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Assessing the Effects of Nudge and Boost for Methane Emission Reduction from Paddy Field

-Cluster Randomized Controlled Trial in Japan-

Hiroki SASAKI [1], Shinya HORIE [2], Tetsuya HORIE[3], and Katsuya TANAKA[4]

1: Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries, Japan. 2: Onomichi City University. 3: Sophia University. 4: Shiga University.

Corresponding author email: sasakih@affrc.go.jp

Abstract

In this study, we explore the impact of "Nudge" and "Boost" methodologies on mitigating methane emissions from rice cultivation, a significant contributor to global greenhouse gas emissions. Through a cluster randomized control trial conducted in Japan, we assess whether strategic informational campaigns, incorporating these behavioral insight, can enhance the adoption of a prolonged mid-season drainage period, which can lower methane emissions from rice paddies. Our experimental results show notable differences in the effectiveness of basic communications from the local government as before (Control group) versus those enriched with social comparison messaging focusing on methane emission from paddy fields (Nudge). Specifically, we find a clear positive effect of social comparison messaging for farmers participating in community-based agriculture. Furthermore, our research indicates that targeted technical guidance (Boost), addressing prevalent concerns about altering traditional farming methods, significantly sways farmers' future intentions toward methane-reduction techniques. The study underscores the importance of combining nudges, which subtly alter the external choice architecture, with boosts that empower farmers' decision-making capabilities and counter cognitive biases, to effectively steer behavior towards environmentally sustainable practices.

JEL Codes: C93, Q15, Q18.

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1. Introduction

Rice, as the world's most extensively cultivated and consumed crop, contributes significantly to global methane emissions, accounting for 10-12% of the total. It also represents 1.5% of overall greenhouse gas emissions. The international community has recognized the urgency of reducing methane emissions. The Global Methane Pledge, initiated at the United Nations Climate Change Conference (COP26) in 2021, is a testament to this commitment. This initiative aims to cut global methane emissions by a minimum of 30% from 2020 levels by 2030, as part of a broader effort to address climate change. Among water management practices, one effective method to lower methane emissions from rice paddies is to extend the mid-season drainage (MSD) period. Extending the mid-drying period by an additional 7 days beyond conventional practice can decrease methane emissions by an average of 30% (Itoh et al. 2011)[1].

However, despite the negligible cost of adopting prolonged MSD, its global dissemination in rice farming remains limited, presenting a crucial policy challenge especially in Asia-Monsoon region which is a central region for methane emissions from rice farming. Although scientific research results on the methane reduction effects of MSD are accumulating, there has been an insufficient investigation into policy measures that could effectively motivate farmers to adopt these prolonged MSD. Alongside existing agri-environmental payment schemes, non-monetary incentives, particularly the dissemination of well-designed information, could be a viable approach. Addressing this issue, our study explores the types of information, including behavioral insights, that encourage rice farmers to adopt prolonged MSD. This exploration is grounded in a large-scale field experiment conducted in partnership with the Shiga Prefectural Government in one of the major rice-growing areas in Japan.

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[1] Other than prolonged midseason drainage, the International Rice Research Institute and its collaborators developed alternate wetting and drying (AWD), a multiple aeration practice, to minimize irrigation water use and CH_4 emission (Lampayan et al., 2004) although its wide dissemination is still under way(Hoang et al. 2023).

In this study, we divided 408 agricultural settlements, known as "*nougyou-syuraku*" in Japanese, across four municipalities in eastern Shiga Prefecture into four random groups. Each group received different information taking into account the paddy rice growing calendar and the schedule for applying for subsidies (agri-environmental payments). The control group did not receive any specific new information concerning methane emission from paddy during this experiment. Traditionally, local governments have informed about productivity enhancements, including the benefits of MSD in rice paddies, which strengthens rice roots and increases plant resistance to lodging; no information was provided on the reduction of methane gas emitted by the paddy fields by extending the period of MSD. The first treatment group received information based on social norms that many farmers in this region have already implemented environmentally friendly managements (Treatment 1: a social norm nudge), the second was informed about the negative impacts of climate change on rice cultivation (Treatment 2: a loss aversion nudge), and the third used a Q&A format addressing farmers' concerns identified in a preliminary survey conducted by authors. The approach of third treatment group, offering direct guidance (Treatment 3: a 'boost' strategy), contrasts with the indirect 'nudge' used in Treatments 1 and 2. Methodologically,to minimize the risk of unintended information spillover (Ragasa et al. 2022), we employed the cluster Randomized Controlled Trial (cRCT) method. This method contributed to the effective distribution of information to each farmer: approximately 10,000 informational materials were sent to individual farmers through 408 leaders of each agricultural settlement.

This study is distinctive for its observation of behavioral changes across two outcomes. The primary outcome derives from questionnaire responses about the stated of implementation of MSD and other environmentally friendly farm management starting from the year of the experiment, shedding light on behavioral changes prompted by the information intervention. In Shiga Prefecture, prolonged MSD is subsidized. Therefore, while it's feasible to analyze administrative data from farmers' subsidy applications, this only reflects 'farmers who applied for subsidies and undertook mid-drying extensions'. Given the low effort required for practices like MSD, many farmers might adopt them without subsidies, meaning reliance on administrative data alone might undervalue the actual behavioral changes. Additionally, the questionnaire inquired about plans for the future when respondents are not implementing the practice the year of the experiment. This is the second outcome. These responses help measure the impact on intentions, leading to future behavioral change. Concerning the outcome of the behavioral intention, the impact of repeated information provision can also be seen, as treatment groups 1, 2, and 3 were further grouped into a group that was only provided with information once and a group that was provided with information a second time (reminder).

Our experimental results show a clear difference in the effectiveness of basic communications from the local government as before (Control group) versus those enriched with social norms and loss aversion messaging focusing on methane emission from paddy fields (Nudge). Notably, we find a clear positive effect of social norm messaging on self-reported prolonged MSD for farmers participating in community-based agriculture. On the other hand, large farmers who did not participate in community farming had higher rates of prolonged MSD with and without nudges. In addition, our research shows that targeted technical advice (Boost), which addresses common concerns about changing traditional farming practices, significantly influences farmers' future intentions to adopt methane mitigation techniques, although it did not lead to behavioral change in the experimental year. Additionally, the impact of repeated information provision on future implementation intentions was statistically positive.

It is fascinating that in our experiment, while the letter to farmers informed only about global warming and the methane reduction benefits of prolonged drying periods, a noticeable increase in autumn plowing was observed in the treated group. Just as effective at reducing methane emissions from paddy fields, autumn plowing, which entails tilling the soil after harvest and mixing in rice straw and stubble, can markedly decrease methane output. Past experimental studies with consumers, such as those by Jessoe et al. (2021) and Carlsson, Jaime, and Villegas (2021), have shown spillover effects in behavioral interventions, impacting outcome beyond the intended treatment. Interestingly, we found a similar phenomenon in farmers' behaviors.

