



# Mitigation and adaptation in agriculture: effects of framing on farmers' policy support and sustainable practices

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## Abstract

Mitigation and adaptation are both urgently needed to effectively address climate change and reduce its effects. This is particularly pertinent in the agricultural sector, a major contributor to emissions and highly vulnerable to climate impacts. Our study investigates how farmers perceive and respond to mitigation and adaptation information. We develop and test animated video interventions in an incentivised survey experiment with Norwegian horticultural farmers (N=513). We examine how an intervention framed in terms of mitigation (Mitigation treatment) or adaptation (Adaptation treatment) influenced support for sector-wide mitigation policies and actual adoption of a sustainable farming practice (cover crops). The results show that the Adaptation treatment significantly increased support for national agricultural mitigation policy compared to the Control, while the Mitigation treatment had no significant effect, suggesting that adaptation is not seen as a substitute for mitigation. However, neither treatment impacted the adoption of cover crops. These findings highlight the need for careful climate messaging in agriculture.

**Keywords** Climate mitigation · Climate adaptation · Agriculture · Farmers · Risk · Survey experiment

## 1 Introduction

Productive agricultural systems are necessary to feed a growing global population, however they are threatened by climate change and environmental degradation. At the same time the agricultural sector is a key contributor to these crises, being responsible for a significant proportion of global greenhouse gas emissions and biodiversity decline (Lynch et al. 2021; IPCC 2019; Newbold et al. 2016). Addressing this unsustainable trend requires large-scale shifts along the agricultural value chain (McGreevy et al. 2022; Poore and Nemecek 2018).

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Recognising the urgent need for a sustainable agricultural transition, the agriculture-climate-biodiversity nexus has climbed political agendas worldwide (European Commission 2020; FAO et al. 2023; IPBES 2019; IPCC 2019). Many countries have launched programs to encourage the uptake of sustainable farming practices, including information campaigns, economic incentives and subsidies, and long-term innovation projects.

It is urgent that more farmers adopt such sustainable farming practices as they can contribute to emissions reductions at the aggregate level as well as provide critical benefits at the farm level (Clark et al. 2020; Jones and Kammen 2011). For one, farmers can implement mitigation strategies and thereby contribute to addressing the root cause of climate change. Examples of such mitigation strategies include optimising fertiliser applications, reducing tillage and machinery operations, and using diverse crop rotations (Camargo et al. 2013; Wollenberg et al. 2016). Farmers can also take adaptation actions which offer more private benefits to protect themselves from damages caused by climate change. Examples of farm-level adaptation actions include ensuring a flexible farm organisation, diversifying production systems to spread risks and create buffers, and optimising soil and crop management to make their production more resilient (Anderson et al. 2020; Darnhofer et al. 2010).

While there is an established consensus that pursuing both mitigation and adaptation at individual and systemic levels is essential to effectively tackle climate change (Calvin et al. 2023; IPCC 2022), early responses focused primarily on mitigation (Pielke et al. 2007). As adaptation has gained growing attention, concerns have been raised that these adaptation activities could influence risk perceptions and dampen already insufficient mitigation efforts (Tol 2005; Weber 2006). In fact, if people learn about adaptation options, they may view it as a viable alternative to mitigation. However, some evidence suggests that emphasizing adaptation may actually enhance engagement in mitigation by highlighting the risks of climate change (Brügger et al. 2015; Carrico et al. 2015; Greenhill et al. 2018).

Although risk perceptions play a central role in farmers' decision-making (Arbuckle et al. 2013; Mase et al. 2017; Rodríguez-Barillas et al. 2024), limited knowledge exists regarding the extent to which farmers think about adaptation and mitigation as complements or substitutes, and how this shapes support for large-scale policies and decisions to adopt sustainable farming practices (Arbuckle et al. 2013; Haden et al. 2012; Moerkerken et al. 2020; Zhang et al. 2020). Large-scale policy efforts provide additional incentives and infrastructure to facilitate individual actions. In turn such policies can enable more wide-spread opportunities to act sustainably (Chater and Loewenstein 2023). Given that farmers are the ones upon whom the tasks of agricultural mitigation and adaptation will largely fall, and both are urgently needed, it is critical to improve our understanding of how farmers perceive and respond to mitigation and adaptation information.

To address this gap we conduct an information provision experiment with Norwegian farmers and evaluate how farmers respond to information about cover crops, a sustainable farming practice, framed either in terms of mitigation or adaptation. We focus on information not because we believe it by itself can create the large-scale change necessary for a sustainable transition—instead, it is likely a necessary factor for any intervention aiming to promote change, including regulations, incentives, and campaigns. Indeed, information plays an important role to raise awareness about mitigation and adaptation and creating support for systemic action (Fang and Innocenti 2023; Jalil et al. 2023; Moser and Dilling

2011). Since information approaches remain some of the most readily available to policy makers and practitioners there is a cost–benefit argument to enhance their efficacy.

## 1.1 Related literature and gap

Climate change can be addressed either through prevention (i.e. by implementing mitigation strategies) or by managing its effects (i.e. taking steps to adapt to it). Previous studies on the relationship between mitigation and adaptation have focused on responses to risk at the individual level of decision-making. Several studies suggest that emphasizing the salience of one risk can amplify concerns about related risks and potentially lead to stronger support for preventive actions (Carrico et al. 2015; Evans et al. 2014; Greenhill et al. 2018). This is known as the risk salience effect.

For instance, prompting participants to answer survey questions about sea level rise and local adaptation measures for their community increased their willingness to engage in mitigation actions, more so than for participants who did not answer adaptation-related questions (Evans et al. 2014). Similarly, Carrico et al. (2015) found that presenting the public with mock newspaper articles that framed a policy as helping farmers adapt to climate change increased support for both agricultural mitigation and adaptation policies compared to a focus on mitigation or energy efficiency (control). It also increased climate risk perceptions (Carrico et al. 2015). Urban et al. (2021) surveyed residents in four countries across five experiments to find partial evidence (in two of five studies) that a prior focus on adaptation increased participants' attitudes toward mitigation. A prior focus on mitigation did not influence subsequent adaptation attitudes (Urban et al. 2021).

Some studies suggest that increasing the risk salience could stimulate such effects also in agricultural decision-making. In particular, farmers who are more concerned about climate change impacts on agriculture have been found to support both mitigation and adaptation (Arbuckle et al. 2015; Mase et al. 2017; Prokopy et al. 2015). Studies focusing specifically on adaptation further suggest that farmers who are more concerned about climate change, perceive higher risks, and have stronger capacity for action are more likely to undertake further climate adaptation measures (Azadi et al. 2019; Kreft et al. 2021; Nainggolan et al. 2023; Skevas et al. 2022; Woods et al. 2017). Moreover, a scoping review of nearly 18 000 papers finds that the strongest motivations for farmers to adopt sustainable practices is perceived benefits for either their farms, the environment, or both (Piñeiro et al. 2020). How such practices are communicated, framed, and made salient, for example by the media, can also alter their perceived relevance and influence uptake (Piñeiro et al. 2020; Rust et al. 2021). Overall, salience effects could thus enhance farmers' responses to protect against threats from climate change.

However, there are also indications that focusing on adaptation might crowd out mitigation efforts. This is known as the risk compensation effect. Previous studies have demonstrated the occurrence of risk compensation when measures that provide partial protection against risks lead to increased risky behaviour, such as when information about possible adaptations reduce perceived risks and increase intentions to engage in the risky behaviour (Bolton et al. 2006; Hasanzadeh et al. 2020). This effect is evident in various fields, such as energy conservation, where increased efficiency, despite reducing energy costs, has been shown to also increase overall energy consumption (see for example Gillingham et al. 2013).

In the agricultural sector, farmers who believe in technological solutions to climate change may be less willing to adopt additional measures by perceiving these solutions as sufficient (Gardezi and Arbuckle 2020). Some studies also suggest that farmers pursue mitigation strategies due to economic benefits rather than wanting to reduce greenhouse gas emissions (Davidson et al. 2019; Rochecouste et al. 2015). Moreover, if farmers perceive climate change as highly uncertain and too far in the future, they may not believe that extensive short-term investments or changed farming practices are warranted (Mortreux and Barnett 2017; Wheeler and Lobley 2021). The single-action bias may partially explain this dynamic, where individuals focus on a single response and neglect additional actions, even if the chosen response only offers incremental risk reduction or is not the most effective solution (Weber 2020).

Taken together the literature does not offer conclusive evidence on how farmers respond to calls for agricultural mitigation and adaptation. The fact that few studies have actively used an intervention and monitored its behavioural impact adds additional uncertainty. A recent review of farm-related behavioural change found that only 15 did, across which education interventions were the most common (Rose et al. 2018). For example, information provision and educational interventions have been shown to improve farmers' soil nutrient management (Genskow 2012), pest control (Helitzer et al. 2014), and increased uptake of precision agriculture technologies (Barnes et al. 2019). However, evidence of how such interventions impact actual behaviour has been scarce and sometimes mixed. A study with Ugandan farmers found that providing rice farmers with information about agronomic practices via videos increased their knowledge, but there was no evidence that it affected their actual use of the practices (Campenhout 2021). Thus, while the way information is presented can significantly affect how farmers respond to it, it remains unclear whether the information received translates into support for environmental policies aiming to reduce emissions (Andrews et al. 2013; Doran et al. 2020; Ngo et al. 2022; Rust et al. 2021).

