Zeitschrift: Yearbook of socioeconomics in agriculture : Agrarwirtschaft und Agrarsoziologie = économie et sociologie rurales

Herausgeber: Schweizerische Gesellschaft für Agrarwirtschaft und Agrarsoziologie

Band: - (2012)

Artikel: Climate change mitigation in Swiss agricultural practice

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DOI: https://doi.org/10.5169/seals-966708

Climate Change Mitigation in Swiss Agricultural Practice

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Abstract

This paper investigates farmers' response to climate change mitigation strategies in Swiss agriculture. It reports the results of a discriminant analysis carried out using data from a survey (n = 1'909) among farmers in the German-speaking part of Switzerland. Thereby, the main focus lies on the role of risk perception and barriers to adoption within a conceptual model of decision- making based on the protection motivation theory.

Keywords: *climate change, mitigation, agriculture, risk perception, barriers, decision-making, protection motivation theory*

JEL classification: *Q54, Q15, Q16*

1. Introduction

There is a broad scientific consensus that a progressive global warming already has, or will have, negative impacts on agriculture in most parts of the world (e.g. Rosenzweig et al. 2005; Smith et al. 2007b). Global warming or climate change respectively therefore represents a global environmental risk, endangering the existence of farmers and, consequently, worldwide food security. For Switzerland, experts prognosticate that a warming of less than 2 to 3° C would have an overall positive effect on farming (OcCC 2007). However, if the temperature rises by more than 2 to 3° C, the disadvantages will outweigh the advantages (Rosenzweig and Tubiello 2007). In particular, water scarcity and droughts during the growing season potentiate the risk of crop failure and lead to a drop in net growth and yield (Jasper et al. 2005; Parry et al. 2005). More-over, an increment of climate variability and extreme weather events threatens reliable returns for Swiss agriculture (Lüscher et al. 2005; Fuhrer 2006; Frei et al. 2007). The negative consequences of these events' interactions would be manifold and exclusively negative (Grimm et al. 2002; Parry et al. 2005; Fuhrer et al. 2007). However, agriculture is not only affected by, it is also a source of greenhouse gas (GHG) emissions and thus a causer of climate change. In Switzerland, agriculture's share of GHG emissions amounted to 11.9% of the total releases in 2009 and accounted for 83.7% of the CH_4 and 78.6% of the N_2O emissions. In contrast to the global trend and likewise in Western Europe as a whole, GHG emissions from Swiss agriculture are decreasing, from 6.66 (1990) to 6.18 Mt CO_2 equivalents in 2009 (BAFU 2011a). Nevertheless, Swiss agriculture still has an obligation to search for potential to reduce GHG emissions other than compensating them by certificate trading or externalizing them by offshoring the production of GHG-intensive commodities through imports. Thereby, the challenge is to find efficient strategies that can be easily adopted in agricultural practice. In the present study, we try to identify such solutions by focusing on two different problem approaches. Having identified relevant and suitable options to mitigate GHG emissions from Swiss agriculture at farm-level, we concretely ask: (a) Does the perception of the above-mentioned farm-specific risks encourage Swiss farmers to implement strategies to mitigate climate change? (b) Which are the main barriers that hinder Swiss farmers from putting them into practice?

2. Theoretical framework

2.1 Climate change mitigation in Swiss agriculture

Basically, before addressing *how to reduce GHG emissions from agriculture by mitigation strategies*, we must establish *where the sources of these emissions are*. A literature review (e.g. Smith et al. 2007a; Bellarby et al. 2008) as well as the Swiss GHG inventory (BAFU 2011a; BAFU 2011b) reveal that about 40% of total releases of agricultural GHG stem from enteric fermentation (CH_4) and from fertilized soils (N_2O) each. A further 20% originate from manure management (CH_4 and N_2O), while emissions from fossil energy use (CO_2) account for an infinitesimal 1%. Note that N_2O emissions originate from nitrogen (N) losses to the environment in various forms and that there are trade-offs between gases, e.g. NH_3 and CH_4, when changing an environment from oxygen-deprived to aerobic (Bellarby et al. 2008; Peter et al. 2009). In the light of these interfaces, Smith et al. (2007a) state that, while agricultural GHG fluxes are complex, the active management of agricultural systems offers possibilities of mitigation. Paustian et al. (2006, p. 1) are even more enthusiastic, writing that «agriculture has great potential to reduce the buildup of these gases in the atmosphere.» Corresponding main mitigation strategies are either GHG emission reductions from agricultural operations or removals of atmospheric C in the soil by sequestration (Smith et al. 2007b; Schneider and Kumar 2008; Niggli et al. 2009). Removals are ultimately finite, i.e. reversible and saturating, because organic carbon stocks will reach a maximum and thus can only be achieved temporarily. By contrast, GHG reductions from agricultural operations are permanent and non-saturating since they represent emissions which have been avoided and will last as long as the relative management changes are maintained (Frelih-Larsen et al. 2008). «Therefore, even when such flux reductions appear small compared to total anthropogenic emissions, they may contribute substantially to mitigate sectorial emissions» (Rosenzweig and Tubiello 2007, p. 865). In addition, reduction options will help significantly to mitigate global anthropogenic emissions since, due to land scarcity, there is more land available for management than for land use changes, such as afforestation (Bellarby et al. 2008). Either way, opportunity and transaction costs as well as social welfare implications are always inherent in climate change mitigation as are leakage effects which arise if, for example, tillage reduction increases herbicide applications impairing of water quality. Schneider and Kumar (2008, p. 22) thus conclude that «Agriculture has a limited potential to provide low cost emission reductions.» Other authors disagree, voicing the opinion that many of the mitigation options use current technologies and can be implemented immediately and thus are relatively low-cost (Paustian et al. 2006; Smith et al. 2007a).

Furthermore, mitigation strategies often have positive externalities, i.e. unintended synergies and co-benefits for the productivity and environmental integrity of agricultural ecosystems, such as improved water storage capacity of organic C restored soils or beneficial effects on climate change adaptation (Smith et al. 2007b; Frelih-Larsen 2008; Niggli et al. 2009). Indeed, lots of them are so-called best agricultural practice (GAP) measures, evolved as means to enhance the sustainability and resilience of agricultural systems rather than with C sequestration or general GHG reduction in mind (Rosenzweig and Tubiello 2007, p. 863).

With reference to these different perspectives, we defined the six management change mitigation options in table 1 as suitable for Swiss agriculture.