In the context of the literature, these results are in line with studies that implemented large-scale field experiments to explore the effect of informational intervention in the United States (Wallander, Ferraro, and Higgins 2017; Wallander et al. 2023; Hrozencik et al. 2023)and Europe(Chabé-Ferret et al. 2019; Chabé-Ferret, Le Coent, David-Legleye, et al. 2023; Chabé-Ferret, Le Coent, Lefebvre, et al. 2023; Bougherara et al. 2023). We contribute to the literature on large-scale field experiments for farmers, since only a handful of studies have conducted field experiments with farmers in developed countries and measured real behavioral outcomes[2]. Social comparison nudges were the most commonly tested in these

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[2] Field experiments with farmers in developed countries are difficult to implement due to various constraints (Behaghel, Macours, and Subervie 2019; Wuepper et al. 2023). Primary, recruitment of farmers to participate in the experiment is difficult(Weigel et al. 2021; Rosch et al. 2021; Höhler et al. 2023). In

studies, but larger evaluations yield less optimistic results. Previous studies have shown that nudges aimed at farmers often fail in general situations(Bougherara et al. 2023). Our study is most closely related to Hrozencik et al. (2023) and Chabé-Ferret, Le Coent, David-Legleye, et al. (2023) in terms of sample size and experimental design, unlike those who focused on dry field farming in North America and Europe, our study addresses small field size in average rice production in an Asian Monsoon region[3], which globally practiced with serious methane emission concerns, and we found social comparison nudge was effective particularly for farmers participating in community-based agriculture. Small field-size rice paddy farmers often participate in villages practicing cooperative community farming, where often rather than individual decisions, communal adoption of farming methods (collective action) based on relationships with others is common(Takahashi, Fujie, and Senda 2022). Therefore, the relationship with neighboring farmers, i.e., whether or not they participate in community farming, has a great bearing on whether or not the information provided is effective. Furthermore, we incorporated agricultural census data into our analysis to assess the impact of village level's presence. This analysis is further distinguished by considering various village-specific characteristics, such as settlement features like soil aridity and altitude. This allows a more detailed analysis of the effects of informational interventions in paddy farming.

Behavioral insights are progressively influencing policy development; regulatory and financial incentives have been complemented by no-monetary low-cost interventions inspired by behavioral economics(Haaland, Roth, and Wohlfart 2023), where two prominent approaches, “Nudge” and “Boost”. Nudges are strategies designed to subtly guide behavior without restricting choices (Thaler and Sunstein 2009). Boosts are interventions aimed at fostering

addition, online-based experiment with information intervention which does not involve any public authority may also cause sample selection bias, since farmers does not have any incentive to cooperate the experiment. In a past studies which invite huge number of farmers to participate in an experiment by email, but the email response rate was relatively low(Pellegrin et al. 2018; Ocean and Howley 2021; Kuhfuss, Préget, Thoyer, and Hanley 2016). Studies that have attempted to induce behavior change by sending negative text messages to farmers in developing countries include (Duflo, Kremer, and Robinson 2011; Mwambi et al. 2023; Balew et al. 2023) . On the other hand, a second best method, where the outcome is not strictly 'behavior', is to present realistic options in choice-type experiments (also known as quasi-experimental surveys) (Kuhfuss, Préget, Thoyer, Hanley, et al. 2016)). A relatively large number of studies have treated expressed intention (Stated Intention), rather than actual behavior, as a proxy variable for behavior change, and such studies have indeed confirmed the effects of the typical nudge, Social Comparison.

[3] In Japan, the area of arable land per farming operation is 3.1 ha (30.2 ha in Hokkaido and 2.2 ha in all prefectures except Hokkaido).

competencies that improve capacity for choice (Grüne-Yanoff and Hertwig 2016; R. Hertwig 2017; Ralph Hertwig and Ryall 2020). Regarding informational intervention as a policy tool, this study also contributes to the literature on the comparative effectiveness of nudges and boosts. Provide insight into what interventions influenced 'behavior' as a spontaneous reaction and influenced 'future intentions' as a result of deliberation. Although commonly discussed in the same scientific and policy context, few studies have directly compared nudges and boosts (Ralph Hertwig and Grüne-Yanoff 2017).

Numerous previous studies have focused on the impact of nudges on relatively minor, immediate decisions such as food selection, utility usage, or charity donations. However, as Bougherara et al. (2023) pointed out, nudges may have less sway over more significant, long-term choices made in professional contexts. Therefore, our study represents a pioneering empirical comparison of the effects of nudges and boosts on farmers. We conducted a field experiment tailored to rice farmers' planting cycles and subsidy applications, thoroughly examining how our information intervention influenced their decision-making processes.

In addition, what missing from the literature is more studies examining the repeated information provision. One exceptional study by Wallander et al.(2017), examined peer comparisons and social norms nudge in field experiments intending to induce greater farmer participation in CRP (Conservation Reserve Program) AESs. While this study failed to detect a statistically significant impact of these interventions, reminders cost-effectively increased enrollment in a USDA conservation program.[4] Taking advantage of the large sample size of this field experiment, we further divide the three intervention groups into two groups to observe the effect of the repeated exposure to the information on the intention to perform future mid-dry extensions. We use this two-stage design to detect the persistence of the effects of information intervention and the effect of reminders.

For these reasons, this paper provides new evidence for the effectiveness of information provision on environmentally friendly management adoption of farmers focusing on the reduction of methane emission from paddy fields.

The remainder of this article is organized as follows. Section 2 describes the background of

[4] Regarding electricity consumption,(Gilbert and Graff Zivin 2014) explored how receiving electricity bills, serving as reminders, impacts hourly electricity use. They observed a reduction in electricity consumption by 0.6 to 1 percent after households received their bills. However, this effect showed significant variation among different households and across various seasons.

this study. Section 3 contains the experimental design including treatment intervention, data, sample size, and randomization procedure. Then, section 4 contains the results of the field experiment. Finally, section 5 concludes.

2. Context

2.1. Methane emission from paddy fields and reduction technique

Methane (CH_4), a significant greenhouse gas, has a global warming potential 34 times greater than carbon dioxide (CO_2) over 100 years, including its indirect effects like tropospheric ozone production, another powerful greenhouse gas. CH_4's shorter atmospheric lifespan means that prompt mitigation can more effectively prevent exceeding the critical 2℃ global temperature rise than solely reducing CO_2 emissions (Shindell et al. 2012).