Given this context, our main objective is to study how farmers react to a mitigation or an adaptation frame and how such information alters farmers' self-reported mitigation policy support using experimental methodology. Specifically, we investigate how Norwegian farmers respond to information interventions that emphasise the benefits of cover crops as either a climate adaptation or mitigation strategy.

In particular we ask: how does information about cover crops framed in terms of mitigation or adaptation influence farmers' support for mitigation policy? Is the effect aligned with the risk salience or risk compensation effect? We specifically evaluate support for the Agricultural Climate Mitigation Agreement, a large policy initiative between the Norwegian government and farmer unions. It forms the foundation for agricultural climate policy and sets targets to reduce emissions from agriculture and increase carbon sequestration in soils by 5 million tonnes CO<sub>2</sub> equivalents by 2030 (Bondelaget 2020).

Based on the reviewed literature we expected the two frames to have the following effects. Given a risk salience effect, we anticipated that participants exposed to either the Adaptation or the Mitigation frame would show stronger support for the national mitigation policy than their counterparts in the control condition. This is because learning about adaptation strategies may increase climate concerns and therefore heighten the perceived need for mitigation. Equally, informing people about the importance of collective measures to counteract climate change might increase risk perceptions and the need for adopting large-scale mitigation policies (Carrico et al. 2015; Greenhill et al. 2018).

In the case of a risk compensation effect, however, we would expect participants in either the Adaptation or Mitigation condition to demonstrate lower levels of policy support. This is because emphasising adaptation might trigger people to view adaptation as a remedy to a problem that can be dealt with in the future and does not require costly preventative measures such as the implementation of large mitigation policies (Carrico et al. 2015). Equally, learning about the possibility to collectively mitigate climate risks in the future might make immediate mitigation efforts less attractive due to their high upfront financial and coordination costs, thereby lowering support for national mitigation policies.

We also evaluate the influence of our intervention on farmers' actual behaviour by retrieving participants' applications for a cover crops subsidy in the 2023 growing season to indicate their adoption of cover crops.<sup>1</sup> Since the literature predominantly relies on self-reported measures of adoption intentions despite the well-known gap between intentions and actions in general (Kollmuss and Agyeman 2002) as well as in the agricultural context (Luh et al. 2023), this offers a novel contribution to understand how calls for mitigation and adaptation influence farmers' preferences and, ultimately, actions. Our approach thus helps inform whether video information interventions could influence support for large-scale mitigation policy, including an objective measure of behaviour to further inform whether farmers are influenced by these interventions.

## 2 Methods

### 2.1 Study context and participant recruitment

We conducted a pre-registered survey experiment incorporating animated video interventions with a sample of 513 Norwegian farmers in February–April 2023. Farmers were recruited from the horticultural farmer population in the country.<sup>2</sup>

The agricultural sector in Norway is under pressure to reduce emissions in line with national and international commitments. It remains outside the Common Agricultural Policy of the European Union and is a high-latitude country where farmers face both potential benefits and challenges due to climate change. Coastal regions are expected to experience increased heavy precipitation and flooding, while inland and boreal areas, such as those around Oslo, may benefit from an extended growing season and higher crop yields (McEldowney 2020; Rosenzweig et al. 2014). There are however considerable uncertainties due to the potential rise in soil diseases and pests which could significantly impact yields (Wiebe et al. 2019).

We focus our interventions on cover crops for several reasons. They represent a sustainable farming practice involving crops that are planted alongside or after the main crop. Planting cover crops is widely available to farmers, however it emerged relatively recently

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<sup>1</sup>In Norway, farmers can apply for a subsidy in October (i.e. to receive a refund) through the Agricultural Agency if they planted cover crops in that year. The size of the subsidy is determined by the size of the land area on which the cover crops are planted, measured in hectares. The cover crops subsidy application period is from end of September to the end of October every year.

<sup>2</sup>A statistical power analysis conducted a priori using G x Power revealed that a planned sample size of  $n=400$  complete responses would give the study sufficient statistical power,  $1-\beta=.95$ , to detect a small effect size,  $w<0.2$  (95% Confidence Interval). To account for possible missing data we decided to sample approximately 500 participants.

in Norway and requires additional economic and time investments (Bergtold et al. 2019). The relevance of information interventions is therefore plausible even for experienced farmers. Moreover, cover crops offer both mitigation and adaptation benefits, such as binding soil nutrients, alleviating weed infestation, improving yields, reducing soil erosion, and enhancing carbon sequestration (Büchi et al. 2018; Kaye and Quemada 2017; Lugato et al. 2020).

Three reasons motivate our focus on horticultural farmers. First, horticultural fields are to a larger extent exposed to soil erosion and runoff than other productions since larger areas are not covered by crops. Measures such as cover crops could thus be beneficial, however uptake remains low (Bøe et al. 2019). Second, the economic value of horticultural crops is larger per hectare of land than for other types (e.g. cereals). Due to the high quality requirements and shorter growing seasons, horticultural farmers are more vulnerable to climate change and associated impacts (OECD 2021; Statistics Norway 2024). Third, horticultural farmers have received considerably less empirical attention than other types, such as animal husbandry and cereal production.

The recruitment process entailed multiple steps. First, we accessed the national Production Subsidy Registry from the Norwegian Agricultural Authority. The Registry includes data on farmland used for the cultivation of various crops on all Norwegian farms entitled to governmental payments. It lists all farm holdings that receive any kind of government subsidies, capturing virtually all farms in Norway. Based on the Registry we sent email invitations to all vegetable and/or potato farmers in line with preregistered criteria (a total of 2076 invitations). We sent out three rounds of email reminders and one round of SMS-based reminders over a period of six weeks. This yielded 460 responses from interested farmers. Second, we collaborated with the Farm Advisory Service (Norsk Landbruksrådgivning, NLR) to post a link to the survey in their newsletter sent to farmers as well as on relevant online forums. Fifty-three responses were collected thanks to this effort.<sup>3</sup> As such, we were able to survey approximately 20% of our target population. Given the particularity of our sample (i.e. horticultural farmers) and findings from a small pilot, it was evident that forcing respondents to answer all questions could deter participation. We therefore opted to not enforce survey responses. This resulted in some missing values throughout the data set, leaving 369 complete responses out of the 513 for the analysis of our main outcome variable, i.e. Policy Support.

The sample was 82.4 percent male and had a mean age of 53.18 ( $SD=10.97$ ). The median education was "Professional certificate" (completed high school with further professional education) and the median income level was NOK 400–499 k (approx. EUR 34–43 k). Geographically most of the sample was located in central and southern parts of Norway (further south than Nordland county) which corresponds to the distribution of the farmer population. There were no significant differences in any of the demographic variables across conditions (see Table 1 for details). Comparing with statistics of the national farmer population we consider these sample characteristics to be approximately representative (for details see Appendix A Table A2) (Statistics Norway 2024).

<sup>3</sup>The survey was posted on online forums with an unknown number of views so the exact response rate cannot be determined. Of the email recipients the response rate was 24 percent.

**Table 1** Descriptive statistics and balance check, including sample sizes and statistical tests. There was no significant difference between any of the study conditions on any of the variables, suggesting a balanced design

Variable	Mitigation		Adaptation		Control		Test
	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	
Age	54 (SD=11)	134	54 (SD=12)	132	52 (SD=10)	131	F=2.14
Gender		134		131		134	X <sup>2</sup> =0.61
Male	87%	117	84%	110	86%	115	
Female	13%	17	16%	21	14%	19	
Education		135		132		135	X <sup>2</sup> =1.10
No university degree	58%	78	52%	68	54%	73	
University degree	42%	57	48%	64	46%	62	
Land ownership		135		133		134	X <sup>2</sup> =2.28
Own 100%	38%	51	31%	41	30%	40	
Renter	62%	84	69%	92	70%	94	
Pre-intervention support	4.6 (SD=1.4)	118	4.8 (SD=1.5)	120	4.5 (SD=1.2)	120	F=1.97
Concern for climate change	3.5 (SD=1.1)	137	3.5 (SD=1)	135	3.4 (SD=1)	143	F=1.16

## 2.2 Design and procedures

The study was introduced to participants as a survey of horticultural farmers' experience with and use of cover crops in their farming system, without explicit reference to mitigation policies, adaptation, or information videos in the recruitment ad. Because of this it is possible that farmers with prior knowledge or interest in cover crops selected into participating in our study. However, the study followed a complete random assignment procedure and a between-subjects design to tame self-selection bias.<sup>4</sup> Respondents assigned to treatment saw one of two video variants, depending on which experimental condition, while those assigned to the control condition saw no video. We focused on framed video interventions for several reasons. From a cost–benefit perspective, they can help improve communication approaches which are shown to influence attitudes and beliefs (Fang and Innocenti 2023; Jalil et al. 2023; Moser and Dilling 2011). Videos capture attention more effectively than text or static images and can present complex information in a more engaging and accessible manner. Along with the growth of digital platforms, videos that leverage framing thus represent a promising tool for policy makers and practitioners to effectively disseminate targeted information to many people. The content of the survey and video scripts were discussed with regional experts, farm advisors, and farmers to verify that the content was accurate and easy to understand. The survey was coded in Qualtrics and the median time for completion was 15.5 min. At the end of the survey participants could opt in for a lottery to win one of

<sup>4</sup>As noted in randomized controlled trials literature (see for example Belot and James 2014; Duflo and Kremer 2003), randomization within a self-selected sample helps mitigate self-selection bias to yield valid and robust treatment effect estimates, particularly when both positive and negative self-selection occurs (Belot and James 2016). Furthermore, even if participants self-selected into the study, the random assignment procedure was implemented after people joined the study. By being randomly allocated to either the treatment groups or the control, participants' reactions can be attributed to the interventions themselves rather than pre-existing differences between participants.

five prizes of NOK 1,000 (EUR 90) as compensation for their time.<sup>5</sup> The links to the videos and their transcripts are provided in Appendix B.