Table 1: Description of mitigation options and their effects

Fertilization	Optimizing timing and amount of fertilization regarding weather and growth stage	↓ N_2O, less nutrient losses, positive impacts on water quality and biodiversity	Element of existing policy
Liquid manure	Covering liquid manure stores	↓ CH_4, less nutrient losses, positive impacts on biodiversity	
Fallow land	Avoidance of fallow land by growing winter crops or green manure or not clearing crop residues on arable land	↓ N_2O and CO_2, less nutrient losses and more organic matter in soils, positive impacts on soil surface structure and water storage capacity, soil erosion protection, water quality and biodiversity	
Fertilizer application	Manuring with low emission band application systems	↓ NH_3 (and N_2O), less nutrient losses, positive impacts on biodiversity	Element of an existing support program
Renewables	Obtaining energy from renewable sources as far as possible (excluding energy crops and biogas plants)	↓ CO_2	
Information	Acquisition of information on climate change mitigation strategies in agriculture	↓ CO_2, N_2O and CH_4	Long-term reduction of transaction costs

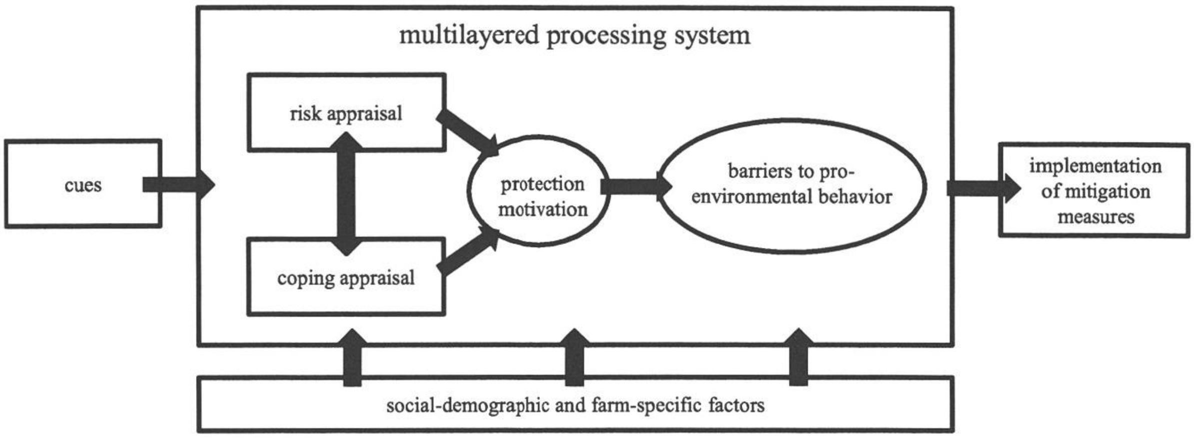
In addition to the implicit co-benefits, little leakage effects and low-cost character, these strategies were also chosen because they are well-accepted by the target group (Peter et al. 2009). A case in point is fertilizer application with low emission band systems, a technology that, thanks to cantonal support programs, enjoys widespread acceptance. This is not true for reduced tillage, as became apparent in expert interviews as well as in qualitative and quantitative pretests. Consequently, reduced tillage was dropped and low emission band systems kept in the choice of suitable mitigation options, although the small-scale structure of Swiss agriculture complicates the implementation of both strategies. The sixth mitigation option places particular emphasis on the issue of acceptance and assumes that information reduces this kind of transaction costs. Together, the six mitigation options listed here represent the basis on which we elaborated our research questions.

2.2 A behavioral model of Swiss farmers' decision-making

General conceptualization

When identifying possible and practicable strategies to mitigate climate change in Swiss agriculture, it is of particular interest to establish *if farmers implement them* and *why they do or they do not*. In order to address these issues, we have chosen the approach of a decision-making model in the tradition of Rogers' (1975; 1983) protection motivation theory (PMT), a well-known concept from health psychology. Later revised to a more general theory of cognitive change, PMT was developed originally to explain responses to health threats as a result of a risk and a coping appraisal (Floyd et al. 2000; Milne et al. 2000). Today, there is a lot of research done in favor of also using PMT as a valuable tool to describe decision-making in the case of environmental concerns. Overall, it has been possible to prove strong relationships between stated pro-environmental behavior, the elements of the risk and the coping appraisal (Martens and Rost 1998, Rost et al. 2001, Grothmann and Patt 2005; Köpke 2006; Martens et al. 2008). Figure 1 shows how PMT works and how its elements interact. Firstly, cues or signals such as an observation or a question concerning climate change mitigation in agriculture, for example, activate both a risk and a coping appraisal. Thereby, we especially stress the role of Swiss farmers' egocentric risk awareness, namely that part of the risk appraisal, which assesses potential negative consequences of a risk that could hit the decision-maker himself.

Figure 1: Conceptual model of Swiss farmers' decision-making in the context of climate change



These two appraisals interact and lead to a protection motivation which, in turn, is mediated by barriers, i.e. ideas about and attitudes towards the feasibility and effects of a behavioral option that hinder the decision in favor of a particular option. As a whole, the model's elements form a multilayered processing system, which results in a stated decision output representing the dependent variable of the conceptual model – that is, in this case, the implementation of climate change mitigating measures in agricultural practice. Last but not least, socio-demographic and farm-specific factors have an overall effect on the elements in the green box of the model. Detailed information about out of which constructs our model's elements consist and how they were measured is to be found in Karrer (2012).

3. Research design and methods

3.1 Survey and sample

The data analyzed in this paper originate from a postal survey conducted for a research project investigating «Swiss farmers' perception of and response to climate change». A qualitative pretest with 10 interview partners and a quantitative pretest involving a sample of 281 farming households were performed in order to fine tune and guarantee the quality of the final questionnaire. In

2010, 5'500 questionnaires were sent to randomly selected farmers in the German-speaking part of Switzerland. A total of 2'110 forms were returned representing a response rate of 38.4%. Of these 201, or 3.7%, were rated as refusals or breaking off. The final sample (n = 1'909) is representative of the target group in all important characteristics, measured by eight socio-demographic and farm-specific variables.

3.2 Methods

The conceptual model and the measurement of its components were developed on the basis of wide desk research. Additionally, twenty-one qualitative interviews with scientists in the field of agriculture and environmental pollution research as well as empirical social research and with members of the target group were done. After the poll, the data from both the quantitative pretest and the postal survey were evaluated within a descriptive analysis with regard to their distribution and item-difficulty. Then, the dimensionality of the multi-factorial constructs was statistically tested within a principal component analysis (PCA) with oblique factors and Promax rotation (Bühner 2006). For further details refer to Karrer (2012). In a next step, a reliability-test was conducted for every factor's and every uni-factorial construct's items which then were averaged to one index per factor. In this way, PCA and reliability tests allow reducing the number of items.

