by farmers. Nevertheless, the implementation of a pesticide ban with the last adaptation of regulations is assumed to be the reason for a decline from 40% to 24% of legumes in EFA between 2017 and 2018 on the EU level [7].

The plant production in Germany is likewise characterized by a large share of cereals, with winter wheat being the most dominantly cultivated cereal by far [8]. Due to the current agronomic practices and favorable climatic conditions winter varieties in particular are highly productive and profitable [9]. This has led to Germany being the second largest producer of wheat within the EU [10] but it is also part of the reason why Germany is the second largest consumer of mineral N fertilizers [11]. The cereal production is heavily reliant on the use of fertilizers and chemical crop protection products. In contrast, the cultivation of grain legumes has steadily declined over the past decades due to the low economic competitiveness [12]. Even though a slight increase in the cultivated area has been observed in recent years [12], the area cultivated with grain legumes still amounts to only approximately 0.2 Mio ha versus over 6 Mio ha of cereals [8]. As a result there has been a national political focus on enhancing the legume production [12].

One possibility to (re)introduce more legumes into crop rotations and promote sustainable intensification is mixed cropping [13,14]. Mixed cropping, also known as the cultivation of mixed stands or intercropping, is by definition the simultaneous production of two or more coexisting crops on the same area of land [15]. The simultaneous cultivation of legumes and non-legumes in particular can contribute to the provision of ecosystem services while maintaining productivity by utilizing basic ecological concepts and the legume's ability to fixate atmospheric nitrogen [16–19]. Combining non-legumes with legumes reduces the intraspecific competition between the non-legumes with respect to the uptake of mineral N. Simultaneously the legumes in mixed stands fixate atmospheric N which is further promoted by the cereals uptake of soil mineral N [16]. These effects inter alia facilitate a sustainable cultivation. However, the adoption of mixed cropping with main crops (e.g., wheat and faba bean, oat and pea) is especially associated with a number of challenges for European farmers that have been recognized and discussed [14,17,18,20]. In a recent review, Mamine and Farés [14] provide a detailed overview of barriers and levers associated with the mixed cropping of wheat and peas in Europe. Their review highlights the challenges along the value chain for such a specialized production method. For instance, the options for chemical crop protection in mixed stands are limited. This is due to the fact that a treatment which is beneficial for one crop species can be detrimental for the other species in the mixed stand. Hence, the production and yield risk is higher for mixed cropping.

Socio-economic research related to the adoption of mixed cropping with grain legumes in Europe, and Germany in particular, is scarce. Lemken et al. [20] were the first who presented empirical results with respect to early adopters of mixed cropping in Germany. Bonke and Musshoff [21] provided deeper insights into the motivation of farmers to adopt mixed cropping and empirically evaluated the barriers that hinder the widespread adoption. To the best of our knowledge no study to date focuses on the profitability dimension of mixed cropping from a farmer's point of view. Still, there is consensus in the literature that adoption across Europe could be facilitated by the implementation of an environmental scheme [14,17,21] and that a lack of research related to the economic efficiency in high-input agricultural systems persists [13,22]. If a shift within the conventional agriculture sector towards the extensive and more sustainable cultivation of mixed stands should be achieved, the assessment of farmers' willingness to accept (WTA) profitability changes is imperative. Especially considering the many associated challenges that have been identified, like technical barriers and difficulties in crop protection [14,18], the adoption of mixed cropping is also associated with a higher risk from the farmers' perspective. Assessing farmers' WTA profitability changes is consequently the first step to evaluate to what extent financial incentives are necessary to facilitate widespread adoption.

While providing additional ecological benefits compared to sole cropping, mixed cropping also maintains the productivity to generate agricultural output from the land [23]. Moreover, some of the ecological benefits associated with mixed cropping can affect the farm directly. For instance by improving soil quality and reducing the need for synthetic N-fertilizers [24]. Especially the possibility to reduce synthetic N-fertilizers is one aspect that has direct economic effects, for example by reducing production costs. Other ecological benefits, like the increased biodiversity and reduced nitrate leaching [18], are ecosystem services that have positive effects beyond the scope of the farm. In this respect, mixed cropping is broadly comparable to conservation agriculture, where production is aimed to be more environmentally friendly while agricultural output is maintained. Nonetheless, from a farmer's point of view switching from sole to mixed cropping with main crops is a far greater conversion than from, e.g., conservational tillage to no-tillage.