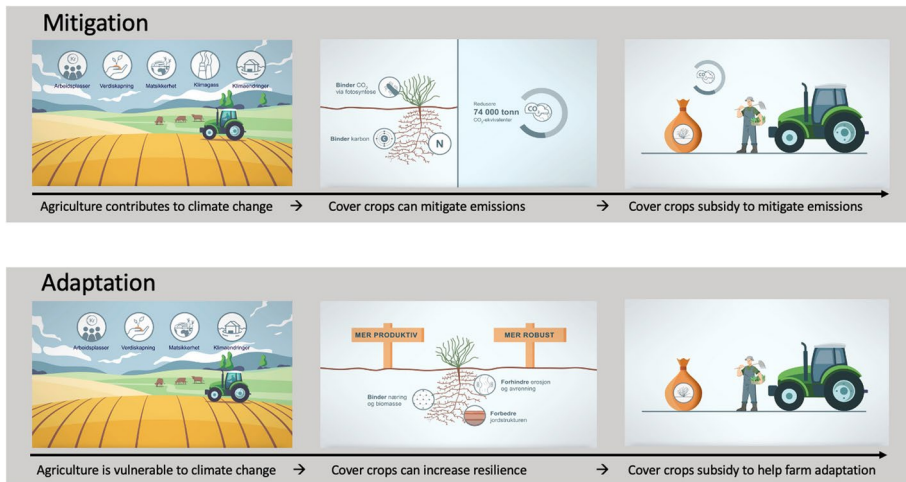
The survey instrument consisted of three main blocks.

**Pre-intervention block** The first block collected information on respondents' personal characteristics. All participants, after accessing the study, provided their informed consent and answered questions about their farming practices, their knowledge about cover crops, and their previous experience using cover crops. They then answered further questions related to their farming including their use of various information sources. They also answered questions about their risk preferences (such as "In general, to what extent are you willing to take risks?" and "To what extent are you willing to try something new in the operation of the farm, without knowing what the outcome is for other farmers who have tried it?" on a 7-point Likert scale), and belief in and concern for climate change (e.g. "To what extent do you agree that climate change is happening?" and "I am concerned about global climate change"). We also assessed participants' pre-intervention support for the Agricultural Intention Agreement to reduce greenhouse gas emissions (signed by the Norwegian Government and farmer interest organisations in 2019) on a 7-point Likert scale as a baseline measure of mitigation policy support.

**Intervention block** The second block of the survey contained the video-based information treatments. The videos were animated by a professional graphic designer and narrated by a professional reporter. The Mitigation condition narrated in simple terms the contribution of agriculture to climate change and the beneficial mitigation effects that widespread adoption of cover crops could offer. The Adaptation condition focused on the vulnerability of agriculture to climate change and that individuals' action of adopting cover crops could offer private benefits and help make their own farming system more resilient (for a visual summary see Fig. 1, and for full scripts see Appendix B). Each video lasted approximately 1.5 min. Participants in the Control condition did not watch any video and proceeded directly to the next survey item.

**Post-intervention block** The third block elicited participants' post-intervention level of support for the Agricultural Climate Agreement between the Norwegian farmer organisations and Government on a 7-point Likert scale (Policy Support). This constitutes our main outcome variable. We also asked their level of intention to adopt cover crops in 2023. To understand how and why farmers may have changed their views on mitigation strategies in response to the treatments we further collected a rich set of post-treatment beliefs, including level of concern about global climate change, perceived need for climate adaptation, priorities of adopting new technology, taking care of soils, biodiversity, and farming with future generations in mind on a 7-point Likert scale (e.g. "To what extent do you agree with the following statement: 'It is important to improve the farm for the next generation'"). The survey concluded with socio-demographic questions, which is normally the case with agricultural surveys. Participants were then thanked for their participation and had the option of providing any comments and to enter the lottery.

<sup>5</sup>The use of a lottery incentive is common practice to stimulate responses in Norwegian farmer surveys. Five participants were randomly selected for the lottery prize, which was a gift card to a well-known farming shop.



**Fig. 1** The content of the video information interventions visually presented with example screenshots and brief explanations. The upper panel illustrates the Mitigation intervention and the lower panel illustrates the Adaptation intervention

Finally, alongside the survey yet independently from it, we obtained participants' post-intervention decision to apply for a cover crops subsidy in the 2023 growing season as a proxy for their adoption of cover crops (variable termed "Adoption"). This constituted our secondary outcome variable (see Appendix A Table A1 for an overview of the dependent measures).

In terms of the cover crops subsidy, farmers can apply for it via an online form during a set application window in September–October every year. It is thus a retroactive process granting farmers a subsidy which refunds a significant amount of the expenses incurred if they implemented cover crops in that season. To be eligible for a subsidy in 2023, farmers could decide to adopt cover crops shortly after being exposed to our interventions in the spring. Farmers can adopt various cover crop options depending on their agronomic conditions and main crop, such as grasses, legumes, and other species. They must also meet certain requirements for being eligible for the cover crops subsidy such as refraining from using pesticides on the covered area and to avoid tillage by March 1st the following year. We extracted the record of submitted cover crops subsidy applications in November 2023 from the Norwegian Agricultural Agency. We then paired the record with respondents' survey responses to determine if a participant had applied for the subsidy (coded as a dummy variable with 1 indicating that an application was made) before performing statistical tests.

### 3 Results

Our experimental conditions were balanced in terms of observable characteristics. We observed no significant differences between conditions on participants' baseline support for the Agricultural Intention Agreement to reduce greenhouse gas emissions ( $F(2, 355)=1.97$ ,  $p=0.14$ ), and that most participants declared at least some level of knowledge of cover

crops (70%) and considered their soils to be suitable (94%) (for details see Table 1 and Appendix A section A.3.).

### 3.1 Post-intervention support for sector-wide mitigation policy

As per our preregistration, we report the effects of our interventions on participants' post-intervention Policy Support (support for nation-wide agricultural mitigation policy) and Application for the cover crops subsidy. All analyses were performed in R version 4.2.3.

We found that 54% of respondents in the Control condition were in favour of mitigation Policy Support (i.e. a score of 5 or higher on the 7-point Likert scale), 66% in Mitigation, and 75% in Adaptation (Fig. 2). A Chi-square test of independence revealed a significant difference between conditions ( $\chi^2=11.36$ ,  $p=0.003$ ). Pairwise comparisons indicated that participants in Adaptation ( $M=4.92$ ,  $SD=1.51$ ) showed significantly higher Policy Support than Control ( $M=4.47$ ,  $SD=1.35$ ). No significant difference was observed between the Mitigation ( $M=4.80$ ,  $SD=1.40$ ) and Adaptation treatments, nor between Mitigation and Control.