Finally, a discriminant analysis (see e.g. Huberty 1975; Klecka 1980; Betz 1987; Burns and Burns 2008) with the factor indices validated our conceptual model for Swiss farmers' perception and decision-making regarding climate change and its mitigation. For discriminant analysis, the statistical software IBM SPSS 19 offers an enter- and a stepwise-option. Note that the latter provides the most parsimonious model but since it exhibits the same stepwise-problematic as in multiple regressions, it must be interpreted with discretion (Bortz 2005; Bühner and Ziegler 2009). In this study, we therefore calculated every model in both ways in order to confirm the stepwise-solutions on the one hand and to identify other predictors with considerable discriminant power on the other hand. Since the linear discriminant analysis can tolerate a deviation from homoscedasticity and multivariate normality for approximately normally distributed variables, large samples and well separated groups mean, the model assumptions were not violated (Gilbert 1968; Lachenbruch 1975; Feilmeier et al. 1981). Also, the strongest within-group correlations found achieved values from 0.5 up to 0.7 which are considered as low to moderate and thus unproblematic (Bühl 2010).

4. Measurement and descriptive results of model constructs

4.1 Risk appraisal

In accordance with the original PMT as well as other authors, e.g. Martens and Rost (1998), we defined *vulnerability* and *severity* to be the main components of the risk appraisal. Vulnerability is the perceived probability of being exposed to a risk while severity is the appraisal of how harmful this risk would be. They were measured by ten concrete and specific climate change-related production risks that had to be rated on two different 6 point scales (see Karrer 2012). Firstly, respondents had to estimate the probability that such a risk could arise (*very unlikely* to *very likely*) and secondly the severity of yield losses it could cause (*no losses* to *more than 45% losses*) on their farm. However, subsequent PCA could not confirm this dual structure since the items loaded on factors unifying similar types of risks. The best solution, achieving a total explained variance of 76.2% (n = 1'602) and high Cronbach's Alphas, showed that Swiss farmers differentiate between risks concerning *dryness and heat* on the one hand ($\alpha = 0.895$) and *diseases* on the other hand ($\alpha = 0.874$).
Observations of climate change manifestations rounded up Swiss farmers' egocentric risk awareness. This construct was of two-factorial design and had already been tested in a survey among Swiss farmers within a master thesis (Grunder 2011). Respondents had to answer seven items referring to extreme weather events and four items concerning the development of natural production factors for its measurement. In both cases, they had to rate observed changes on a 4 point scale ranging from «*no change*» to «*very strong change*». After removing three items because of low communalities and high side loadings, a PCA with a total explained variance of 60.9% (n = 1'774) showed that the selected items load on the two presumed factors, five on weather events ($\alpha = 0.833$) and three on *production factors* ($\alpha = 0.678$).

4.2 Coping appraisal

Generally, the measurement of *responsibility judgment* is based on the differentiation between *external* and *internal responsibility judgment* (Wortmann 1994; Kals et al 2008). In this study, only *internal responsibility judgment* was measured; respondents had to rate the statement that agriculture is responsible to reduce GHG emissions from human activities on a 6 point scale from «*I do not agree at all*» to «*I totally agree*» (n = 1'869).

To quantify *specific knowledge* related to the most important sources of GHG emissions from agriculture, respondents had to assess the sources of GHG emissions in agricultural practice (*ruminant digestion, manure storage, nitrogen losses from soils, machine employment, manure and fertilizer application, fertilizer production* according to e.g. Bellarby et al. 2008 or Peter et al. 2009) («*emits no GHG*» to «*emits a lot of GHG*»). Finally, the correctness of their answers was graded on a scale from 1 to 6 and averaged (n = 1'881). In order to measure Swiss farmers' *conviction of contingency*, we used two items taken from Krampen et al. (1993) and 6 point scales from «*I do not agree at all*» to «*I totally agree*»:

- «*I feel in the position to make an important contribution to climate protection.*»
- «*It also depends on me, if the climate change problem is to be solved.*»

These two items achieve a good reliability ($\alpha = 0.793$, n = 1'867).

The last component of the risk appraisal, *response efficacy*, was queried together with the grouping variable.

4.3 Protection motivation, implementation of and barriers to mitigation strategies

Protection motivation was measured as a single-item construct. Respondents (n = 1'854) had to complete the sentences «*To protect climate, we must take…*» by rating a 6 point scale from «*no action at all*» to «*every action possible*».

The grouping variable *implementation* and the predictor *response efficacy* were also measured as single-item constructs. After reading a short description for each of the six agricultural climate change mitigation options (see theoretical section), respondents had to answer two questions. The first one measured the predictor and remained unchanged:

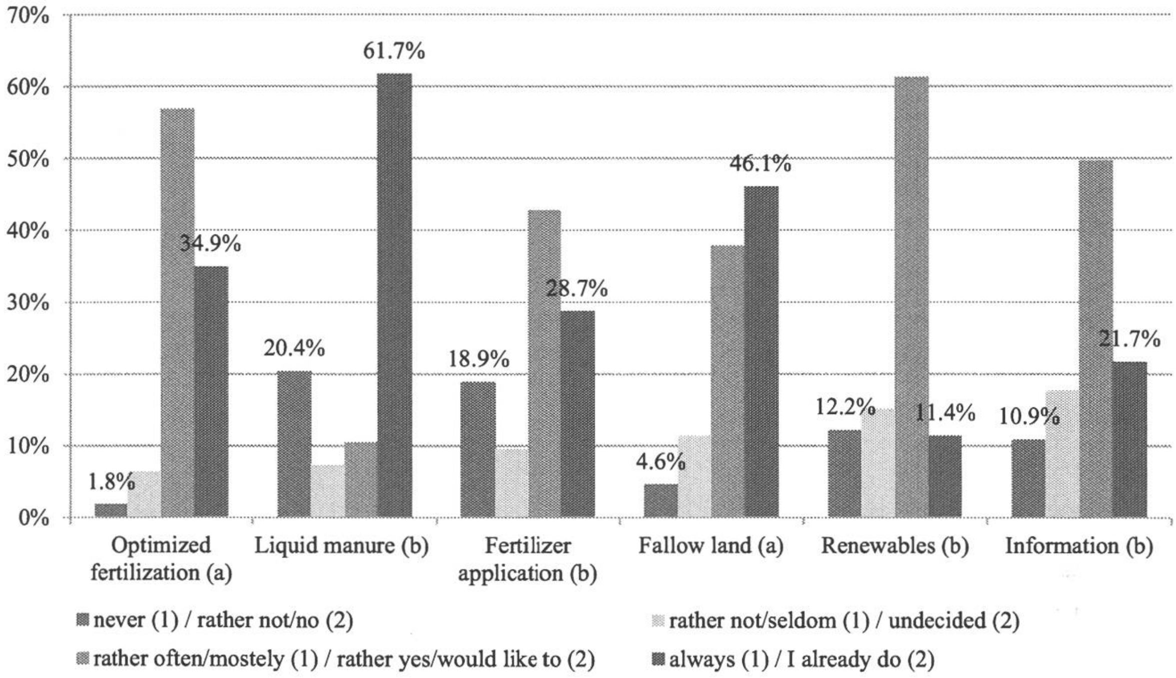
- «*Do you think this instrument is useful or not?*»