Chouinard et al. [25] derived an expanded utility framework for farmers' selection of conservation practices that incorporates self and social interest with respect to the environment as components of a farmer's utility. They hypothesized that some farmers would be willing to forgo parts of profits for eco-friendly agricultural practices, and found empirical support that some farmers are indeed willing to choose less profitable production methods. Their results further show that farmers are heterogeneous with respect to their willingness to pay for an increase in environmental benefits. Several other studies have also shown that farmers are heterogeneous with respect to their WTA payments for ecosystem services and that farmers are not behaving in a strictly profit maximizing way, e.g., [26–28]. If the objective is to establish mixed cropping as a cultivation method within the production portfolio of farms in the long-run, it is hence also essential to get an understanding whether farmers evaluation of the profitability levels mixed cropping needs to reach are heterogeneous. Against this background, we formulated the research questions: (1) Are farmers willing to forgo profits for the sustainable cultivation method of mixed cropping? (2) Do farmers' risk attitude and their perception of the risk associated with mixed cropping influence the willingness to accept profitability changes?

We aim to distinguish groups of farmers that are heterogeneous in their WTA to provide impulses on which non-adopters to target first to facilitate mixed cropping adoption. Non-adopters who have a positive WTA reduction in profitability compared to current dominant production possibilities will be the ones who will demand the lowest financial incentives for adoption. This makes them of particular interest for researchers and policy makers.

2. Materials and Methods

2.1. Willingness to Accept Reduced Gross Margins

To elicit whether farmers are willing to accept reductions in gross margins (€/ha), i.e., forego profits, and are heterogeneous in their willingness to accept we chose a three-step approach. Changing the production towards mixed stands implies that farmers have to reduce their production of pure stands. Thus, with respect to property rights and the economic consequences in line with the contingent valuation literature, the appropriate concept is the evaluation of the WTA [29]. Since cereals vastly dominate the agricultural production in Germany, the gross margin of the cereal was chosen as the reference point. This was done in order to provide a realistic and familiar scenario for the farmers as the status quo comparison. To account for the forgone gross margin of the cereal production, and thus capturing the majority of opportunity costs for adopting mixed cropping, in the first step farmers were asked, whether they would be willing to cultivate mixed stands with main crops if the gross margin is equal to that of the cereal in the pure stand. Farmers who gave a positive response to the first question were subsequently asked if they would be willing to accept lower gross margins in the mixed stands when considering the associated ecological benefits. Only farmers who indicated that they were willing to accept a lower gross margin were presented with a third open-ended question that asked how much of the gross margin they would be willing to give up for the cultivation of mixed stands considering the additional ecological benefits (in %) (Figure 1).