A primary contributor to methane in the atmosphere, rice cultivation represents 10-12% of worldwide man-made methane emissions (Ciais et al. 2013). In flooded rice fields, methane is generated through anaerobic digestion by methanogens, which utilize unstable organic carbon sources. As major rice producers, Asian countries have seen a consistent rise in rice production over the last decade, making Asia a central region for methane emissions from rice farming.

Organic materials in water-filled paddy fields, such as rice straw and compost, emit significant methane amounts during anaerobic decomposition by methanogens. However, several field studies have shown that MSD, a practice involving temporary water removal from rice fields during cultivation, can reduce methane emissions. This reduction occurs as mid-season drying introduces oxygen into the soil, thereby inhibiting anaerobic decomposition of organic matter. A Japanese national research agency has suggested extending the mid-drying period by seven days, potentially cutting methane emissions by 30% through a reduced anaerobic decomposition period(Itoh et al. 2011).

For farmers, the costs associated with prolonged MSD are minimal. However, our prior surveys in Shiga prefecture have shown that some farmers express significant concerns about potential negative impacts on rice yields due to the novelty of this management. Consequently, alongside existing direct payment schemes[5], such as the Japanese agri-environmental

[5] Starting in April 2023, the Japanese Government recognized methane reduction from prolonged mid-dry periods in paddy fields as 'credits' under the J-credit system. This initiative allows farmers to sell these credits to businesses, creating a new revenue stream. The number of credits earned varies based on factors

payment program's modest incentive of JPY 800 (about USD 5.5) per 0.1 hectares for adopting prolonged mid-drainage, which is determined based on cost analysis, non-financial strategies like effective information dissemination are becoming increasingly important. Thus, this situation presents an opportunity to assess the impact of combining minimal financial incentives with informational policies. Moreover, effective information dissemination might persuade more farmers to adopt prolonged mid-drainage practices, even those who do not apply for the direct payment program, by stimulating their intrinsic motivation.

With the rise of behavioral economics, behavioral insights have been increasingly tested as policy instruments(OECD 2012; Wuepper et al. 2023). Pointed by Dessart, Barreiro-Hurlé, and van Bavel (2019) and Thompson et al.(2023), cognitive or attitudinal variables and social factors influence farmers' decisions to adopt environmentally sustainable practices. This understanding contributes to the development of more realistic and effective agri-environmental policies.

2.2. Recruitment of Study Community

According to a survey conducted by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) in 2021(N=2,700), the percentage of prolonged MSD in Japan is only 26%, and the practice is not yet widely spread throughout the country[6]. Shiga Prefecture, the focus of this experiment, is home to Lake Biwa, the largest lake in Japan. It is also the most advanced prefecture in Japan in terms of addressing agricultural environmental issues. In Shiga Prefecture, due to the location of Lake Biwa, agricultural environmental policies have primarily focused on measures to improve water quality affected by agricultural runoff into the lake. Consequently, global warming countermeasures have been a relatively low priority for farmers. For this reason, our research team hoped that a field experiment focusing on

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such as the paddy field's location, its drainage efficiency, and the organic matter used. The pricing of these credits is subject to negotiation with the purchasers. In a model scenario, where paddy fields are well-drained and include ploughed-in straw from the previous crop, projected revenues range from JPY 1,000 to JPY 3,600 per 0.1ha, varying by region.

[6] According to this MAFF survey of paddy rice growers, 10.9% of them "knew" and 86.7% "did not know" that methane emitted from paddy fields accounts for a large proportion of methane emissions in Japan. Regarding whether or not they knew that extending MSD (which reduces methane emissions by approximately 30%) and fall plowing (autumn plowing of rice straw, which is said to reduce methane emissions by approximately 50%) are effective in reducing methane emissions from paddy fields, 30.1% "Yes" and 67.3% "No" to the question. When asked if they were willing to work on extending MSD, 25.9% said they were already working on it, 28.9% said they would work on it even without support, and 24.6% said they would work on it if they had some support (MAFF 2022).

agriculture and global warming in collaboration with Shiga prefecture, which is the most committed to environmental issues in Japan, would have policy implications for other regions of Japan and paddy field management outside of Japan.

Our field experiment was conducted in the Higashi-Oumi area of Shiga prefecture in Japan, which are area with intensive rice production[7]. In consultation with prefectural government policymakers, we first identified the most appropriate district for rice production in this prefecture and then created an all list of agricultural settlements which was 408. Thus, all rice farmers in his region are included in the survey.

3. Methods

3.1. Experimental Design

We implemented a cluster-RCT in the Higashi-Oumi area. The unit of randomization is at the "agricultural settlements(*nougyou-syuraku*)" level, and the unit of analysis is at the household level and agricultural settlement revel. Agricultural settlements are communities formed agriculturally in a part of a municipality. Agricultural settlements were originally spontaneous local communities and are the basic unit of social life, where houses are linked by geographical and blood ties and various groups and social relations have been formed.

Figure 1 shows the timeline of the study. Based on a pre-treatment field visit, discussions with local government staff, and a pre-mail survey of 100 farmers conducted in 2021, the year before the experiment began, we identified an experimental design. The experiment was planned according to the paddy cropping calendar and the farmers' subsidy application schedule. Farmers plant paddy rice at the beginning of May, start MSD in June, and apply for subsidies at the end of July based on the adopted environmentally friendly farming practices. Therefore, the intervention materials needed to be available to the farmers before they made their annual decisions. In consultation with the Shiga prefecture officials, the intervention materials were enclosed in the biannual "extension center bulletins". The bulletins are the only opportunity for local government agencies to reach individual farmers regularly. The

[7] The farmers in Shiga Prefecture are small-scale and rice-centered, with a high ratio of dual-income farmers. The ratio of dual-income farmers to total farmers is over 80%, which is higher than the national average of 67%, and more than 70% of all farm households own small-scale farmland with an area of less than 0.3ha. The percentage of organized farming households, mainly community farming, is high, but they remain small-scale farmers. The number of community farming is one of the highest in Japan, but it does not extend beyond individual farming communities and remains small-scale.

distribution schedule is almost fixed each year, and we decided to enclose the intervention material in February 2022, in time for the planting. The intervention materials (flyers) are distributed to the leaders of the 408 agricultural settlements and then to each farmer through earch leader within the settlement. Farmers will therefore see the intervention materials before making planting and MSD decisions. It is also possible that this flyer will be brought up during community meetings within the settlement. We then distributed a questionnaire in October 2022, after the harvest was over, asking farmers if they had newly implemented prolonged MSD along with some other environmentally friendly management practices this year[8]. This will be the main outcome of interest. We asked questions at this time that would allow us to understand whether the implementers of prolonged MSD had done so with or without receiving subsidies because the results of MAFF's nationwide mail survey (MAFF, 2022) indicate that about half of the farmers who intend to implement the management in the future will do so even without subsidies. We also asked whether they had not done any prolonged MSD this year but would be willing to do so in the future. Furthermore, the respondents were also asked information related to agricultural production such as cultivated area and the number of farmers engaged, the status of community farming participation, awareness of climate change risks, and knowledge of climate change (e.g., that paddy fields are a source of methane emissions).