Measured on a 6 point scale from «*it is completely useless*» to «*it is very useful*», respondents' response efficacy are highest for optimizing fertilization and fertilizer application with low emission band application systems and lowest for covering liquid manure stores (n = 1'789). The latter's 10.9% share of respondents rating «*it is completely useless*» indicates serious psychological reactance concerning this mitigation option. Another peculiarity of the sample is that renewables – in contrast to their real potential – are considered to be important for climate change mitigation in agriculture, whereas avoidance of fallow land and residue management, one of the most potent strategies, is judged to be less effective.
The second question concerned the grouping variable and was written in two different ways, depending on whether it related to an activity Swiss farmers should already perform (1) in accordance with Good Agricultural Practice (GAP) or whether it focused on an additional measure (2):

- «*To what extent do you implement this measure?*» (1)
- «*Would you implement this measure*?» (2)

4 point rating scales define the grouping variable to divide the sample into four groups, depending on the extent to which respondents (would) implement a certain mitigation strategy (see figure 2). While covering liquid manure stores is the most widely implemented option proposed, it is also the one with the highest percentage of respondents who (rather) do not implement it, even though it is a mandatory measure. This finding is in line with the psychological reactance presumably inherent in the corresponding response efficacy. In the case of optimizing fertilization and avoidance of fallow land, which are GAP measures, 34.9%, respectively 46.1% of adopters cannot be regarded as entirely satisfying. The same must be stated for information concerning climate change mitigation in agriculture and renewables. Nevertheless, it is striking to note that there is, as for almost all other options, a strong interest in these two measures, i.e. respondents rather would or would like to implement them.

Figure 2: Frequencies of the dependent variable «implementation» (n = 1'811)



Barriers to pro-environmental behavior were designed as common reasons and excuses for not implementing a certain mitigation measure. «*Why is it difficult or impossible to implement that measure on your farm?*» For each of the six measures, respondents had to rate several of these barriers on 6 point scales from «*I do not agree at all*» to «*I totally agree*».

5. Results and discussion of the research questions

5.1 How risk perception influences the implementation of mitigation strategies

Does increasing perception of farm-related risks have a positive effect on the implementation of climate change mitigation measures? And if yes, does it have a strong influence compared to other components of the corresponding decision-making process? A discriminant analysis of our survey data should shed light on these interfaces by identifying those characteristic variables that best describe the differences between the groups, namely non-implementers, adopters and respondents in between. In doing so, it should validate our conceptual model for Swiss farmers' perception and decision-making regarding climate change and its mitigation.

Table 2 contains an overview of the discrimination results, namely the total discriminant power of each predictor and the proportion of explained variance for every model. As it is computed on the basis of the standardized canonical discriminant function coefficients, the former allows a comparison of the influence of the different predictors. The explained variance on the other hand is the sum of the squared canonical correlations which indicate the multiple correlations between the predictors and the discriminant functions (Burns and Burns 2008). It is thus a measure of inter-group variability and consequently an index of overall model fit. In every case, the listed predictors account for 28.1% to 88.8% of total explained variance. Such a proportion of inter-group variability indicates that the conceptual model of Swiss farmers' decision-making provides a good description of the differences in their implementation of climate change mitigation options up to now. With the exception of response efficacy, the same conclusion must be drawn when considering the discriminant power of the predictors. In both the stepwise and the enter solution, response efficacy and barriers are always the predictors with the most discriminant power. That is to say, those respondents who have high response efficacy more often belong to the adopters than those with low ones. By way of contrast, respondents who rated barriers highly are more likely to belong to the non-implementers than their colleagues with low barrier ratings.

Table 2: Comparison of predictors' total discriminant power and proportion of explained variance*

	Fertilization		Liquid manure		Fertilizer application		Fallow land		Renewables		Information	
	step	enter	step	enter	step	enter	step	enter	step	enter	step	enter
Response efficacy	**0.79**	**0.75**	**0.69**	**0.67**	**0.77**	**0.74**	**0.68**	**0.68**	**0.91**	**0.85**	**0.80**	**0.75**
Internal responsibility judgment		0.09		0.03	0.06	0.05				0.04		0.05
Conviction of contingency		0.11		0.02		0.03				0.03	0.16	0.13
Specific knowledge	0.22	0.18		0.09		0.06		0.05	0.09	0.11	0.09	0.08
Vulnerability/severity dryness and heat		*0.12*		*0.07*		*0.02*				*0.10*		*0.11*
Vulnerability/severity diseases		*0.03*				*0.11*				*0.10*		*0.02*
Observations weather events		*0.05*		*0.06*		*0.05*				*0.04*		*0.05*
Observations production factors				*0.07*		*0.03*				*0.05*		*0.03*
Educational level		0.09			0.14	0.13				0.06	0.19	0.15
Age		0.13		0.02								
Financial situation on farm						0.04						0.07
Production intensity						0.06	0.24	0.17				
Direct payments for steep slopes		0.08				0.10						0.07
General production level				0.11						0.08		0.10
Protection motivation		0.13		0.04		0.14				0.02		0.09
Barriers (all items together)	**0.60**	**0.64**	**0.87**	**0.86**	**1.01**	**1.20**	**0.74**	**1.22**	**0.30**	**0.50**	**0.37**	**0.45**
% total explained variance	**28.1**	**33.2**	**56.8**	**60.9**	**83.4**	**88.8**	**45.3**	**47.1**	**44.8**	**48.4**	**53.1**	**55.6**

Compared to response efficacy and barriers, the *variables of the risk appraisal* achieve considerably less discriminant power. Among these, vulnerability and severity concerning yield risks are obviously stronger predictors than farmers' observations of climate change manifestations. Generally, high values on risk appraisal variables go together with the affiliation to a group that exhibits willingness to, or does indeed, implement a certain mitigation option. In fact, the influence of risk appraisal variables resembles that of the coping appraisal variables whereby, with the exception of information, specific knowledge is the strongest predictor in every case. The more respondents know about GHG emissions in agriculture, the more likely they are to implement mitigation strategies. Information is influenced in particular by conviction of contingency, i.e. the more a respondent feels that he is in a position to contribute to climate change mitigation, the more likely he is to belong to the group of those who seek to inform themselves about climate change mitigation in agriculture.