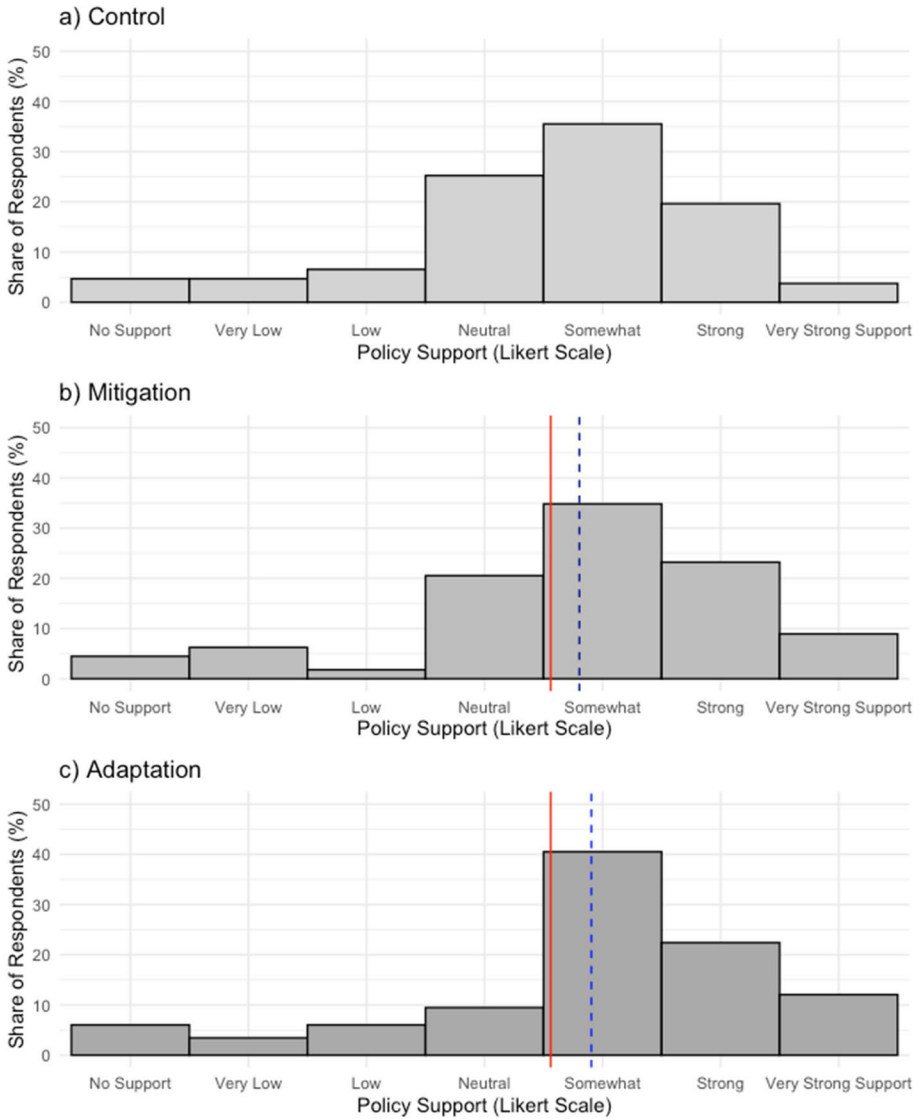
Following our pre-registration we estimated linear regression models (LMs) with robust standard errors (Table 2, columns 1–3).<sup>6</sup> Column 1 shows that in the full sample, the level of mitigation Policy Support was significantly higher for participants in the Adaptation condition relative to those in Control ( $p<0.05$ ). We note the low explanatory power of the model ( $R^2=0.02$ ).

Moreover, to better understand the effects of the interventions based on participants' prior attitudes to the policy we considered different segments of the population accordingly. We observed a positive effect of both the Mitigation and Adaptation conditions (albeit stronger for the Adaptation condition) when excluding participants who reported strong opposition to the policy in baseline (i.e. those who expressed 1 or 2 on the 7-point Likert scale in baseline). However, when excluding those strongly supportive in baseline (reporting 6 or 7 on the 7-point Likert scale), we observed no significant differences in effects.

To more accurately account for the ordinal nature of the post-treatment Policy Support measure and to address the slight deviation from normality in the distribution of residuals we also employed an ordered logistic regression (OLR) to consider the robustness of the effects. Taken together these complimentary findings help ensure that our conclusions do not depend on the specific model chosen. The results (Table 2, columns 4–6) are consistent with those from the linear models while also showing a marginally significant effect of the Mitigation condition in the full sample (column 4).

These findings partially support a risk salience effect and offer no evidence for a risk compensation effect. Furthermore, the results show that the increase in Policy Support achieved through the exposure to the Adaptation condition is primarily driven by a shift in the views of those who were already favourable toward national mitigation policy. We did not observe any change for those who initially had strong opposition to it.

<sup>6</sup>To retain as many observations as possible we handle the missing values in each regression model, hence the reduced  $n$  in certain models. We performed several checks of our regression models to ascertain that the missing values did not bias our results or interpretation thereof (for statistical details see Appendix A section A.4).



**Fig. 2** Share of respondents indicating level of post-intervention Policy support (i.e. support on a 7-point Likert scale for the Agricultural Climate Mitigation Plan) by condition. Panel **a)** shows the control condition. Panel **b)** shows the Mitigation condition, with the red solid line indicating the control mean and the blue dashed line indicating group mean. Panel **c)** shows the Adaptation condition, with the red solid line indicating the control mean and the blue dashed line indicating group mean

**Table 2** Support for agricultural mitigation policy after the intervention

	Linear regression			Ordered logistic regression		
	(1)	(2)	(3)	(4)	(5)	(6)
Mitigation	0.33 (0.18)	0.33* (0.16)	0.26 (0.19)	0.49* (0.23)	0.47 (0.26)	0.26 (0.28)
Adaptation	0.44* (0.18)	0.51** (0.15)	0.10 (0.21)	0.73*** (0.23)	0.67*** (0.25)	0.14 (0.29)
Observations	369	272	342	369	238	308
Excl. strong prior opposers		Yes			Yes	
Excl. strong prior supporters			Yes			Yes
R <sup>2</sup>	0.02	0.01	0.03			
Adjusted R <sup>2</sup>	0.01	-0.001	0.03			
AIC				1227.67	774.34	953.21

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ . Dependent variable: Policy support as measured on a 7-point Likert scale. Columns 1–3 report results from linear regression with robust standard errors in parentheses. Columns 4–6 report ordered logistic regression results with standard errors in parentheses. Variables Mitigation and Adaptation are treatment variables and Control is the reference variable

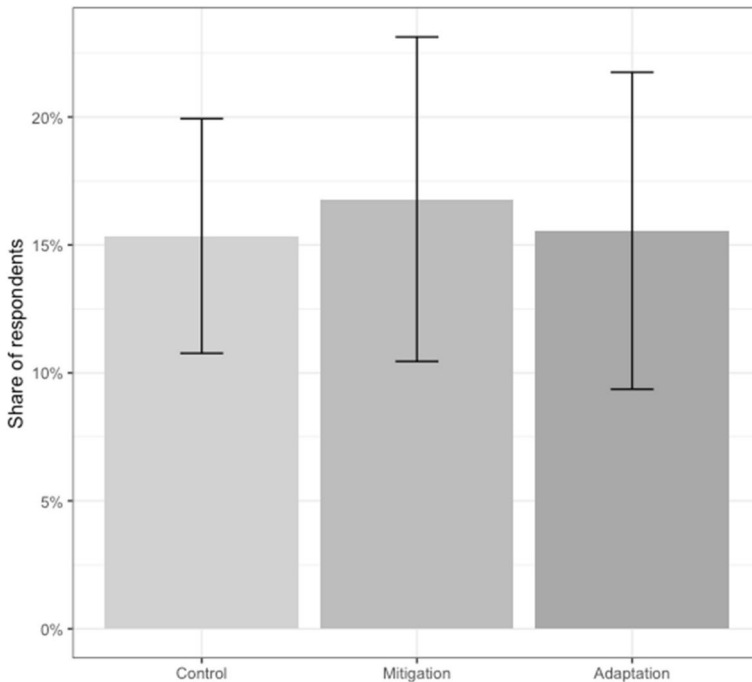
### 3.2 Heterogeneous effects and mechanisms

To understand how the effect of the interventions may vary depending on participants' prior characteristics we performed pre-registered moderation analyses also using LMs. Specifically, we assess the effects of the treatment conditions on Policy Support based on participants' baseline beliefs, sociodemographic factors, and farm-related characteristics.

The results (reported in Appendix A section A.5) showed a significant effect of the Mitigation (Table A4 column 2: coef. = 0.48,  $p = 0.02$ ) and Adaptation (coef. = 0.50,  $p = 0.02$ ) conditions among participants who reported high climate concern before the intervention. We observed no such effect for those with low levels of climate concern (column 3). This suggests that the effect of the Mitigation condition captured in the OLR presented in Table 2 could be driven by individuals with high levels of climate concern.

Analyses of participants' baseline risk preferences showed that the Adaptation treatment significantly increased Policy Support among risk seeking individuals (Table A4 column 4: coef. = 0.54,  $p = 0.02$ ). We found no significant differences in treatment effects for risk averse individuals (Table A4 column 5). However, we observed significantly higher levels of policy support in both conditions compared to control for farmers with larger farm areas, those holding a university degree, and those renting land, and stronger levels of support in the Adaptation condition for those who were older and had higher income (for statistical details see Appendix A Table A5).

We also investigated the mechanism underpinning these effects. Based on our hypotheses, we would expect both interventions to heighten concerns about the possible climate change impacts given a risk salience effect. Conversely, if risk compensation took hold, we would expect profit-making to overshadow environmental concerns, as the farmer might feel either absolved of responsibility or confident that environmental issues can be managed in other ways. The results of this exploration (Appendix A.6 Table A6) showed that the Adaptation condition increased participants' concern for local impacts of climate change (column 3, coef. = 0.41,  $p = 0.03$ ). We observed no effects of either intervention on participants' perceived importance of making profits of the farm. We thus consider these results to



**Fig. 3** Share of respondents applying for the subsidy to adopt cover crops in 2023 by treatment condition (n=513)

align with the risk salience effect in that our interventions, particularly the Adaptation intervention, appear to work by heightening concerns about climate change risks in the region.