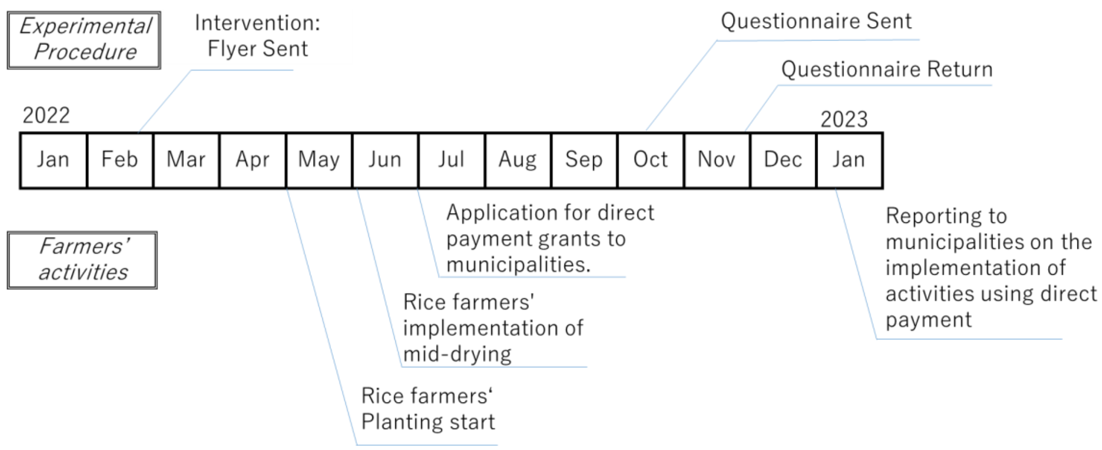


Figure 1. Agriculture calendar and timeline of intervention and data collection.

[8] Given the operation of distributing the questionnaires through the farmer leaders of the 408 agricultural settlements, the questionnaire was a one-time survey and no baseline questionnaire was administered prior to the intervention. Leaders voluntarily cooperated with this survey from the national government and Shiga Prefecture. In agricultural settlements with a large number of members, the leader of the settlement unites dozens of farmers, and we asked them to distribute the questionnaires one by one.

Figure 2 illustrates the experimental design (approval was obtained from the Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries, Japan (PRIMAFF) Review Board on January 31, 2022). To minimize the contamination or spillover of effects across treated and control households, a cluster-randomized design was chosen as Ragasa et al. (2022). In contrast to a recently published similar study by Chabe-Ferret et al. (2023) who randomly selected farmers out of the total eligible for a Payment for Ecosystem Service (PES) program to receive an information letter, we sent the letters to all the farmers in the region.

The number of people distributed and the list of recipients of "extension center bulletins" are compiled by the city, town, and village level and Agricultural Cooperatives of the four municipalities (Omihachiman City, Higashiomi City, Ryuoh Town, and Hino Town), and each municipality reports the number to the prefectural government every few years. The number of people who received the in 2021 the year before this experiment started was 9,877, therefore, this number is the maximum number of farmers in the area. However, it should be noted that this number includes farmlandowning non-farmers and subsistence farmers.

The bulletins feature a range of agricultural information and are distributed to each community's agricultural settlement representatives. It is customary for representatives of agricultural settlements to distribute this information to individual farmers within the community. The number of members varies from settlement to settlement, with some settlements having only a few farmers and others having dozens of farmers. After consulting with a Shiga prefecture policymaker, we decided to include an equal number of leaflets on MSD in the bulletins for agricultural settlements in our treatment group. Due to privacy concerns, as the contact details of individual farmers are not publicly available, this method remains our sole direct channel for disseminating information to them.

The control group was randomly divided into 103 settlements, treatment group 1 into 103 settlements, treatment group 2 into 101 settlements, and treatment 3 group into 101 settlements. Thus, we disseminated nudge and boost information through one-page flyers, tailoring each version to specific groups. These were enclosed in the February 2022 issue of the Higashi-Oumi region's 'extension center bulletins'.

The four cities and towns then re-tallied the number of extension center bulletins needed to be distributed in the next year and reported to Shiga Prefecture that the total number had decreased from 9,877 to 7,206. This was due to a review of the totals from several years ago, which reflected farmers who had left or moved out of the area[9]. We decided to match this number to the number of questionnaires to be distributed in October 2022. Questionnaires were collected one month after distribution and mailed by individual farmers to the address specified by the experimenter using a self-addressed envelope.