Furthermore, socio-demographic and farm-specific variables have important discriminant power. A higher educational level is characteristic for adopters in four cases, whereas age and the financial situation on the farm have no essential influence. Unsurprisingly, respondents with intensive production are less likely to avoid fallow land. Then again, IP Suisse and organic producers are more likely to cover their liquid manure stores and, in addition, are more likely to obtain energy from renewables and inform themselves about climate change mitigation in agriculture.

To summarize in reference to the first research question, we can state that the perception of farm-related risks resulting from climate change (a1) seems to have a similar influence as the coping appraisal variables, but (a2) does not play such a prominent role as response efficacy and barriers when it comes to implementing climate change mitigation strategies.

5.2 Barriers that hinder the implementation of mitigation strategies

What are the principal barriers that prevent Swiss farmers from putting climate change mitigation options into practice? With the exception of response efficacy, barriers have the most discriminant power. Therefore the answer to this question seems to be an essential step towards improving the implementation of such strategies in Swiss agriculture.

Barrier-focused insights can be gained from the discriminant loadings in the structure matrix, i. e. from the bivariate correlations of each discriminating variable with each discriminant function (Huberty 1975). This is due to the fact that the identification of the largest discriminant loadings of a discriminant function allows the dimensionality of the group differences to be described (Betz 1987). Generally, just like factor loadings in factor analysis, 0.30 is seen as the

cut-off between important and less important variables (Burns and Burns 2008). For our survey data, the stepwise solution revealed three discriminant functions in every one of the six cases. The first function is always the most powerful discriminator because it has the largest eigenvalue (Klecka 1980). With one exception (avoidance of fallow land), the third one's is very low. It thus achieves a high p-value for Wilk's lambda, the proportion of total variability not explained, which indicates the insignificance of the discriminant functions. So the third function obviously has no significant additional value for describing the group differences regarding adoption of climate change mitigation measures in agriculture. However, since its predictors are also part of the first and the second function, they are still kept in the solution.
As shown exemplarily for the stepwise-solution of optimized fertilization, the first function denotes the dimension of response efficacy (see table 3). This observation is true for all six mitigation options proposed. Thus it is clear that a respondent's affiliation to one of the four groups depends first and foremost on whether or not he considers this strategy to be a valuable option to mitigate climate change. That is to say, a high value on response efficacy makes the individual discriminant scores move closer to the group centroid of the adopters.

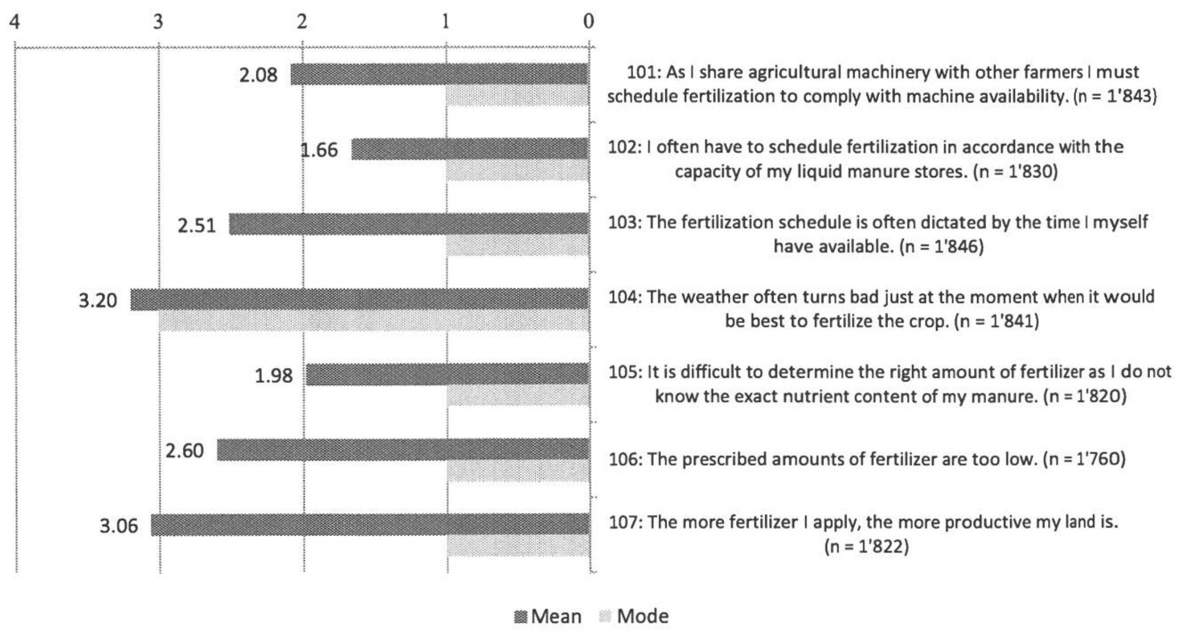
Table 3: Key performance indicators for optimized fertilization (stepwise, n = 1'203)

Predictors and key performance indicators	Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions		
	Function 1	**Function 2**	**Function 3**
Response efficacy	**0.898***	0.427	0.097
Barrier 103**	-0.387	**0.668***	0.545
Barrier 105**	-0.236	0.505*	0.096
Specific knowledge	0.007	0.617	**-0.772***

* Variables ordered by absolute size of correlation within function, largest absolute correlation between each variable and any discriminant function; ** Please see figure 3 for wording