### 3.3 Application for cover crops subsidy in the aftermath of the interventions

To investigate the effect of our treatments on farmers' behaviour we examined whether they applied for a cover crops subsidy in the 2023 growing season.

Overall, we observed a low rate of subsidy applications: 15.8% of our sample applied for the cover crops subsidy in 2023 (Fig. 3). A Chi-square test of independence revealed no difference between the share of participants that applied in the Mitigation ( $M=16.8$ ,  $SD=37.5$ ), Adaptation ( $M=15.6$ ,  $SD=36.4$ ), or Control ( $M=15.4$ ,  $SD=36.1$ ) conditions ( $\chi^2=0.14$ ,  $p=0.93$ ).

The low rate of applications contrasted with the significantly higher share of individuals who expressed an intention to apply (49%)<sup>7</sup> when completing the survey. We found a weak relationship between Intention to apply and Actual application for cover crops subsidy (Pearson's  $r(397)=0.22$ ,  $p<0.001$ ). As per our pre-analysis plan, we examined further predictors for Actual application using logistic regressions, reported in Appendix A Table A7. Overall, treatment exposure does not predict the subsidy applications. Having previously used cover crops significantly predicts the likelihood of applying for the subsidy, and con-

<sup>7</sup>A Chi-square test of independence revealed no difference between the share of participants that intended to apply in the Mitigation ( $M=.5$ ), Adaptation ( $M=.5$ ), or Control ( $M=.47$ ) conditions ( $\chi^2=0.36$ ,  $p=.83$ ).

cern for climate change is a negative predictor of applying (see Appendix A.7 for statistical details).

## 4 Discussion

Mitigating emissions and adapting to the consequences of climate change are both urgent aspects of addressing climate change, particularly in a context like agriculture. These tasks will largely fall on farmers. We show in an experimental setting that an adaptation information intervention is most effective for increasing farmers' support for national agricultural mitigation policy. We also find a discrepancy between intentions to adopt and actual adoption of cover crops as a sustainable farming practice. Our findings thus corroborate evidence that information interventions can influence support for agricultural mitigation policy, yet they do not close the gap between farmers' intentions to adopt and their actual adoption.

We find that farmers' support for sector-wide mitigation policy increased when exposing participants to a short video intervention focusing on agricultural adaptation featuring cover crops as a farming practice. This suggests that risk compensation effects may be less prevalent than previously suggested (Bolton et al. 2006), at least in the agricultural sector. The risk salience effect appears to be more pronounced in this context. While the effect sizes reported in our paper are small, they are consistent with and build on previous studies addressing the mitigation-adaptation relationship in the general population (Carrico et al. 2015; Evans et al. 2014; Urban et al. 2021) and results which indicate that climate-related concern, perceived risks and need for adaptation are linked to farmers' efforts to address climate change (e.g., Haden et al. 2012; Mase et al. 2017; Roesch-McNally et al. 2017).

Our results further suggest that the interventions primarily influenced farmers who are already in favour of implementing agricultural mitigation policies. Conversely, the interventions were not effective in swaying those who were initially opposed to the policy. Indeed, we find evidence to suggest that the Adaptation condition worked in part through heightened concerns for local impacts of climate change. This aligns with previous findings that link belief in and concern for climate change with the perceived psychological distance to climate change, both in the general population (Maiella et al. 2020; Vlasceanu et al. 2024) and in farmers (Azadi et al. 2019; Haden et al. 2012). Moreover, the heterogeneity analysis showed that the Mitigation condition increased policy support for individuals who held a university degree, rented land, and farmed on larger areas. More educated farmers may be more familiar with and receptive to the abstract nature of mitigation efforts, and farmland tenure status and size could influence farmers' perceived ability to carry out and deliver successful outcomes.

Theoretically, these findings contribute to the framing literature by demonstrating that farmers respond differently to the mitigation and adaptation frames and that targeted adaptation narratives can influence farmers' support for mitigation policy. The results are in line with the wider policy support literature showing that attitudes and perceived personal benefits predict support and that such narratives can help bridge farmers' immediate priorities and concerns with long-term policy goals (Bergquist et al. 2022; Dechezleprêtre et al. 2022; Drews and Van Den Bergh 2016; Klenert et al. 2018). Practically, they underscore the need for equitable and tailored communication strategies that meet individual needs over a

“one-size-fits-all” approach to agricultural policy, since a certain level of leniency is needed to for interventions to be effective.

We complemented the analysis of Policy Support with an objective behavioural measure to allay concerns of experimenter demand effects (Haaland et al. 2023). Our findings revealed no effect of our interventions on farmers' actual behaviour, as measured by their applications for a subsidy to adopt cover crops in 2023. The adoption rate was notably low, with only 16% of farmers taking advantage of the opportunity to receive a refund for cover crop expenses. This observed gap helps demonstrate how attitudinal change is decoupled from behaviour change in agriculture (Luh et al. 2023; Swart et al. 2023), which is also widely discussed in various pro-environmental contexts (see for example ElHaffar et al. 2020; Kollmuss and Agyeman 2002; Laffan et al. 2023). It is thus important to differentiate between stated intentions and actual behaviours. Our intervention could have influenced farmers at an early stage of behaviour change such as the contemplation stage (Hanna et al. 2014), but it was not sufficient to ultimately alter their behaviour (Campenhout 2021; Sutherland et al. 2012). As suggested earlier, to be eligible for the subsidy farmers must meet additional criteria such as avoiding tillage until March 1st the following year, suggesting that these criteria could constrain intentions and prevent them from turning into action, despite the persuasiveness of the intervention. It is beyond the scope of this paper to elaborate on the potential mechanisms behind this intention-action gap (it was explored separately by Byfuglien et al. (2025)). Future research should further examine how to close the gap in the agricultural context.

Taken together, this study holds important implications for a context like agriculture by linking an adaptation frame and farmers' support for mitigation policy—measured immediately after the intervention—and detaching intentions to adopt from actual adoption. It corroborates evidence that specific population segments are more supportive of government action and that policy effectiveness may improve by considering the characteristics of the target population (Arbuckle et al. 2013; Brown et al. 2021; Piñeiro et al. 2020; Sutherland et al. 2012; Woods et al. 2017). Combined with the finding of a significant intention-action gap, our findings further underline the importance of measuring actual behaviours as opposed to stated intentions and assessing long-term impacts for policy-relevant insights.

#### 4.1 Limitations and further directions

We acknowledge several limitations to this work and opportunities for future studies. First, while the use of videos is novel and important from a cost-benefit perspective to develop effective interventions, they were short and not repeated, thus their effects were likely limited. Our findings add to previous studies showing that video information interventions that are pedagogical and/or story-based could be more effective and they warrant further study (Fang and Innocenti 2023; Morris et al. 2019; Stantcheva 2021) as they can facilitate mental simulations of possible future events rendering risks more salient. There are also certain limitations to information provision as an intervention (Bergquist et al. 2023), as it does not remove e.g. cost barriers and may thus exacerbate inequalities. It is thus a tool to consider alongside others such as financial interventions.

Second, related to our design, while our sample was representative of the horticultural farmers population based on demographics, we acknowledge that the online survey format and recruitment strategy may have introduced a selection bias. Predominantly technologi-

cally literate farmers or those with a particular interest could have self-selected to participate. Although we used a diverse recruitment strategy tailored to reach a wide range of the population and minimise such biases (i.e. not only inviting via emails but also leveraging the Advisory Service and sending SMS-reminders), it is possible that many did not see or chose to ignore the advertisements. As noted by Belot and James (2016), self-selection bias could operate at different levels and arise from the simultaneous occurrence of both positive and negative selection. In our case, randomization occurred after participants self-selected into the study to ensure that differences between the treatment groups and control can be attributed to the interventions rather than pre-existing differences between participants. However, biases in the initial selection process could still influence the generalisability of our findings due to the violation of the assumption of external unconfoundedness of participation. The responses to the survey also included cases of missing data, plausibly biasing downward our effects so the results and interpretations could be strengthened with improved power.

Third, we cannot exclude the possibility that farmers could have adopted cover crops without applying for subsidy. This is however unlikely as the costs and time commitment associated with cover crops are considerable. Given the economic incentive covering a significant amount of the expenses it is thus highly likely that those who adopted cover crops applied for the subsidy to obtain a refund.

We conducted our randomized study in a real-world setting with farmers, using an objective (though possibly imperfect) measure of behaviour—specifically, the adoption of cover crops. This approach allowed us to move beyond the limitations of standard laboratory settings. However, we acknowledge that the study was tailored for the Norwegian context and policies. Therefore, also in view of the small effect size, we recommend further research to determine whether these results are generalisable beyond the Nordic context, and if similar information interventions produce comparable outcomes (see List 2020).

We already noted the fruitful research area of the intention-action gap. Another important question concerns the fact that we focused on cover crops. Future work is needed to examine whether the interventions produced spillover-effects in the sense that participants were influenced to adopt other sustainable farming practices.