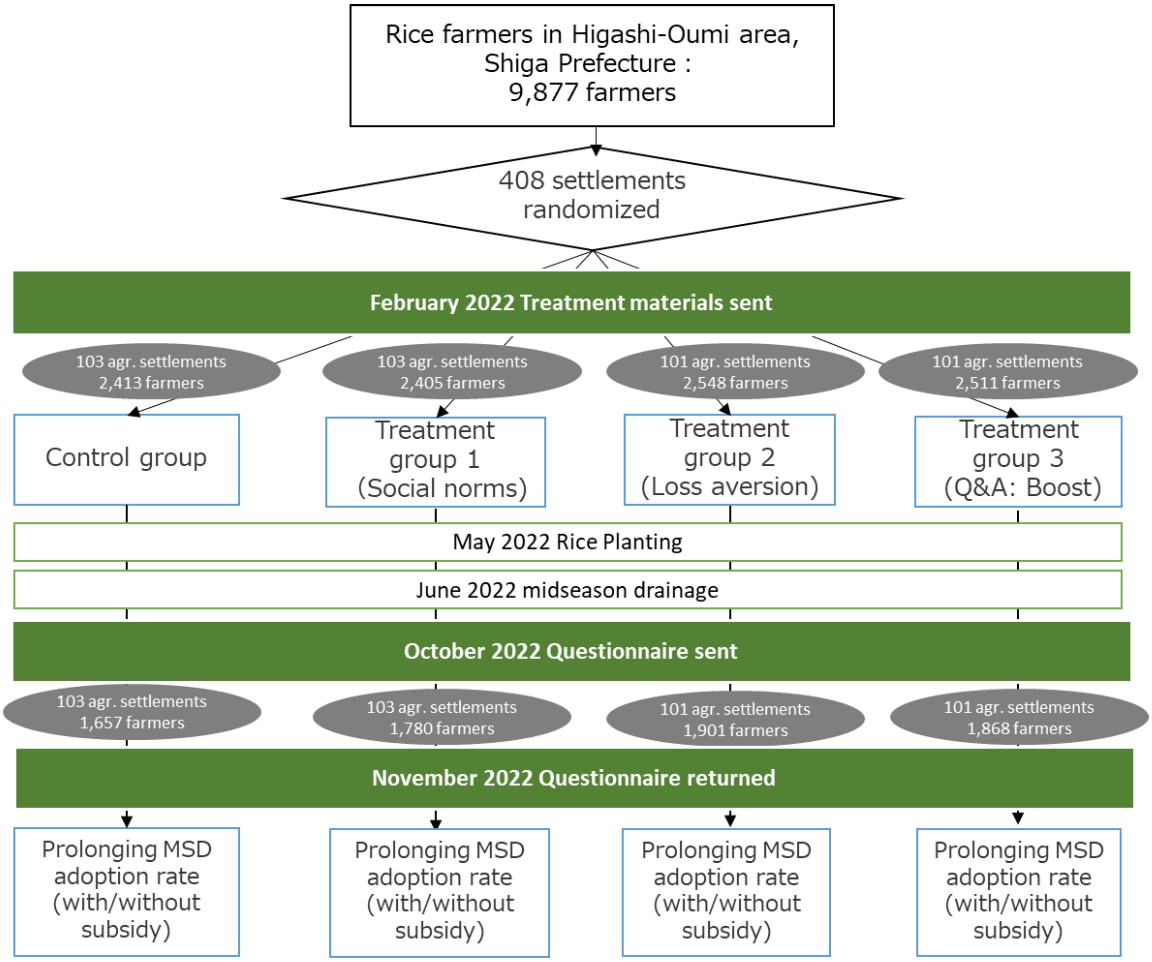


Figure 2. Structure of the experiment (1): nudge and boost comparison

[9] In Japan, the number of key agricultural workers, the household members of private farming enterprises, continues to decline. The country had 1,363,000 key agricultural workers in 2020, down 22% from 1,757,000 in 2015.

Figure 3 shows the structure of the experiment analyzing the effect of repeated provision of information. This RCT design included sub-arms in which the same flyer that was distributed in February 2022 was re-enclosed in the questionnaires in 2022 October. Naturally, since the 2022 crop had already been harvested when the questionnaires were distributed, our interest in this second phase of the experiment is whether repeated information provision is effective in influencing the intention of farmers who did not perform long-term mid-drying in 2022 to do so in the following year. Specifically, the number of farmers in treatment group 1 is 1,780 in 103 settlements, while 968 farmers have the same leaflet enclosed in the questionnaire. Similarly, in the treatment group 2, 871 of 1,901 farmers had the leaflet enclosed again, and in the treatment group 3, 913 of 1,868 farmers had the leaflet enclosed again.

Figure 4 shows the geographical spread of the sampled agricultural settlements, by treatment status, across the district of Higashi-Oumi region.

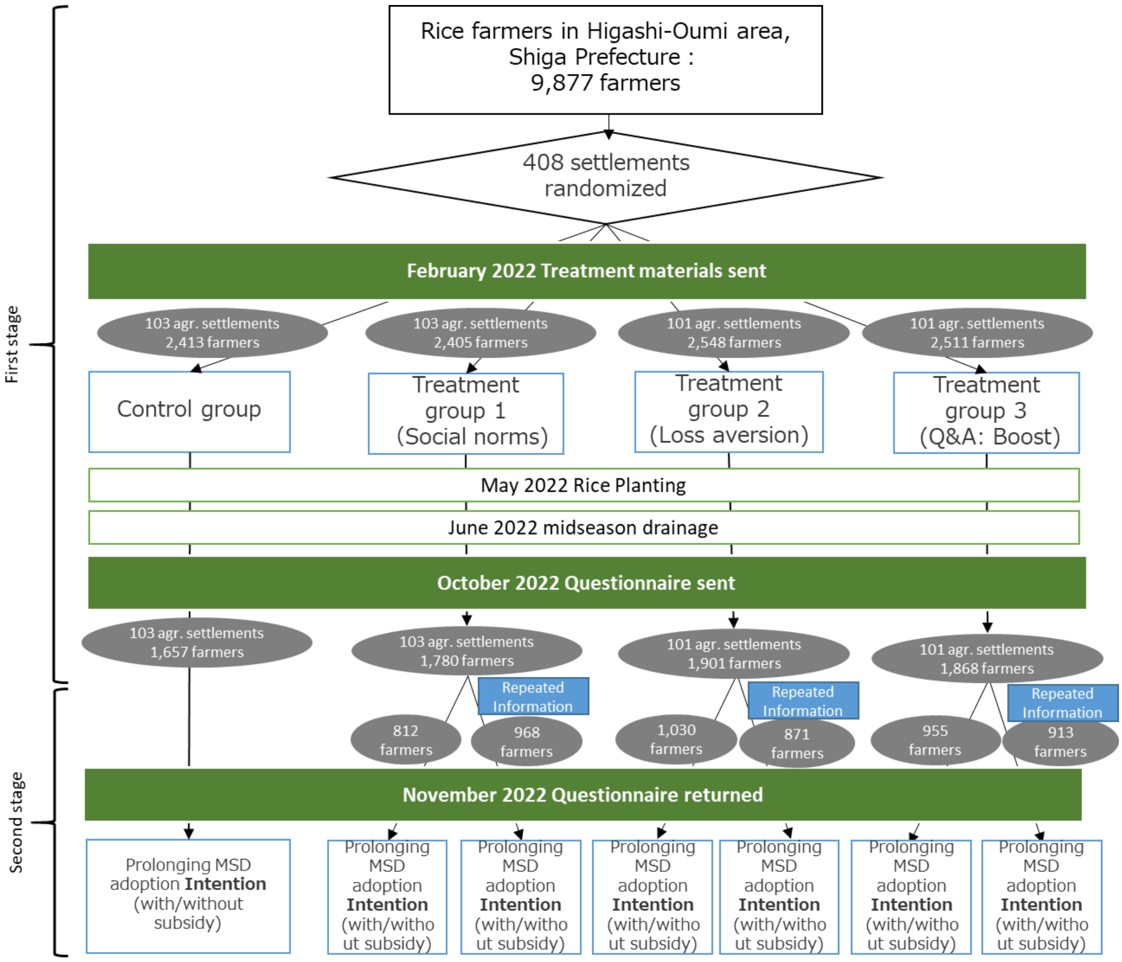
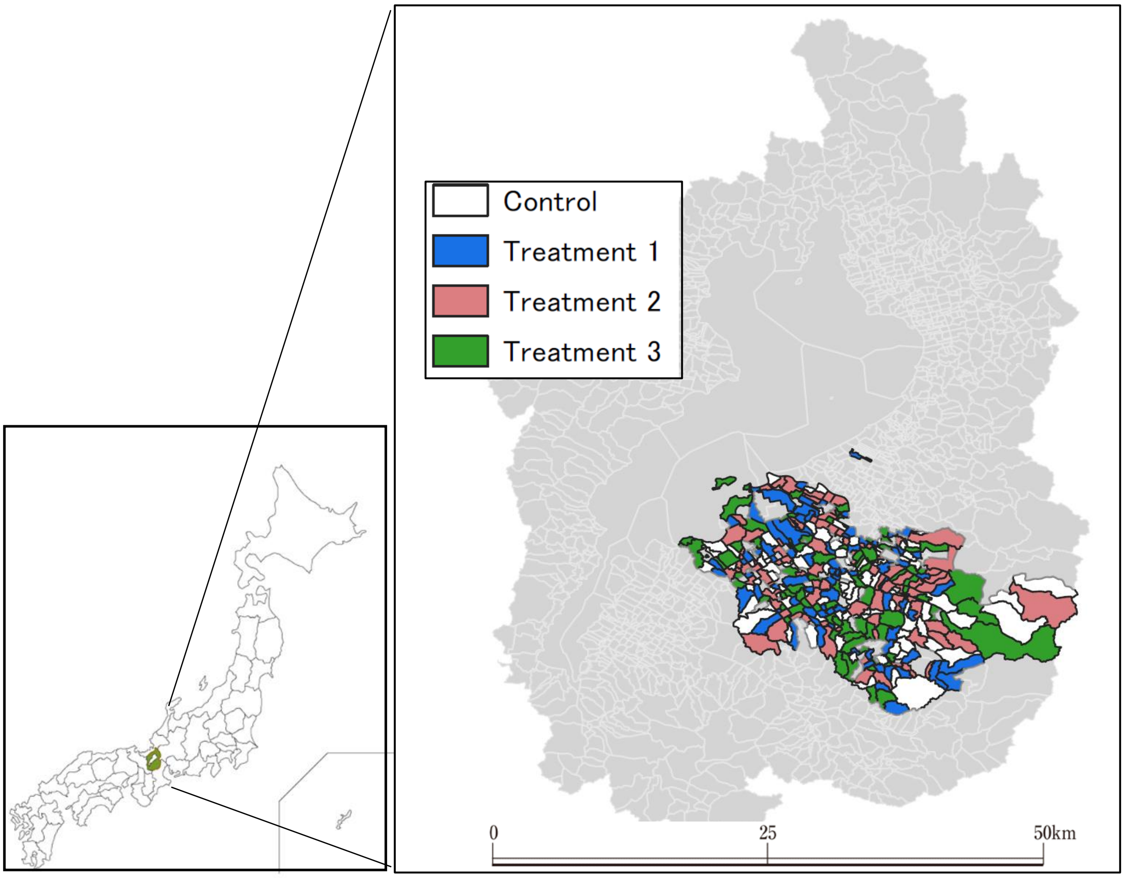