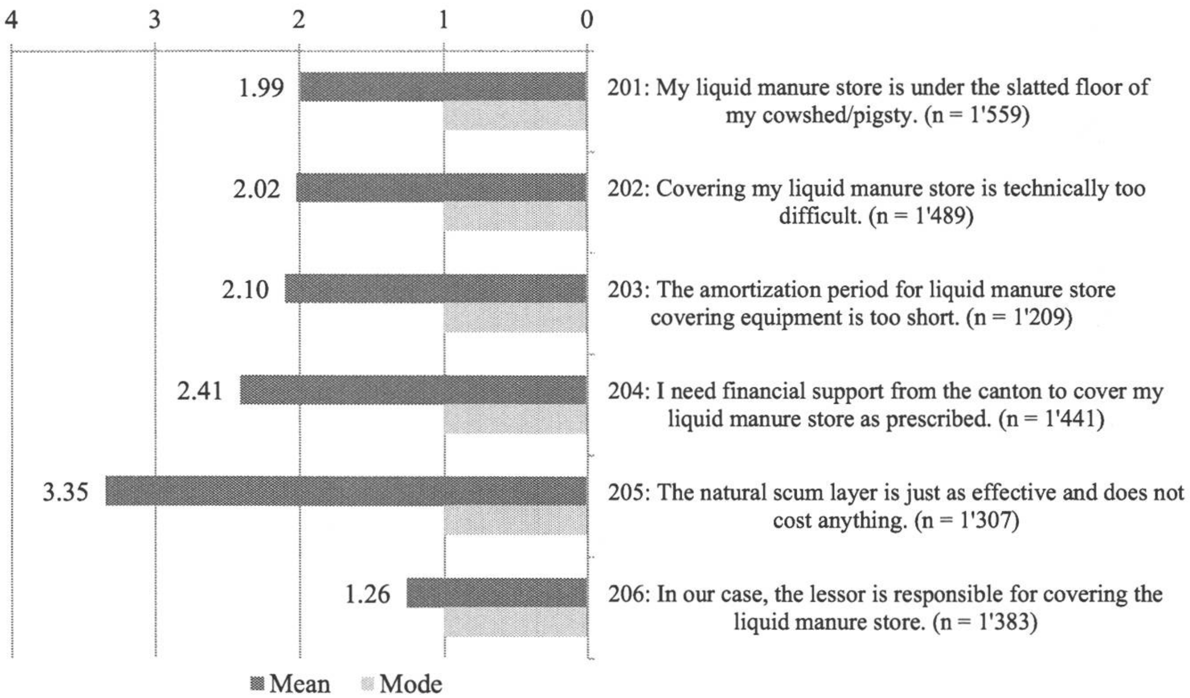
The second function stands for particular barriers, i.e. a high value on these items makes the individual discriminant scores move nearer to the centroid of the group «rather not/seldom». The third function, representing GHG specific knowledge, must be interpreted in the same way. The greater a respondent's awareness of GHG sources in agriculture, the higher the probability that he belongs to a group that is most likely to, or always implements optimized fertilization. A corresponding enter-solution resulted in a similar dimensionality of the group differences. Finally, a closer look at the barriers' means and modes in figure 3 emphasizes the special advantage of discriminant analysis as a multivariate tool. It not only describes *which barriers are generally perceived as a drawback by all respondents, but also reveals which barriers, considered simultaneously, do in fact prevent farmers from positioning themselves in the group which performs well.* Even though unfavorable weather (104) and erroneous beliefs (107) exhibit the highest means and mode over the whole sample, a respondent's membership to one group or the other is determined by the time available (103) and the unknown nutrient content of the farmyard manure (105). Therefore, these two barriers can be considered as the most important reasons for not implementing optimized fertilization.

Figure 3: Means and modes of «fertilization» barriers (n = 1'846)



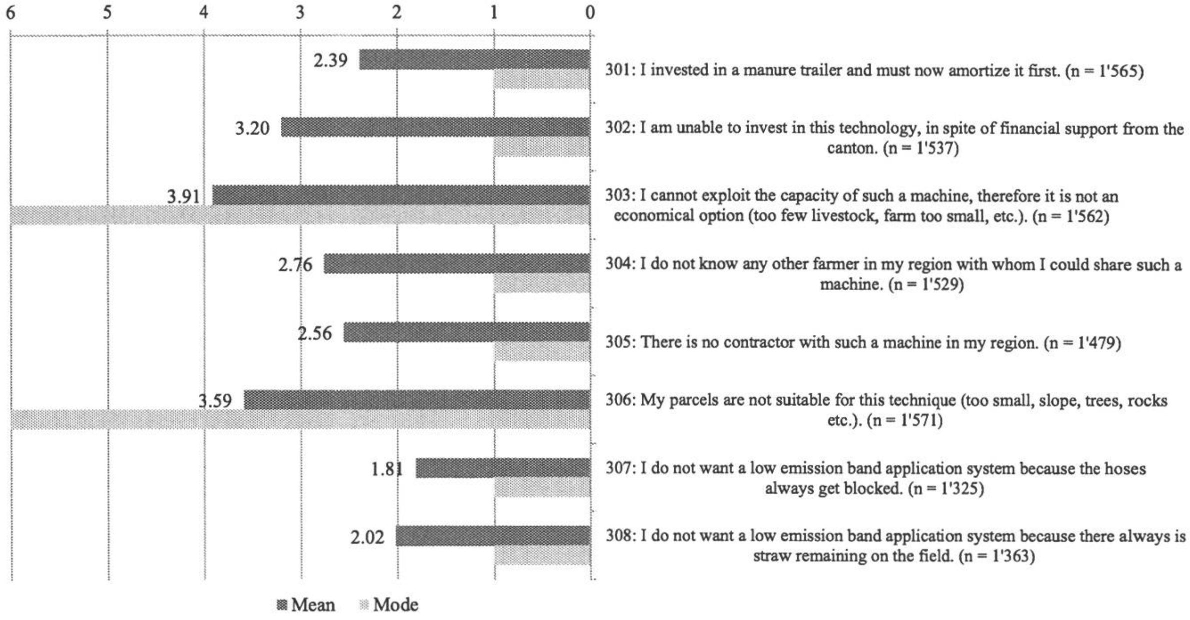
The relevant barriers for the other five mitigation measures were identified using the same procedure. It must be borne in mind that the first dimension always denotes response efficacy and that the sample sizes vary noticeably because some respondents either have no manure or no crops. For covering liquid manure stores, the discriminant analysis revealed high discriminant loadings for the barriers 202, 204 and 205, describing the functions two and three. In this case, erroneous beliefs (205) and need for financial support (204) are also the items with the highest means (see figure 4).