## 5 Conclusion

This paper shows that a short video information intervention highlighting the adaptation benefits of cover crops significantly increased farmers' support for mitigation policy, suggesting that adaptation can be a unifying argument for attracting farmers' support, especially among those who are already in favour of mitigation efforts. Considering the urgent need for adaptation and mitigation, this survey experiment is a timely contribution to augment our scientific knowledge of adaptation-mitigation dynamics and specifically how farmers think and act on them. We find our results to be better explained by a risk salience effect and no reason to suspect a risk compensation effect. The adaptation narrative does not crowd out support for sector-wide mitigation policies in the Norwegian agricultural context. We did not observe an effect of our treatment on farmers' adoption of cover crops, underlining the importance of dissociating stated intentions and support from actual behaviour. Ultimately, these findings move us one step closer to understanding the adaptation-mitigation

relationship as well as how climate change communication can be framed in the agricultural context.

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**Author contributions** All authors contributed to the study conception, design, and material preparation. Data collection and analysis were performed by AB. The first draft of the manuscript was written by AB and all authors commented on and edited previous versions of the manuscript. All authors read and approved the final manuscript.

AB: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Validation; Visualization; Writing—original draft; and Writing—review and editing. SI: Conceptualization; Data curation; Methodology; Formal analysis; Supervision; Writing—review and editing. VK: Conceptualization; Methodology; Supervision; Writing—review and editing.

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**Data availability** The datasets generated during and/or analysed during the current study are not publicly available due to risk of compromising respondents' anonymity but are available from the corresponding author on reasonable request.

## Declarations

We pre-registered the study in the Open Science Framework website (link to pre-registration here: [osf.io/5tnc4](https://osf.io/5tnc4)). Ethical approval was received from the Central University Research Ethics Committee (SOGEC1A-23-2). The authors have no relevant financial or non-financial interests to disclose. This research was conducted in partnership with and supported financially (grant no. 320810) by the Norwegian Institute for Bioeconomy (NIBIO) that has a long-standing experience with conducting agricultural research in Norway.

**Ethics approval** Ethics approval was obtained from the Central University Research Ethics Committee of the University of Oxford: SOGEC1A-23-2. Our study was pre-registered on OSF, [osf.io/5tnc4](https://osf.io/5tnc4). We thank Antonio Rodriguez- Romera for helpful statistical assistance.

**Conflict of interest** None.

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## References

- Anderson R, Bayer PE, Edwards D (2020) Climate change and the need for agricultural adaptation. *Curr Opin Plant Biol* 56:197–202. <https://doi.org/10.1016/j.pbi.2019.12.006>
- Andrews AC, Clawson RA, Gramig BM, Raymond L (2013) Why do farmers adopt conservation tillage? An experimental investigation of framing effects. *J Soil Water Conserv* 68(6):501–511. <https://doi.org/10.2489/jswc.68.6.501>
- Arbuckle JG, Morton LW, Hobbs J (2013) Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: evidence from Iowa. *Clim Change* 118(3–4):551–563. <https://doi.org/10.1007/s10584-013-0700-0>
- Arbuckle JG, Morton LW, Hobbs J (2015) Understanding farmer perspectives on climate change adaptation and mitigation: the roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environ Behav* 47(2):205–234. <https://doi.org/10.1177/0013916513503832>
- Azadi Y, Yazdanpanah M, Mahmoudi H (2019) Understanding smallholder farmers' adaptation behaviors through climate change beliefs, risk perception, trust, and psychological distance: Evidence from wheat growers in Iran. *J Environ Manage* 250:109456. <https://doi.org/10.1016/j.jenvman.2019.109456>
- Barnes AP, Soto I, Eory V, Beck B, Balafoutis AT, Sanchez B, Vangeyte J, Fountas S, Van Der Wal T, Gómez-Barbero M (2019) Influencing incentives for precision agricultural technologies within European arable farming systems. *Environ Sci Policy* 93:66–74. <https://doi.org/10.1016/j.envsci.2018.12.014>
- Belot M, James J (2014) A new perspective on the issue of selection bias in randomized controlled field experiments. *Econ Lett* 124(3):326–328
- Belot M, James J (2016) Partner selection into policy relevant field experiments. *J Econ Behav Organ* 123:31–56. <https://doi.org/10.1016/j.jebo.2015.12.007>
- Bergquist M, Nilsson A, Harring N, Jagers SC (2022) Meta-analyses of fifteen determinants of public opinion about climate change taxes and laws. *Nat Clim Chang* 12(3):235–240. <https://doi.org/10.1038/s41558-022-01297-6>
- Bergquist M, Thiel M, Goldberg MH, Van Der Linden S (2023) Field interventions for climate change mitigation behaviors: a second-order meta-analysis. *Proc Natl Acad Sci* 120(13):e2214851120. <https://doi.org/10.1073/pnas.2214851120>
- Bergtold JS, Ramsey S, Maddy L, Williams JR (2019) A review of economic considerations for cover crops as a conservation practice. *Renew Agric Food Syst* 34(1):62–76. <https://doi.org/10.1017/S1742170517000278>
- Bøe F, Bechmann M, Øgaard AF, Sturite I, Brandsæter LO (2019) Fangvekstenes økosystemtjenester–Kunnskapsstatus om effekten av fangvekster. NIBIO. [https://nibio.brage.unit.no/nibio-xmlui/bitstream/handle/11250/2582027/NIBIO\\_RAPPORT\\_2019\\_5\\_9.pdf?sequence=1&isAllowed=y](https://nibio.brage.unit.no/nibio-xmlui/bitstream/handle/11250/2582027/NIBIO_RAPPORT_2019_5_9.pdf?sequence=1&isAllowed=y)
- Bolton LE, Cohen JB, Bloom PN (2006) Does marketing products as remedies create “Get Out of Jail Free Cards”? *J Consum Res* 33(1):71–81. <https://doi.org/10.1086/504137>
- Bondelaget (2020) Landbrukets klimaplan 2021–2030. <https://www.bondelaget.no/bondelaget-mener/miljog-og-klima/klima/landbrukets-klimaplan-pdf/les-klimaplanen-her>
- Brown C, Kovács E, Herzon I, Villamayor-Tomas S, Albizua A, Galanaki A, Grammatikopoulou I, McCracken D, Olsson JA, Zinngrebe Y (2021) Simplistic understandings of farmer motivations could undermine the environmental potential of the common agricultural policy. *Land Use Policy* 101:105136. <https://doi.org/10.1016/j.landusepol.2020.105136>
- Brügger A, Morton TA, Dessai S (2015) Hand in Hand: Public Endorsement of Climate Change Mitigation and Adaptation. *PLoS ONE* 10(4):e0124843. <https://doi.org/10.1371/journal.pone.0124843>
- Büchi L, Wendling M, Amossé C, Neepalova M, Charles R (2018) Importance of cover crops in alleviating negative effects of reduced soil tillage and promoting soil fertility in a winter wheat cropping system. *Agr Ecosyst Environ* 256:92–104. <https://doi.org/10.1016/j.agee.2018.01.005>
- Byfluglien A, Van Valkengoed AM, Innocenti S (2025) Good intentions, limited action: When do farmers' intentions to adopt sustainable farming practices turn into actual behaviour? *J Environ Psychol* 102:102522. <https://doi.org/10.1016/j.jenvp.2025.102522>
- Calvin K, Dasgupta D, Krinner G, Mukherji A, Thorne PW, Trisos C, Romero J, Aldunce P, Barrett K, Blanco G, Cheung WWL, Connors S, Denton F, Diongue-Niang A, Dodman D, Garschagen M, Geden O, Hayward B, Jones C, Péan C (2023) IPCC, 2023: Climate Change 2023: synthesis report. Contribution of working groups I, II and III to the sixth assessment report of the intergovernmental panel on climate change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. (First). Intergovernmental Panel on Climate Change (IPCC). <https://doi.org/10.59327/IPCC/AR6-9789291691647>
- Camargo GGT, Ryan MR, Richard TL (2013) Energy use and greenhouse gas emissions from crop production using the farm energy analysis tool. *Bioscience* 63(4):263–273. <https://doi.org/10.1525/bio.2013.63.4.6>