Figure 3. Structure of the experiment (2): role of repeated information provision



Note: Gray-colored areas are outside the area covered by this experiment. Because the handful number of names of agricultural settlements (including names unique to the region) provided to us by cities and towns during the questionnaires and flyer distribution did not match the names of settlements in the national statistical data in a very few cases, such areas are also classified as gray on this map, even though they are within the area of the experiment.

Figure 4. Location of Shiga Prefecture and Higashi-Oumi region by treatment status

3.2. Treatment Intervention

There are several theoretical rationales for the potential effectiveness of our information letter as below.

Treatment Group 1: Social Norm (Social Comparison)

While existing research primarily examines the impact of social norms and comparisons on "consumer behavior" in various environmental and non-environmental settings, much less attention, however, has been paid to understanding how social comparisons may affect farmer behaviors[10]. Recently, other than experimental studies, Bakker et al. (2021) identified that farmers' intention to reduce pesticide use was strongly determined by whether other farmers also act, and Coyne et al. (2021) found based on their in-depth interview that both economic and societal factors are crucial for English dairy producers' participation in agri-environmental schemes. In the aspect of policy design, social comparison might be able to supplement existing financial incentive policies. According to Brown et al. (2021) who conducted large-scale interviews with European policymakers, a narrow focus was on economic and structural factors. The simplistic design of environmental subsidies may limit uptake and effectiveness, and a better understanding of farmer motivations can help achieve environmental goals.

In our experiment, the "social comparison" message adds the information that "Many people in the community are already working on this!" in Treatment Group 1. Followed by more detailed information: "Shiga Prefecture has by far the largest area of direct payment grants for environmentally friendly agriculture in Japan. Many people are already involved, and 85% of the grant initiatives involve long-term medium-dry farming. The actions of every one of you have meaning, so if you are not already involved, we urge you to start in 2022. Let's protect the local environment together."

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[10] As one of the closest study, Chabé-Ferret et al. (2019) test a social comparison nudge to promote water-saving behavior. They find a small average effect comprised of reductions from those who irrigated the most and some increases from those who did not irrigate before, and nudges based on social comparisons can be effective in promoting water-saving behavior among farmers who irrigate the most. In contract, Chabé-Ferret, Le Coent, David-Legleye, et al. (2023) revealed that social comparison nudges seem to decrease farmers' enrollment into PES. Furthermore, nudges based on conveying information relating to other farmers' behavior (i.e. descriptive social norms) have recently been highlighted by both Howley and Ocean (2021) and Kuhfuss, Préget, Thoyer, and Hanley (2016).

Treatment Group 2: Loss Aversion

Loss aversion theory contends that any loss seems twice as painful to consumers as the same amount of gain(Kahneman and Tversky 1979). In the behavioral economics literature, these interventions are widely used to enhance individual behavioral change. In the agri-food sector literature, Ocean and Howley (2021) determine that mental accounting and loss aversion can be used to inform the design of new agricultural policy schemes to improve uptake, which is supported by the data from a randomized survey experiment. Concerning loss aversion, we include a phrase reminding farmers that "Global warming is causing adverse effects." Followed by more detailed information: "The annual average temperature in Hikone-city (note: the capital of Shiga Prefecture) has increased by 1.3 degrees Celsius in 100 years. It is predicted to rise another 2.9 degrees by the latter half of this century unless each of us takes action now. (An increase of about 2.9 degrees Celsius is equivalent to the annual average temperature of Miyazaki Prefecture today.) Rice production in Japan has already seen a decrease in yield in some areas or in extremely hot years."

To encourage farmers to change their behavior, not only the content of the information provided but also who gives the advice is important. As Wuepper, Roleff, and Finger (2021) found that farmers who are advised by public extension use more preventive measures, we also included testimonies from a public extension worker who reported that negative effects on the appearance and taste have also been reported in this region's areas. Since this person has been in charge of this area for a long time and many farmers in the area recognize his face and name, we included his picture and comments in the letter with his permission[11].