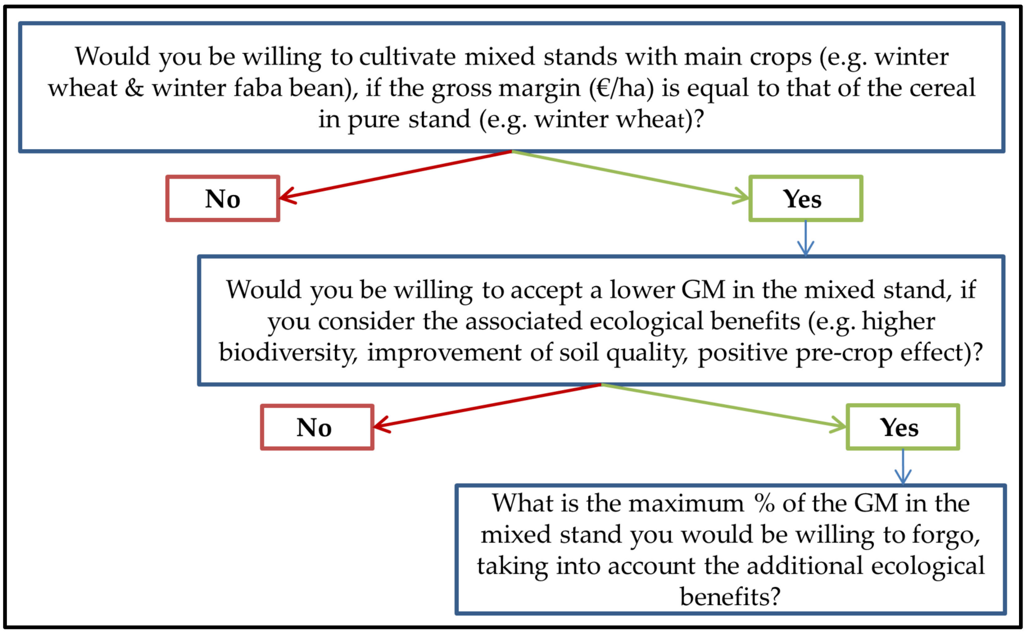

Figure 1. Three Step Questioning Approach (GM—Gross Margin).

This three-step approach allows us to distinguish three groups of farmers that are heterogeneous in their WTA foregone profits in exchange for the ecologically advantageous production method of mixed cropping (Table 1). However, an equal gross margin between the pure stand and the mixed stand does not account for all cost components associated with a change towards mixed cropping. Using the gross margins abstracts from the possibility that additional investment might be necessary [14], that learning costs arise [30], that variable labor costs could be higher or that income risks increase. On the other side, the positive pre-crop effect of mixed cropping, which inter alia can reduce costs for N fertilizer in the following crop [17], is also not included in the gross margins. Nevertheless, since the gross margin is one of the most common profitability criteria that farmers are familiar with and base their production decisions on, using the gross margins allows for the most realistic baseline in our case.

Table 1. Classification of Groups by Willingness to Accept (WTA).

Group	Description	Implication
"negative" WTA	Not willing to accept equal gross margin for mixed cropping	$GM_{Mixed} > GM_{Pure}$
"neutral" WTA	Willing to accept equal gross margin for mixed cropping	$GM_{Mixed} = GM_{Pure}$
"positive" WTA	Willing to accept lower gross margin for mixed cropping	$GM_{Mixed} < GM_{Pure}$

GM_{Mixed}—Gross Margin Mixed Stand; GM_{Pure}—Gross Margin Pure Stand.

Furthermore, we explicitly decided to frame the questions without implying any relation to a political scheme or subsidy. For one, implying that an equal gross margin would be achieved by politically subsidized payments increases the likelihood of a bias that farmers state the demand of higher payments [29]. Second, there are several possibilities how an equal gross margin could be achieved, for instance by enhancements in the yield through optimizing plant breeding and agronomy. Moreover, reducing the WTA question to changes in the gross margin and abstracting from potential subsidy payments and regulatory implications, allows for a more direct insight in the WTA as a trade-off between economic and ecological benefits.

2.2. Risk Attitude and Risk Perception

As briefly outlined in the introduction, the adoption of mixed cropping is related to many challenges from a farmer's point of view [14,20]. Since mixed cropping is a new production method for famers addressed in this study, its implementation is associated with higher risks, not at least due to the fact that farmers do not have experience in the cultivation of mixed stands. Adopting mixed cropping hence also implies a change in the income risk for the farmer. Dörschner and Musshoff [31] demonstrated based on a normative model that considering changes in income risk as well as the risk attitude of the farmer can considerably influence WTA compensation payments for agri-environmental related measures. Moreover, empirical studies have shown that the farmers' risk attitude and their perception of risks associated with a measure can substantially influence their willingness to adopt agri-environmental related measures and accept payments [32–34].

Neglecting changes in income risk and the risk attitude can therefore cause major changes in the magnitude of farmers' WTA. Our evaluation of the WTA based on the gross margins cannot explicitly account for changes in income risk. Nevertheless, we hypothesize that the farmers' perception of risk associated with the cultivation of mixed stands does influence their WTA and can serve as an indicator. Likewise, we assume that farmers' subjective risk attitude influences their WTA. Therefore, we used the 11-point scale proposed by Dohmen et al. [35] to assess the farmer's attitude toward risk (How do you personally rate yourself: Are you generally a person who is willing to take risks or do you try to avoid risks? 0 = "not at all willing to take risks", . . . , 10 = "very willing to take risks").

Furthermore, we included an indicator for the farmer's risk perception of mixed cropping which was measured on a 5-point Likert scale ("The cultivation of mixed stands is associated with a higher risk" 1 = "totally disagree", . . . , 5 = "totally agree"). If the risk perception and risk attitude have an influence on the farmer's WTA, this has implications for the design of subsidy-schemes and contractual agreements for the production of mixed cropping, and in a broader context other sustainable practices as well.