- Campenhout BV (2021) The role of information in agricultural technology adoption: experimental evidence from rice farmers in Uganda. *Econ Dev Cult Change* 69(3):1239–1272. <https://doi.org/10.1086/703868>
- Carrico AR, Truelove HB, Vandenberg MP, Dana D (2015) Does learning about climate change adaptation change support for mitigation? *J Environ Psychol* 41:19–29. <https://doi.org/10.1016/j.jenvp.2014.10.009>
- Chater N, Loewenstein G (2023) The i-frame and the s-frame: how focusing on individual-level solutions has led behavioral public policy astray. *Behav Brain Scie* 46:e147. <https://doi.org/10.1017/S0140525X22002023>
- Clark MA, Domingo NGG, Colgan K, Thakrar SK, Tilman D, Lynch J, Azevedo IL, Hill JD (2020) Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science* 370(6517):705–708. <https://doi.org/10.1126/science.aba7357>
- Darnhofer I, Bellon S, Dedieu B, Milestad R (2010) Adaptiveness to enhance the sustainability of farming systems. A review. *Agron Sustain Dev* 30(3):545–555. <https://doi.org/10.1051/agro/2009053>
- Davidson DJ, Rollins C, Lefsrud L, Anders S, Hamann A (2019) Just don't call it climate change: Climate-skeptic farmer adoption of climate-mitigative practices. *Environ Res Lett* 14(3):034015. <https://doi.org/10.1088/1748-9326/aafa30>
- Dechezleprêtre A, Fabre A, Kruse T, Planterose B, Chico AS, Stantcheva S (2022) Fighting climate change: international attitudes toward climate policies. *Nat Bur Econ Res* w30265. <https://doi.org/10.3386/w30265>
- Doran EMB, Zia A, Hurley SE, Tsai Y, Koliba C, Adair C, Schattman RE, Rizzo DM, Méndez VE (2020) Social-psychological determinants of farmer intention to adopt nutrient best management practices: implications for resilient adaptation to climate change. *J Environ Manage* 276:111304. <https://doi.org/10.1016/j.jenvman.2020.111304>
- Drews S, Van Den Bergh JCJM (2016) What explains public support for climate policies? A review of empirical and experimental studies. *Clim Pol* 16(7):855–876. <https://doi.org/10.1080/14693062.2015.1058240>
- Dufflo E, Kremer M (2003) Use of randomization in the evaluation of development effectiveness. *Eval Dev Eff* 7:205
- ElHaffar G, Durif F, Dubé L (2020) Towards closing the attitude-intention-behavior gap in green consumption: a narrative review of the literature and an overview of future research directions. *J Clean Prod* 275:122556. <https://doi.org/10.1016/j.jclepro.2020.122556>
- European Commission (2020) Farm to fork strategy: for a fair, healthy and environmentally-friendly food system. [https://food.ec.europa.eu/system/files/2020-05/f2f\\_action-plan\\_2020\\_strategy-info\\_en.pdf](https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf)
- Evans L, Milfont TL, Lawrence J (2014) Considering local adaptation increases willingness to mitigate. *Glob Environ Chang* 25:69–75. <https://doi.org/10.1016/j.gloenvcha.2013.12.013>
- Fang X, Innocenti S (2023) Increasing the acceptability of carbon taxation: the role of social norms and economic reasoning. *INET Oxford Working Paper Series*, pp 2023–25
- FAO, IFAD, UNICEF, WFP, WHO (2023) The state of food security and nutrition in the world 2023. FAO. <https://doi.org/10.4060/cc3017en>
- Gardezi M, Arbuckle JG (2020) Techno-optimism and farmers' attitudes toward climate change adaptation. *Environ Behav* 52(1):82–105. <https://doi.org/10.1177/0013916518793482>
- Genskow KD (2012) Taking stock of voluntary nutrient management: measuring and tracking change. *J Soil Water Conserv* 67(1):51–58. <https://doi.org/10.2489/jswc.67.1.51>
- Gillingham K, Kotchen MJ, Rapson DS, Wagner G (2013) The rebound effect is overplayed. *Nature* 493(7433):475–476. <https://doi.org/10.1038/493475a>
- Greenhill B, Dolšák N, Prakash A (2018) Exploring the adaptation-mitigation relationship: Does information on the costs of adapting to climate change influence support for mitigation? *Environ Commun* 12(7):911–927. <https://doi.org/10.1080/17524032.2018.1508046>
- Haaland I, Roth C, Wohlfart J (2023) Designing information provision experiments. *J Econ Lit* 61(1):3–40. <https://doi.org/10.1257/jel.20211658>
- Haden VR, Niles MT, Lubell M, Perlman J, Jackson LE (2012) Global and local concerns: what attitudes and beliefs motivate farmers to mitigate and adapt to climate change? *PLoS ONE* 7(12):e52882. <https://doi.org/10.1371/journal.pone.0052882>
- Hanna R, Mullainathan S, Schwartzstein J (2014) Learning through noticing: theory and evidence from a field experiment. *Q J Econ* 129(3):1311–1353. <https://doi.org/10.1093/qje/qju015>
- Hasanzadeh S, De La Garza JM, Geller ES (2020) Latent effect of safety interventions. *J Constr Eng Manag* 146(5):04020033. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001812](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001812)
- Helitzer D, Gary H, Benally J, Ortega C (2014) Culturally relevant model program to prevent and reduce agricultural injuries. *J Agric Saf Health* 20(1):175–198. <https://doi.org/10.13031/jash.20.10333>
- IPBES (2019) Summary for policymakers of the global assessment report on biodiversity and ecosystem services. Zenodo. <https://doi.org/10.5281/ZENODO.3553579>

- IPCC (2019) Summary for policymakers. In: Shukla PR, Skea J, Calvo Buendia E, Masson-Delmotte V, Pörtner H-O, Roberts DC, Zhai P, Slade R, Connors S, van Diemen R, Ferrat M, Haughey E, Luz S, Neogi S, Pathak M, Petzold J, Portugal Pereira J, Vyas P, Huntley E, Kissick K, Belkacemi M, Malley J (eds) Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems
- IPCC (2022) Climate change 2022: impacts, adaptation and vulnerability. <https://www.ipcc.ch/report/ar6/wg2/>
- Jalil AJ, Tasoff J, Bustamante AV (2023) Low-cost climate-change informational intervention reduces meat consumption among students for 3 years. *Nat Food* 4(3):218–222. <https://doi.org/10.1038/s43016-023-00712-1>
- Jones CM, Kammen DM (2011) Quantifying carbon footprint reduction opportunities for U.S. households and communities. *Environ Sci Technol* 45(9):4088–4095. <https://doi.org/10.1021/es102221h>
- Kaye JP, Quemada M (2017) Using cover crops to mitigate and adapt to climate change. A review. *Agron Sustain Dev* 37(1):4. <https://doi.org/10.1007/s13593-016-0410-x>
- Klenert D, Mattauch L, Combet E, Edenhofer O, Hepburn C, Rafaty R, Stern N (2018) Making carbon pricing work for citizens. *Nat Clim Chang* 8(8):669–677. <https://doi.org/10.1038/s41558-018-0201-2>
- Kollmuss A, Agyeman J (2002) Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environ Educ Res* 8(3):239–260. <https://doi.org/10.1080/13504620220145401>
- Kreft C, Huber R, Wuepper D, Finger R (2021) The role of non-cognitive skills in farmers' adoption of climate change mitigation measures. *Ecol Econ* 189:107169. <https://doi.org/10.1016/j.ecolecon.2021.107169>
- Laffan K, Lades LK, Delaney L (2023) Paths that lead astray: examining the situational predictors of intention-behaviour gaps in meat consumption. *J Environ Psychol* 89:102045. <https://doi.org/10.1016/j.jenvp.2023.102045>
- List J (2020) Non est disputandum de generalizability? a glimpse into the external validity trial. *Nat Bur Econ Res* w27535. <https://doi.org/10.3386/w27535>
- Lugato E, Cescatti A, Jones A, Ceccherini G, Duveiller G (2020) Maximising climate mitigation potential by carbon and radiative agricultural land management with cover crops. *Environ Res Lett* 15(9):094075. <https://doi.org/10.1088/1748-9326/aba137>
- Luh Y-H, Tsai M-H, Chang Y-C (2023) Actions speak louder than words: adoption of sustainable farming practices based on an integrated model. *J Clean Prod* 416:137856. <https://doi.org/10.1016/j.jclepro.2023.137856>
- Lynch J, Cain M, Frame D, Pierrehumbert R (2021) Agriculture's contribution to climate change and role in mitigation is distinct from predominantly fossil CO<sub>2</sub>-emitting sectors. *Front Sustain Food Syst* 4. <https://www.frontiersin.org/articles/10.3389/fsufs.2020.518039>
- Maiella R, La Malva P, Marchetti D, Pomarico E, Di Crosta A, Palumbo R, Cetara L, Di Domenico A, Verrocchio MC (2020) The psychological distance and climate change: a systematic review on the mitigation and adaptation behaviors. *Front Psychol* 11:568899. <https://doi.org/10.3389/fpsyg.2020.568899>
- Mase AS, Gramig BM, Prokopy LS (2017) Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers. *Clim Risk Manag* 15:8–17. <https://doi.org/10.1016/j.crm.2016.11.004>
- McEldowney J (2020) EU agricultural policy and climate change. European Parliamentary Research Service. [https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651922/EPRS\\_BRI\(2020\)651922\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651922/EPRS_BRI(2020)651922_EN.pdf)
- McGreevy SR, Rupprecht CDD, Niles D, Wiek A, Carolan M, Kallis G, Kantamaturapoj K, Mangnus A, Jehlička P, Taherzadeh O, Sahakian M, Chabay I, Colby A, Vivero-Pol J-L, Chaudhuri R, Spiegelberg M, Kobayashi M, Balázs B, Tsuchiya K, Tachikawa M (2022) Sustainable agrifood systems for a post-growth world. *Nat Sustain* 5(12):1011–1017. <https://doi.org/10.1038/s41893-022-00933-5>
- Moerkerken A, Blasch J, van Beukering P, van Well E (2020) A new approach to explain farmers' adoption of climate change mitigation measures. *Clim Change* 159(1):141–161. <https://doi.org/10.1007/s10584-019-02595-3>
- Morris BS, Chrysochou P, Christensen JD, Orquin JL, Barraza J, Zak PJ, Mitkidis P (2019) Stories vs facts: Triggering emotion and action-taking on climate change. *Clim Change* 154(1):19–36. <https://doi.org/10.1007/s10584-019-02425-6>
- Mortreux C, Barnett J (2017) Adaptive capacity: exploring the research frontier. *WIREs Clim Change* 8(4). <https://doi.org/10.1002/wcc.467>
- Moser SC, Dilling L (2011) Communicating climate change: closing the science-action gap. In *The Oxford Handbook of Climate Change and Society*, Oxford University Press