Treatment Group 3: Boost

For Treatment Group 3, we enclosed a Boost message. This treatment is intended to increase the knowledge of farmers so that they can make the desired decisions, so it can be positioned as similar to the agricultural training or Farmer Field Experiment's impact analysis study(Ragasa et al. 2022; Pan and Zhang 2018). We consulted with administrative officials in Shiga Prefecture, and based on the typical concerns expressed by farmers in this area, we added Q&A style explanations to the letter, such as "Extended drying has no negative impact on rice yield," "Soil cracking is not a problem," and "Chemical basis for methane reduction.

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[11] Ouvrard et al. (2023) use a discrete choice experiment with treatments to test if the voluntary adoption of smart water meters by French farmers can be fostered through monetary and non-monetary incentives (nudge and testimonial message). They were not able to detect any significant effect of the testimonial nudge.

4. Estimation Methodology and Experimental Results

4.1. Baseline characteristics

First, Table 1 summarizes the collection of the questionnaires sent to the farmers. The average response rate was 35.1%, although the response rate varied somewhat from group to group. The number of questionnaires sent this time was not the same as the number of farmers but was based on the number of extension center newsletters distributed, due to the experimental design. Therefore, if the total number of farmers in the region, 5,244, obtained from the official statistical data published in 2020, is used as the population size, the survey would cover 48.4% of the region[12].

Table 1. Returned rate of questionnaires and sample size

	The total number of questionnaires distributed	Number of questionnaires returned (Sample size)	Return rate
Control	1,657	634	38.3%
Treatment 1 (Social norm)	1,780	675	38.0%
Treatment 2 (Loss aversion +Testimony)	1,901	642	33.8%
Treatment 3 (Boost)	1,868	574	30.7%
Total	7,206	2,525	35.1%

As can be seen from Table 2, although most of the attributions were well-balanced, some variables were unbalanced. Potential biases arising from these imbalances are controlled regression analyses in the following section. We discuss our main results, in turn.

[12] The "Census of Agriculture and Forestry," a national all-inclusive survey, defines "farm households," which are subject to data collection, as households engaged in agriculture with an arable land area of 0.1ha or more or with total sales of agricultural products of 150,000 yen or more for the past one year. Therefore, statistical data do not exist for very small-scale farmers who do not fall into this category, but it is possible that the prefectural government distributes extension center bulletins.

Table 2. Descriptive statistics and balance of control variables

		(1)		(2)		(3)		(4)		(1)-(2)		(1)-(3)		(1)-(4)		(2)-(3)		(2)-(4)		(3)-(4)
		Control		Treatment 1		Treatment 2		Treatment 3		Pairwise t-test		Pairwise t-test		Pairwise t-test		Pairwise t-test		Pairwise t-test		Pairwise t-test
Variable	N	Mean/(SE)	N	Mean/(SE)	N	Mean/(SE)	N	Mean/(SE)	N	Mean difference	N	Mean difference	N	Mean difference	N	Mean difference	N	Mean difference	N	Mean difference
Number of fulltime member	425	1.24	455	1.719	439	1.456	383	1.433	880	-0.479***	864	-0.216*	808	-0.193*	894	0.263	838	0.285*	822	0.022
		-0.054		-0.125		-0.1		-0.089												
Number of parttime member	527	2.095	524	2.231	525	2.491	476	3.008	1051	-0.136	1052	-0.397	1003	-0.914***	1049	-0.261	1000	-0.777**	1001	-0.517
		-0.109		-0.172		-0.219		-0.276												
Total plannted area (ha)	603	8.51	633	8.448	605	11.088	526	9.766	1236	0.062	1208	-2.578	1129	-1.256	1238	-2.64	1159	-1.318	1131	1.322
		-1.129		-0.985		-1.403		-1.16												
Paddy area:Ratio of paddy rice acreage to total cropland(0 to 10 at maximum)	602	7.781	625	7.493	603	7.285	532	7.744	1227	0.288*	1205	0.496***	1134	0.037	1228	0.209	1157	-0.251	1135	-0.459***
		-0.112		-0.114		-0.113		-0.116												
Participation in community farming (YES)	606	0.604	645	0.678	609	0.685	548	0.557	1251	-0.074***	1215	-0.081***	1154	0.047	1254	-0.007	1193	0.121***	1157	0.128***
		-0.02		-0.018		-0.019		-0.021												
Participation in community farming (NO)	606	0.335	645	0.273	609	0.269	548	0.383	1251	0.062**	1215	0.066**	1154	-0.048*	1254	0.004	1193	-0.110***	1157	-0.114***
		-0.019		-0.018		-0.018		-0.021												
Participation in community farming (Others: e.g. agricultural corporations)	606	0.061	645	0.05	609	0.046	548	0.06	1251	0.011	1215	0.015	1154	0.001	1254	0.004	1193	-0.011	1157	-0.014
		-0.01		-0.009		-0.008		-0.01												
Percentage of income from rice cultivation (0 to 1)	524	0.353	563	0.35	527	0.348	482	0.32	1087	0.003	1051	0.005	1006	0.032	1090	0.002	1045	0.03	1009	0.028
		-0.016		-0.014		-0.015		-0.015												
Realized impact of climate change on rice farming (negative impact)	606	0.772	637	0.79	608	0.76	543	0.772	1243	-0.017	1214	0.012	1149	0.001	1245	0.03	1180	0.018	1151	-0.012
		-0.017		-0.016		-0.017		-0.018												
Realized impact of climate change on rice farming (positive impact)	606	0.03	637	0.03	608	0.03	543	0.017	1243	0	1214	0	1149	0.013	1245	0	1180	0.013	1151	0.013
		-0.007		-0.007		-0.007		-0.005												
Realized impact of climate change(don't realize)	606	0.198	637	0.181	608	0.211	543	0.212	1243	0.017	1214	-0.013	1149	-0.014	1245	-0.03	1180	-0.031	1151	-0.001
		-0.016		-0.015		-0.017		-0.018												
Recognizing that rice paddies are a source of methane emissions (strongly)	619	0.178	646	0.166	619	0.165	555	0.148	1265	0.012	1238	0.013	1174	0.03	1265	0.001	1201	0.018	1174	0.017
		-0.015		-0.015		-0.015		-0.015												
Recognizing that rice paddies are a source of methane emissions (to some extent)	619	0.438	646	0.505	619	0.52	555	0.497	1265	-0.067**	1238	-0.082***	1174	-0.059**	1265	-0.016	1201	0.007	1174	0.023
		-0.02		-0.02		-0.02		-0.021												
Recognizing that rice paddies are a source of methane emissions(don't realize)	619	0.384	646	0.33	619	0.315	555	0.355	1265	0.055**	1238	0.069**	1174	0.03	1265	0.015	1201	-0.025	1174	-0.04
		-0.02		-0.019		-0.019		-0.02												
Leaflet check dummy (Dummy that takes 1 if the respondent learned about the "methane reduction benefits of MSD" from the flyer.)	634	0.27	675	0.301	642	0.265	574	0.263	1309	-0.031	1276	0.005	1208	0.007	1317	0.036	1249	0.038	1216	0.002
		-0.018		-0.018		-0.017		-0.018												
Significance: ***=.01, **=.05, *=.1.																				