2.3. Ordered Logistic Regression

The sequential questioning allows us to distinguish three separate groups with respect to the WTA. These groups can be ranked on an ordinal scale by design: negative WTA, neutral, and positive WTA reductions in gross margins (see Table 1). For such an ordinal limited dependent variable, in our case with three distinct categories, the ordered logistic regression can be used [36]. In accordance with our conceptual framework we estimate a model that includes the farmers' risk attitude and risk perception. Moreover, socio-demographic and farm variables are included as explanatory variables (Table 2) to assess if these can explain the heterogeneity in the WTA. Therefore, the following model specification is estimated:

$$\begin{aligned}\text{WTA Group}_i = \;& \beta_0 + \beta_1 \text{ Risk attitude} + \beta_2 \text{ Risk perception} + \beta_3 \text{ Farm size} \\ & + \beta_4 \text{Full time farm} + \beta_5 \text{Legumes} + \beta_6 \text{ No. EFA measures} \\ & + \beta_7 \text{ Region} + \beta_8 \text{ Rented land} + \beta_9 \text{ Training enterprise} \\ & + \beta_{10} \text{ Age} + \beta_{11} \text{College degree} + \varepsilon_i\end{aligned} \quad (1)$$

where i represents the individual respondent and ε_i is assumed to be an error term with a logistic distribution. The included farm and farmer related variables were chosen since these are objectively measurable characteristics among the features that have been found to statistically significantly influence farmers' adoption behavior of conservation and agri-environmental practices, e.g., [20,34,37]. Including objectively measurable variables supports an easier distinction between potential target groups for voluntary agri-environmental schemes.

Statistical analysis was conducted with STATA 15. Regression results are displayed in form of odds ratios. An odds ratio larger than one thereby implies a positive effect of the independent variable on the dependent variable WTA. This means an increase in the independent variable increases the likelihood of being in a higher WTA group. An important assumption for the ordered logit model is the parallel regression assumption. This indicates that the coefficients are equal across all ordinal stages of the dependent variable. If this holds true, there is only one set of coefficients to be estimated, because the relationship between each pair of stages is the same. The Brant test is applied to validate this critical model assumption [38].

2.4. Sample and Descriptive Statistics

The data used to analyze the presented research question were gathered as part of a survey that focused on German farmers' motivations and the perceived barriers for the adoption of mixed cropping. The survey was conducted online between September and November 2018 [21] . The online questionnaire was designed in the way that farmers who are non-adopters of mixed cropping were subsequently presented with the WTA questions. Thus, after removal of incomplete surveys, the sample used in this analysis comprised of 134 conventional German farmers who are non-adopters of mixed cropping. Focusing on non-adopters has two reasons: First, it can be assumed that these farmers all have the same level of real experience with mixed cropping, namely none, which implies the hypothetical bias is the same for all of them. Providing an explanation about mixed cropping with main crops at the beginning of the survey and giving examples of crop combinations (with pictures) that fulfill this specification ensured that all participants had the same specification in mind when answering the questions.

Second, it is the non-adopters who will need additional financial incentives compared to the real world status quo to include mixed cropping in their production, making them especially relevant for our research question. Farmers with a positive WTA lower gross margins in exchange for the environmentally friendly production of mixed stands are the ones that will be of particular interest for the implementation of voluntary environmental-schemes, as those farmers will participate with lower financial incentives.

The descriptive statistics (Table 2) show that our sample comprises of highly educated young farmers, who work on large farms. Our sample is not representative for the German farms [39]. However, especially considering the long-term sustainable development of agricultural production, focusing on younger farmers delivers more relevant results since these are the farmers who will make the production decisions for years to come. Likewise, it is the production decisions on larger farms that will influence the sustainability of production to a greater extent.