Figure 4: Means and modes of «manure stores» barriers (n = 1'559)



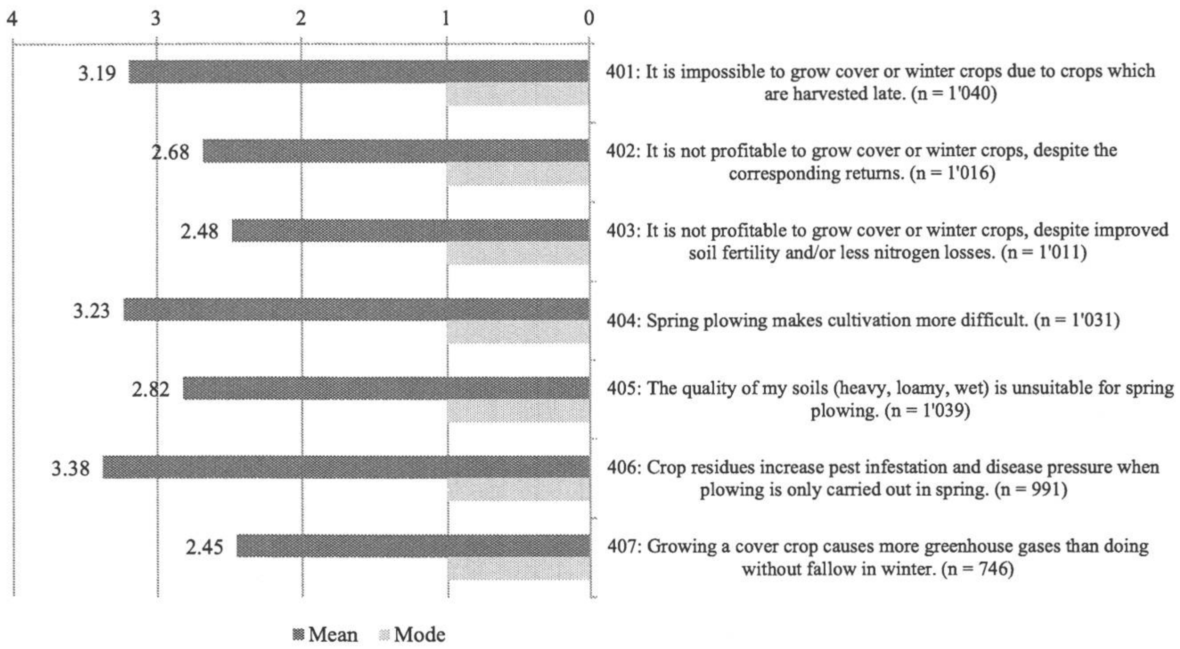
Also the use of low emission band application systems is importantly hindered by barriers. On the one hand, farm structure (303) and investments in manure trailers (301) discourage respondents from switching to this kind of fertilizer application, whereby both load highest on the second function. On the other hand, high implementation costs (302) and parcel structure (306) play a predominant role in defining function three. Consideration of the means and modes in figure 5 could also lead to another conclusion: It would seem that the lack of a possibility to share (304) or contract (305) a low emission band machine is a greater barrier than for previous investments in other technologies (301).

Figure 5: Means and modes of «fertilizer application» barriers (n = 1'571)



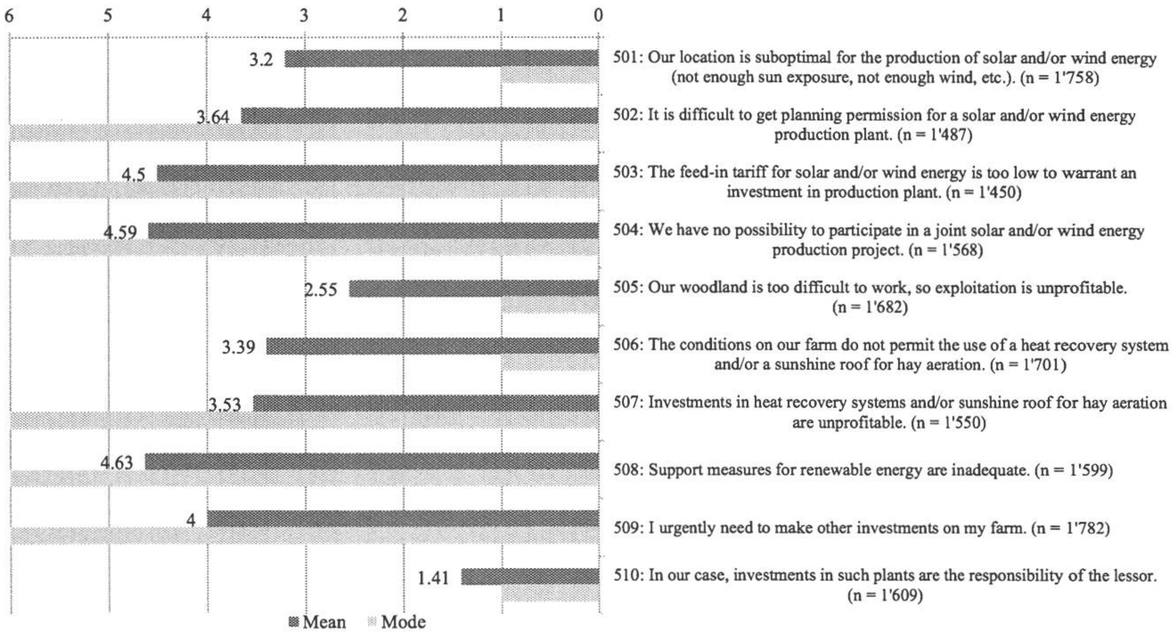
Unlike the other mitigation options, the avoidance of fallow land by growing winter crops or green manure or leaving crop residues on arable land do not just depend on response efficacy and barriers, but also on production intensity. The latter defines function three, i.e. high production intensity makes the individual discriminant scores move closer to the centroid of the group «rather not/ seldom». Finally, the barriers late harvest crops (401) and unsuitable soil quality (405) give a meaning to the second function. As in the preceding examples, the descriptive results in figure 6 suggest an order of the barriers» importance which differs from that of the discriminant analysis.

Figure 6: Means and modes of «fallow land» barriers (n = 1'040)