- Nainggolan D, Moeis FR, Termansen M (2023) Does risk preference influence farm level adaptation strategies?—survey evidence from Denmark. *Mitig Adapt Strat Glob Change* 28(7):40. <https://doi.org/10.1007/s11027-023-10077-2>
- Newbold T, Hudson LN, Arnell AP, Contu S, Palma AD, Ferrier S, Hill SLL, Hoskins AJ, Lysenko I, Phillips HRP, Burton VJ, Chng CWT, Emerson S, Gao D, Pask-Hale G, Hutton J, Jung M, Sanchez-Ortiz K, Simmons BI, Purvis A (2016) Has land use pushed terrestrial biodiversity beyond the planetary boundary? a global assessment. *Science* 353(6296):288–291. <https://doi.org/10.1126/science.aaf2201>
- Ngo CC, Poortvliet PM, Klerkx L (2022) The persuasiveness of gain vs. loss framed messages on farmers' perceptions and decisions to climate change: a case study in coastal communities of Vietnam. *Clim Risk Manag* 35:100409. <https://doi.org/10.1016/j.crm.2022.100409>
- OECD (2021) Policies for the future of farming and food in Norway. OECD. <https://doi.org/10.1787/20b14991-en>
- Pielke R, Prins G, Rayner S, Sarewitz D (2007) Lifting the taboo on adaptation. *Nature* 445(7128):597–598. <https://doi.org/10.1038/445597a>
- Piñeiro V, Arias J, Dürr J, Elverdin P, Ibáñez AM, Kinengyere A, Opazo CM, Owoo N, Page JR, Prager SD, Torero M (2020) A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nat Sustain* 3(10):809–820. <https://doi.org/10.1038/s41893-020-00617-y>
- Poore J, Nemecek T (2018) Reducing food's environmental impacts through producers and consumers. *Science* 360(6392):987–992. <https://doi.org/10.1126/science.aag0216>
- Prokopy LS, Arbuckle JG, Barnes AP, Haden VR, Hogan A, Niles MT, Tyndall J (2015) Farmers and climate change: a cross-national comparison of beliefs and risk perceptions in high-income countries. *Environ Manage* 56(2):492–504. <https://doi.org/10.1007/s00267-015-0504-2>
- Rochecouste J-F, Dargusch P, Cameron D, Smith C (2015) An analysis of the socio-economic factors influencing the adoption of conservation agriculture as a climate change mitigation activity in Australian dryland grain production. *Agric Syst* 135:20–30. <https://doi.org/10.1016/j.agsy.2014.12.002>
- Rodríguez-Barillas M, Poortvliet PM, Klerkx L (2024) Unraveling farmers' interrelated adaptation and mitigation adoption decisions under perceived climate change risks. *J Rural Stud* 109:103329. <https://doi.org/10.1016/j.jrurstud.2024.103329>
- Roesch-McNally GE, Gordon Arbuckle J, Tyndall JC (2017) What would farmers do? Adaptation intentions under a Corn Belt climate change scenario. *Agric Hum Values* 34(2):333–346. <https://doi.org/10.1007/s10460-016-9719-y>
- Rose DC, Keating C, Morris C (2018) Understand how to influence farmers' decision-making behaviour. AHDB. [https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/FarmersDecisionMaking\\_2018\\_09\\_18.pdf](https://projectblue.blob.core.windows.net/media/Default/Imported%20Publication%20Docs/FarmersDecisionMaking_2018_09_18.pdf)
- Rosenzweig C, Elliott J, Deryng D, Ruane AC, Müller C, Arneth A, Boote KJ, Folberth C, Glotter M, Khabarov N, Neumann K, Piontek F, Pugh TAM, Schmid E, Stehfest E, Yang H, Jones JW (2014) Assessing agricultural risks of climate change in the 21st century in a global gridded crop model inter-comparison. *Proc Natl Acad Sci* 111(9):3268–3273. <https://doi.org/10.1073/pnas.1222463110>
- Rust NA, Jarvis RM, Reed MS, Cooper J (2021) Framing of sustainable agricultural practices by the farming press and its effect on adoption. *Agric Hum Values* 38(3):753–765. <https://doi.org/10.1007/s10460-020-10186-7>
- Skevas T, Massey R, Grashuis J (2022) Farmer adoption and intensity of use of extreme weather adaptation and mitigation strategies: evidence from a sample of missouri farmers. *Clim Change* 174(1):18. <https://doi.org/10.1007/s10584-022-03439-3>
- Stancheva S (2021) Understanding tax policy: how do people reason? *Q J Econ* 136(4):2309–2369. <https://doi.org/10.1093/qje/qjab033>
- Statistics Norway (2024) Fakta om jordbruk. Jordbruk. <https://www.ssb.no/jord-skog-jakt-og-fiskeri/faktaside/jordbruk>
- Sutherland L-A, Burton RJF, Ingram J, Blackstock K, Slee B, Gotts N (2012) Triggering change: towards a conceptualisation of major change processes in farm decision-making. *J Environ Manage* 104:142–151. <https://doi.org/10.1016/j.jenvman.2012.03.013>
- Swart R, Levers C, Davis JTM, Verburg PH (2023) Meta-analyses reveal the importance of socio-psychological factors for farmers' adoption of sustainable agricultural practices. *One Earth* 6(12):1771–1783. <https://doi.org/10.1016/j.oneear.2023.10.028>
- Tol RSJ (2005) Adaptation and mitigation: trade-offs in substance and methods. *Environ Sci Policy* 8(6):572–578. <https://doi.org/10.1016/j.envsci.2005.06.011>
- Urban J, Vačkářová D, Badura T (2021) Climate adaptation and climate mitigation do not undermine each other: a cross-cultural test in four countries. *J Environ Psychol* 77:101658. <https://doi.org/10.1016/j.jenvp.2021.101658>

- Vlasceanu M, Doell KC, Bak-Coleman JB, Todorova B, Berkebile-Weinberg MM, Grayson SJ, Patel Y, Goldwert D, Pei Y, Chakroff A, Pronizius E, Van Den Broek KL, Vlasceanu D, Constantino S, Morais MJ, Schumann P, Rathje S, Fang K, Aglioti SM, Van Bavel JJ (2024) Addressing climate change with behavioral science: A global intervention tournament in 63 countries. *Sci Adv* 10(6):eadj5778. <https://doi.org/10.1126/sciadv.adj5778>
- Weber EU (2006) Experience-based and description-based perceptions of long-term risk: why global warming does not scare us (Yet). *Clim Change* 77(1):103–120. <https://doi.org/10.1007/s10584-006-9060-3>
- Weber EU (2020) Seeing is believing: understanding & aiding human responses to global climate change. *Daedalus* 149(4):139–150. [https://doi.org/10.1162/daed\\_a\\_01823](https://doi.org/10.1162/daed_a_01823)
- Wheeler R, Lobley M (2021) Managing extreme weather and climate change in UK agriculture: impacts, attitudes and action among farmers and stakeholders. *Clim Risk Manag* 32:100313. <https://doi.org/10.1016/j.crm.2021.100313>
- Wiebe K, Robinson S, Cattaneo A (2019) Climate change, agriculture and food security. In: *Sustainable Food and Agriculture*. Elsevier, pp 55–74. <https://doi.org/10.1016/B978-0-12-812134-4.00004-2>
- Wollenberg E, Richards M, Smith P, Havlík P, Obersteiner M, Tubiello FN, Herold M, Gerber P, Carter S, Reisinger A, Vuuren DP, Dickie A, Neufeldt H, Sander BO, Wassmann R, Sommer R, Amonette JE, Falcucci A, Herrero M, Campbell BM (2016) Reducing emissions from agriculture to meet the 2 °C target. *Glob Change Biol* 22(12):3859–3864. <https://doi.org/10.1111/gcb.13340>
- Woods BA, Nielsen HØ, Pedersen AB, Kristofersson D (2017) Farmers' perceptions of climate change and their likely responses in Danish agriculture. *Land Use Pol* 65:109–120. <https://doi.org/10.1016/j.landusepol.2017.04.007>
- Zhang L, Ruiz-Menjivar J, Luo B, Liang Z, Swisher ME (2020) Predicting climate change mitigation and adaptation behaviors in agricultural production: a comparison of the theory of planned behavior and the value-belief-norm theory. *J Environ Psychol* 68:101408. <https://doi.org/10.1016/j.jenvp.2020.101408>

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