Based on our three-step approach, we can classify 23.13% of our sample as having a "negative" WTA, 23.13% as having a "neutral" WTA (=0) and 53.73% of having a "positive" WTA reductions in gross margins for the adoption of mixed cropping (Table 1). With respect to our first research question, this implies that farmers with a "positive" WTA are willing to forgo profits for mixed cropping, farmers with a "neutral" WTA are not willing to forgo profits, and farmers with a "negative" WTA would even demand higher profits for mixed cropping. This result confirms that farmers are heterogeneous in their willingness to forgo profits as a trade-off for the more sustainable cultivation method of mixed cropping. Detailed sociodemographic characteristics for the separate groups as well as the indicators for the risk attitude and the risk perception of mixed cropping are also depicted in Table 2. Though our share of famers' with a "positive" WTA might seem high, it parallels the results of Chouinard et al. [25] that a share of farmers is willing to forego profits for environmental benefits. Since parts of the ecological benefits associated with mixed cropping will also directly positively influence the farm itself, this share seems plausible.

Table 2. Descriptive Results for Identified WTA Groups.

Variable		Full Sample N = 134 (100%) Mean (SD ∣ Median)	"Negative" WTA N = 31 (23.13%) Mean (SD ∣ Median)	"Neutral" WTA N = 31 (23.13%) Mean (SD ∣ Median)	"Positive" WTA N = 72 (53.73%) Mean (SD ∣ Median)
Risk attitude (of the farmer) [a]		6.31 (1.73 ∣ 6)	5.77 (1.87 ∣ 6)	6.32 (1.87 ∣ 6)	6.54 (1.57 ∣ 7)
Risk perception (of mixed cropping) [b]		3.61 (1.02 ∣ 4)	4.00 (1.06 ∣ 4)	3.52 (1.06 ∣ 4)	3.48 (0.95 ∣ 4)
Farm size (ha of arable land)		329.80 (488 ∣ 130)	209.61 (317 ∣ 130)	428.16 (545 ∣ 200)	339.19 (517 ∣ 118)
Full time farm		0.93	0.96	0.94	0.92
Legumes (produced as main crop)		0.27	0.26	0.23	0.29
No. EFA measures [c]		2.99 (1.35 ∣ 3)	2.52 (1.43 ∣ 2)	2.90 (1.40 ∣ 3)	3.22 (1.25 ∣ 3)
Region (% of farms in region)	North	0.44	0.41	0.29	0.51
	East	0.13	0.10	0.16	0.14
	West	0.21	0.13	0.29	0.21
	South	0.21	0.35	0.26	0.14
Rented land (% rented of total land)		0.54	0.53	0.55	0.53
Training enterprise (educate junior farmers)		0.75	0.80	0.84	0.68
Age (in years)		35.80 (11.37 ∣ 33)	39.71 (11.31 ∣ 37)	38.87 (11.03 ∣ 37)	32.79 (10.78 ∣ 29)
College degree (at least B.Sc.)		0.63	0.55	0.58	0.68

[a] Measured on the 11-point scale proposed by Dohmen et al. [35]: How do you personally rate yourself: Are you generally a person who is willing to take risks or do you try to avoid risks? 0 = "not at all willing to take risks", ..., 10 = "very willing to take risks" [b] Measured on 5-point Likert scale: "The cultivation of mixed stands is associated with a higher risk" 1 = "totally disagree", . . . , 5 = "totally agree" [c] Under the current CAP farmers have to maintain 5% of their land as Ecological Focus Area (EFA), several measures for the provision of this EFA are recognized and farmers can decide freely how many different measures they implement [40] .

Farmers who indicated that they would be willing to accept a lower gross margin for the cultivation of mixed stands were presented with the last question of how much of the gross margin they would be willing to forego. They could type in their response or use a slide bar to settle on a percentage value between 0% and 100%. The mean value of the accepted gross margin reduction is 13.08% (SD 5.96) and the median is 10% for the N = 72 farmers that answered the question (Figure 2). This means on average these farmers would cultivate mixed stands if the mixed stands reach 86.92% of the profitability of currently dominantly produced cereals.

Since the WTA question is hypothetical and did not have any real financial consequences, the stated values can be biased towards a higher positive WTA. The depicted values thus have to be interpreted with caution and have to be validated in future studies. Nevertheless, the stated values can provide a first impression about farmers WTA gross margin reductions and that farmers are willing to accept lower profits has also been shown in other studies. For example, Buckley et al. [26] had a share of 16% in their sample of Irish farmers that were willing to participate in a scheme to provide buffer strips to reduce water pollution and had a WTA payments of 0€/ha. In other words, those farmers were willing to reduce the agricultural output without any compensation, thus also forego profits. Our reference scenario was an equal profitability to the current production; thus, it is plausible that a comparatively large share will accept reductions in the gross margin since the ecological benefits will also have a direct positive influence on their farms.