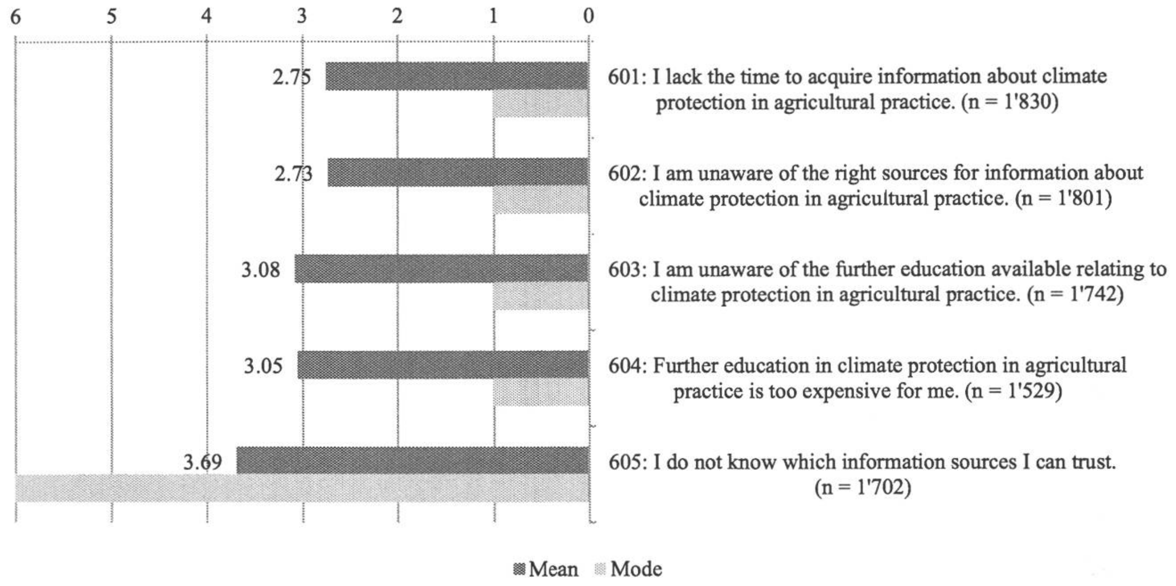
Although specific knowledge about GHG sources in agriculture loads on the second function, the implementation of obtaining energy from renewable sources also depends, besides response efficacy of course, predominately on barriers. While suboptimal location (501) is the item which loads highest on function two, other necessary investments (509) defines function three. Consequently, the adoption of renewables seems to fail mostly just because of these two simple reasons. In this example too, the descriptive results reveal a different picture (see figure 7).

Figure 7: Means and modes of «renewables» barriers (n = 1'782)



As in the case of renewables, the acquisition of information on climate change mitigation strategies in agriculture is hindered by two simple reasons: unawareness of the right information sources (602) and lack of time (601). And similarly to optimized fertilization, the third function is described by specific knowledge. When these results are compared with the descriptive results in figure 8, the essential advantage of discriminant analysis is once again clearly demonstrated. For all other items, the means are higher than for 601 and 602 and the last one, a lack of trust in the information sources (605), achieves even alarmingly high values.

Figure 8: Means and modes of «information» barriers (n = 1'830)



This last observation also emphasises the importance of the descriptive results which indicate that certain attributes of the mitigation options are perceived as a drawback by all respondents, including the adopters. In particular, distrust as revealed in the information example and erroneous beliefs seem to be widespread sources of fundamental difficulties.

6. Conclusions

The discriminant analysis of our survey data resulted in two kinds of outcomes. On the one hand, it showed that our conceptual model of Swiss farmers' decision- making well describes the differences in the sample. The respondents' awareness of climate change related farm-specific risks does influence their willingness to implement mitigation strategies as does the concurrent coping appraisal. Nevertheless, neither risk perception nor the coping elements have a strong effect on the implementation of mitigation options. This depends more predominantly on response efficacy and barriers, i.e. the more respondents consider a measure to be worthwhile and the lower the perceived barriers the more likely they are to adopt it.

On the other hand, the discriminant analysis revealed which of these barriers do indeed prevent farmers from implementing a mitigation option. For optimizing timing and amount of fertilization regarding weather and growth state, it is the time available and the unknown nutrient content of farmyard manure which make respondents practicing it seldom or never at all. The same seems to be true for specific knowledge about GHG sources in agriculture. Moreover, unfavorable weather and erroneous beliefs («*the more fertilizer I apply, the more productive my land is*») are perceived as a drawback by the whole sample. In the case of covering liquid manure stores, erroneous beliefs («*the natural scum layer is just as effective and does not cost anything*»), the need for financial support and the technical difficulty discourage the respondents from implementing the measure. Fertilizer application with low emission band systems is not adopted due to unfavorable farm and parcel structure as well as previous investments in manure trailers and high implementation costs. Late harvested crops and unsuitable soil quality are the most important reasons for not avoiding fallow land, growing winter crops or green manure or not clearing crop residues on arable land. Furthermore, high production intensity also prevents farmers from implementing this measure as do tilling difficulties, increased risk of pest infestation and disease pressure due to spring plowing. Obtaining energy from renewable sources (excluding energy crops and biogas plants) is specifically hampered by suboptimal location and scarce financial resources due to other necessary investments. In addition, difficulties getting planning permission, inadequate feed-in tariffs, lack of availability of joint-projects, unfavorable farm structure or financial reasons seem to be prominent barriers. Last but not least, unawareness of the right information sources and lack of time prevents respondents, either partially or entirely, from acquiring information on climate change mitigation strategies in agriculture. Distrust in information sources is perceived by the whole sample as a major barrier.

Taken together, these insights lead to one key conclusion: there is a fundamental need to provide technical assistance for the implementation of climate change mitigation measures at farm level. Agricultural advisory and extension services must pay particular attention to three main points. Firstly, much more attention must be paid to knowledge about the efficacy of the various measures, since response efficacy predominantly determine if a farmer adopts a strategy or not. Secondly, emphasis should likewise be placed on the transfer of specific knowledge about GHG sources in agriculture, particularly on N_2O emission. Thirdly, the different possible barriers to every mitigation measure should be taken up and discussed with the farmers. A three-step program of this kind would augment the farmers' understanding of the underlying systemic processes and consequently reduce the influence of erroneous beliefs based on smattering or lobbyist information. According to the results of the conceptual model's validation, this approach should motivate farmers far more strongly to implement mitigation strategies than a communication focusing on risks. Moreover, technical assistance should address the issue of the mitigation measures' co-benefits for the productivity and environmental integrity of agricultural natural ecosystems as well as climate change adaptation.

This last point must be stressed implicitly for two reasons. Primarily, it certainly improves farmers' acceptance regarding the adoption of these strategies since they become aware of the system inherent efficiency. Finally, most of the mitigation measures proposed are part of the GAP, i.e. farmers should implement them anyway. In Switzerland, some of them, e.g. the avoidance of fallow land, even represent minimal requirements for receiving direct payments, although more in the sense of recommendations than as crucial criterions. Nevertheless, in our opinion both the additional benefits resulting from practices that reduce GHG emissions from agriculture and these strategies as climate change mitigation per se should be incorporated into a broad and integrated agricultural policy.

This article was written within the project ClimPol (Climate Policy-Making for Enhanced Technological and Institutional Innovations) of the Competence Center Environment and Sustainability (CCES) at ETH Zurich. The authors are grateful to all the reviewers and editors of this article for their highly useful comments and later publishing.

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