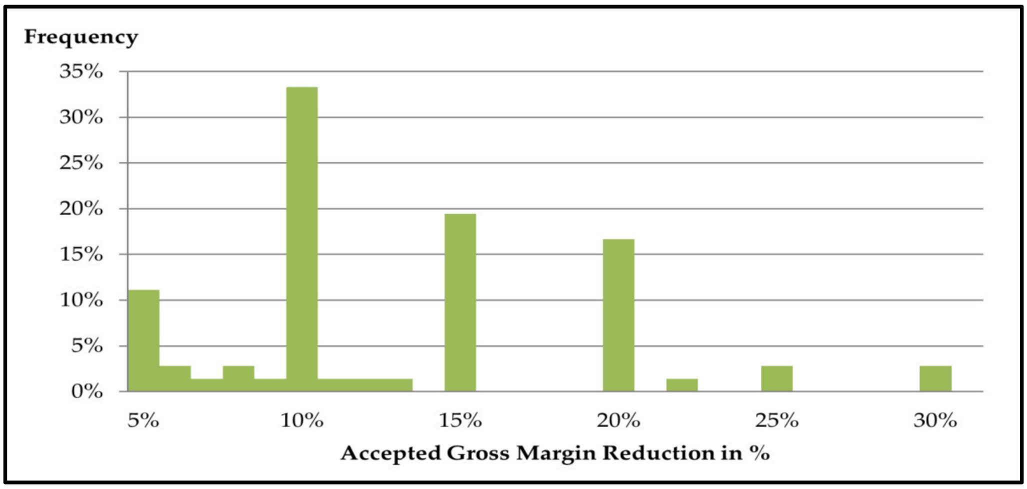

Figure 2. Distribution of responses to the question: "What is the maximum % of the gross margin in the mixed stand you would be willing to forgo, taking into account the additional ecological benefits?" (N = 72, Group "positive" WTA).

3. Regression Results and Discussion

The results of the ordered logistic regression for the dependent variable WTA group are depicted in Table 3. Due to the comparatively small sample size we applied a backward selection procedure to reduce the set of explanatory variables based on their statistical significance. The Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC) and a likelihood ratio test between the reduced and the full model (LR $\chi^2(8) = 3.74$; $p = 0.8796$), imply a better fit of the reduced model. Therefore, the reduced model is depicted below in Table 3, but the full model is included in Appendix A. The likelihood ratio test for the model is statistically significant, rejecting the null-hypothesis that all coefficients are zero (Log-likelihood = −119.78, LR $\chi^2(5) = 31.40$; $p < 0.001$). The Brant test is not statistically significant indicating that the assumption of proportional odds is not violated and the model is suitable ($\chi^2(5) = 2.676$; $p = 0.750$). This implies that the coefficients are equal across all ordinal stages of the dependent variable WTA group. To test for multicollinearity issues the variance inflation factors (VIF) were calculated, which should not surpass the value of 5 [41]. With a maximum value of 1.04 for our model, we conclude that multicollinearity is not problematic.

For the variable Risk attitude, we find a statistically significant effect. The odds ratio of 1.1962 implies that with a one unit increase in the risk attitude score (towards risk seeking), the odds of a positive WTA versus a negative- and neutral WTA are 1.1962 times higher ceteris paribus. This result is in line with previous research [33,42,43]. For instance, Serra et al. [32] show that risk aversion negatively influences the adoption of organic farming practices.

For the variable Risk perception, we find an odds ratio smaller than 1 which is statistically significant at the 10% level. This indicates that holding all other values constant, a one unit increase in the risk perception score (towards higher risk associated with mixed cropping), the odds of being in the group of positive WTA is 0.7083 times lower than being in the negative or neutral WTA group. Risk perception can be interpreted as a proxy for changes in production risk. To illustrate, an example are changes in input risks due to the fact that seed varieties have not been selected and bred for the cultivation in mixed stands [44]. Since varieties are not well adapted for mixed cropping, yield risks increase compared to sole cropping [14]. In line with this, Hannus and Sauer [33] show that a high risk perception of a sustainability standard decreases the likelihood of German farmers participation.

Table 3. Ordinal Regression Results for the dependent variable WTA Group [a] after Backward Selection Procedure (N = 134).

Variable	Odds Ratio	SE	*p*-Value [b]	[95% CI]
Risk attitude (of the farmer)	1.1962	0.1231	0.082 *	[0.9777;1.4635]
Risk perception (of mixed cropping)	0.7083	0.1278	0.056 *	[0.4973;1.0087]
No. EFA measures	1.3432	0.1821	0.029 **	[1.0299;1.7520]
Region South	0.3432	0.1361	0.007 ***	[0.1371;0.7359]
Age	0.9472	0.0150	0.001 ***	[0.9182;0.9771]
Likelihood ratio $\chi^2(5)$	31.40 ($p < 0.001$)			
McFadden pseudo R^2	0.116			
Nagelkerke pseudo R^2	0.241			
Brant test $\chi^2(5)$	2.676 ($p = 0.750$)			
VIF	mean = 1.02 max = 1.04			
AIC	253.57			
BIC	273.85			

SE—Standard Error; CI—Confidence Interval; VIF—Variance Inflation Factor; AIC—Akaike Information Criterion, BIC—Bayesian Information Criterion. [a] Includes the ordinal categories: negative, neutral, and positive WTA. [b] Asterisks indicate different levels of significance (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$).

Combined, the effect of risk attitude and perception indicate that a negative WTA is partially caused by the demand of a risk premium for the adoption of this innovative cultivation method. Reaching a similar profitability in mixed cropping compared to the current cereal production will not be enough for the farmers that are categorized in the "negative" WTA group. They will demand a higher profitability in exchange for the increased risks associated with mixed cropping, which does not necessarily mean that those farmers do not value the environmental benefits. It is more likely to imply that the increased risk outweighs the ecological benefits for them. The demand of a risk premium is in line with expected utility theory and has been demonstrated to increase payments necessary for the adoption of more environmentally friendly production measures [31] . For mixed cropping this implies that reducing the risks associated with the cultivation can be a lever to facilitate adoption and reduce requirements for the profitability. In non-monetary terms, this could for instance be facilitated by enhancing the information availability for farmers, which also calls for further research in plant sciences [14,21].

We also find a statistically significant effect for the number of measures a farmer provides for the Ecological Focus Areas (No. EFA measures). The odds ratio larger than one indicates that an increasing number of different measures implemented on the farm, increases the likelihood of being in higher ranked WTA group. Within the CAP regulations, most conventional farmers have to dedicate a share of 5% of their arable land for the provision of the EFA [40] How many different measures they perform is their decision. It has been argued that German farmers predominantly choose measures that they already perform or that fit well within their established production patterns, like catch crops [45,46]. Hence, performing a higher number of different measures for the EFA can be interpreted as a measurable indicator for farmers whose arable production already includes more ecologically beneficial traits. These farmers thus might have a higher preference for environmentally friendly production methods.

For the variable Region South, we see a statistically significant negative effect for having a positive WTA. The agricultural production in the south of Germany is characterized by comparatively small farms with the highest share of grassland across Germany [39,47] The high share of grassland compared to arable land can be a reason why these farmers display a lower WTA to accept reduced gross margins in their arable production.

With respect to the Age of the farmers, we find a negative effect that is statistically significant at the 1% level. A one-year increase in age, ceteris paribus, decreases the odds of having a positive WTA. While the results of Lemken et al. [20] also show a negative effect of the age on farmers mixed cropping adoption tendencies, the effect was not statistically significant. There is no clear consensus with respect to age of the farmer in studies related to agri-environmental measures, both positive and negative effects have been observed [48].

4. Implications, Limitations, and Future Directions

The presented results provide important first insights about the extent of the financial incentives that would be necessary to facilitate mixed cropping in German agriculture and potentially other European countries where the technological lock-in around dominant cereal crops is prevalent. We deliver a starting point into further research with respect to farmers' willingness to accept payments for the adoption of mixed cropping. Our results support that heterogeneity between farmers with respect to the trade-off between economic and ecological benefits exists for the case of mixed cropping. A group of farmers is willing to forgo profits for the adoption of mixed cropping compared to the current dominant cereal production. Nevertheless, another group of farmers would demand an even higher profitability of mixed stands compared to the cereal production. The results of the ordered logistic regression imply that the farmers' risk attitude and their perception of risks associated with mixed cropping statistically significantly influence their WTA. This indicates that the trade-off between risk and profitability is at least partially responsible for demanding a higher profitability in mixed stands. Our results also show that the farmers' age and the number of measures they perform for the provision of EFA positively influence their WTA. Thus, younger farmers who perform a larger number of EFA measures, are not located in the south of Germany, have a lower risk aversion, and a lower perception of the risks associated with mixed cropping are the farmers who will demand the lowest financial incentives for adoption.

One lever that will facilitate the acceptance of mixed cropping and reduce profitability requirements is reducing the risk associated with the cultivation. Assessing possibilities to reduce risk, for instance by decoupling incentives from the produced marketable output in mixed stands in contractual agreements, poses a potential future research agenda. However, implementing restrictions on the cultivation is likely to increase the requirement for payments.

Our results are based on a comparatively small sample that is not representative for Germany; this has to be considered for the external validity of the results. The small sample limits the generalizability of the results for the population of German farmers. To validate the results, further research is needed which should preferably be based on a representative sample. Nevertheless, our results indicate that there is a share of German farmers that will forgo profits for the adoption of mixed cropping. Our results can give valuable implications for the design of voluntary agri-environmental schemes with respect to mixed cropping, as the adoption of voluntary measures itself is subject to a self-selection bias. The question design with respect to the WTA was hypothetical in nature. This could have led to the farmers overstating their WTA, which is a common criticism of stated preference approaches. It will therefore be necessary to further investigate farmers true WTA with respect to mixed cropping. Nonetheless, our results can serve as a starting point for future research that could for example use incentivized choice experiments to elicit farmers WTA. Furthermore, we cannot distinguish between farmers with a true "negative" WTA and protest responses. Protest responses can also bias the results. Since we explicitly did not frame mixed cropping in a political context, we believe this bias to be negligible.

Against the background that mixed cropping faces many challenges that have to be overcome to be widely adopted in the EU and further research is needed along different steps of the value chain, our results are a first impulse to what extent financial incentives will be necessary to facilitate adoption. How financial incentives could be provided effectively is a further research question that can be addressed in the future.

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Appendix A

Table A1. Ordinal Regression for dependent variable WTA Group [a] with Full Set of Explanatory Variables (N = 134).

Variable	Odds Ratio	SE	*p*-Value [b]	[95% CI]
Risk attitude (of the farmer)	1.2058	0.1274	0.076 *	[0.9803;1.4831]
Risk perception (of mixed cropping)	0.6739	0.1277	0.037 **	[0.4649;0.9769]
Farm size	1.0001	0.0004	0.759	[0.9993;1.0010]
Full time	0.6066	0.5394	0.574	[0.1061;3.4660]
Legumes [c]	1.1863	0.5179	0.696	[0.5041;2.7913]
No. EFA measures	1.3918	0.2018	0.023 **	[1.0476;1.8492]
Region East	0.6765	0.4313	0.540	[0.1939;2.3599]
Region West	0.7303	0.3497	0.511	[0.2858;1.8661]
Region South	0.2773	0.1362	0.009 ***	[0.1058;0.7264]
Rented land	1.0052	0.0079	0.506	[0.9899;1.0209]
Training enterprise	0.5392	0.2952	0.259	[0.1844;1.5767]
Age	0.9534	0.0168	0.007 ***	[0.9209;0.9870]
College degree	1.1028	0.4456	0.809	[0.4995;2.4346]
Likelihood ratio $\chi^2(13)$	35.14 ($p < 0.001$)			
McFadden pseudo R^2	0.130			
Nagelkerke pseudo R^2	0.266			
Brant test $\chi^2(13)$	10.77 ($p = 0.630$)			
VIF	mean = 1.28 max = 1.62			
AIC	265.83			
BIC	309.29			

SE-Standard Error; CI-Confidence Interval; VIF-Variance Inflation Factor; AIC-Akaike Information Criterion, BIC-Bayesian Information Criterion. [a] Includes the ordinal categories: negative, neutral, and positive WTA. [b] Asterisks indicate different levels of significance (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$). [c] Producing Legumes as a main crop can be understood as a proxy for farmers' having an improved understanding of the ecological benefits and maybe the risks associated with the cultivation of mixed cropping. The VIF values suggest however that the correlation between the variables Legumes and Risk perception is low.

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