4.2. Average Treatment Effect in the Cluster RCT

Average Treatment Effects: Basic Specification

Our first specification distinguishes among the three types of treatments to estimate and compare the impact of the three arms on prolonged MSD adoption.

$$Y_{is}^{1} = \beta_c + \beta_T^{T1} T_s^{T1} + \beta_T^{T2} T_s^{T2} + \beta_T^{T3} T_s^{T3} + \beta_X' \boldsymbol{X_{iv}} + \beta_Z' Z_v + \varepsilon_{iv} \quad (1)$$

where Y_{is}^{1} is the outcome that takes value one if a farmer chooses prolonged MSD from this year of the i th farmer in agricultural settlements at end-line survey (i.e. decision in 2022 planting season). T_s^{T1} is a dummy for the assignment of settlement s to Treatment 1 (T1), T_s^{T2} is a dummy for assignment to Treatment 2 (T2), and T_s^{T3} is a dummy for assignment to Treatment 3 (T3). $\boldsymbol{X_{iv}}$ are a set of characteristics for farmer i in settlement s. These controls include cultivated area and number of farmers engaged, status of community farming participation, awareness of climate change risks, and knowledge of climate change (e.g., that paddy fields are a source of methane emissions). To control the potential bias arising from the imbalance of attributions, we also control for a set of settlement characteristics compiled from various official statistics from the MAFF, Z_v, the proportion of paddy land, the proportion of well-drained areas, and average elevation. ε is the error term, which is clustered at the agricultural settlement level.

The main parameter of interest is β_T , which represents the impact of the information treatment (either T1, T2, or T3) on the adoption of prolonged MSD. Since the treatment status was randomly assigned to the sampled agricultural settlements, farmers' exposure to treatment was entirely exogenous. Therefore, the OLS estimation of β_T from equation (1) is the average treatment effect on the treated (ATT) of the awareness program. If information improves prolonged MSD adoption (or other outcomes) then β_T should be significantly positive.

Figure 5 and Table 3 detail the estimated impacts of receiving any of our information letters. In its simplest form, Figure 5 compares the percentage of farmers who adopted prolonged MSD in the year of the experiment with the control and each treatment. Treatment 1 is higher than the other groups at 16.6%, but this is not statistically significant. Table 3 summarizes the regression results of Equation (1) and describes the average effect of two types of Nudges and Boost on prolonged MSD from the 2022 planting season. Dependent variables of columns (1) to (3) refer to the implementation of prolonged MSD with or without subsidy, (4) to (6) refer to the implementation with subsidy, and (7) to (9) refer to the implementation. In addition, (2), (5), and (8) control for the characteristics of individual farmers, while (3), (6), and (9) also control for the characteristics of the settlements to which the farmers belong.

Treatment 1 (Social norm) has a positive sign in all models and is significant at the 5% or 10% level when controlling for covariates in the model with overall MSD implementation as the outcome (Columns 2 and 3). The effect of Treatment 1 was not significant in the model with implementation with receipt of subsidy as a dependent variable, while it was significant at the 5% level in the model with implementation without receipt of subsidy. This means that since the prolonged MSD is not technically different from the current farming method and does not require any additional materials, there are a certain number of potential farmers who will change their behavior simply by improving the way information is provided (in this case, through social comparison), even without applying for special subsidies. On the other hand, we detect no evidence of the impact of treatments 2 and 3.

Regarding farmer characteristics, we found that participation in community farming had a significant impact, especially when subsidies were received and implemented (Columns 5 and 6). Therefore, in the next section, we analyze the heterogeneity of treatment effects with and without participation in community farming.

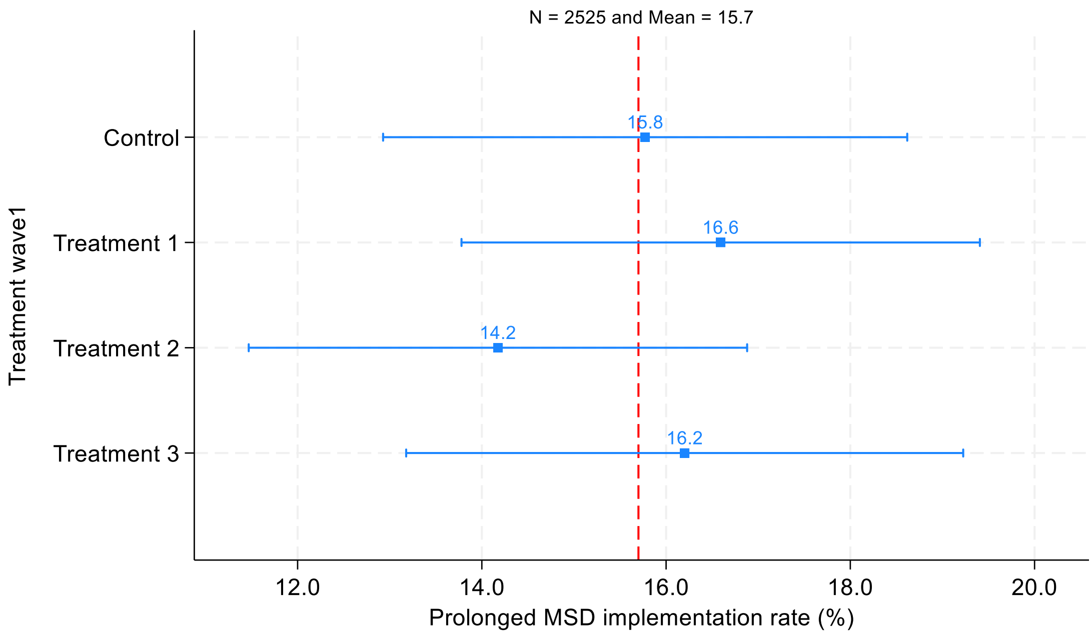

Figure 5. Prolonged MSD implementation rate

Table 3. Average Treatment Effect: Prolonged MSD implementation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Prolonged MSD implement			Prolonged MSD implement with application for subsidies			Prolonged MSD implement without application for subsidies		
Treatments									
Treatment 1 (Social norm)	0.00844	0.0622**	0.0597*	0.00448	0.0269	0.0183	0.0108	0.0517**	0.0567**
	(0.0210)	(0.0293)	(0.0321)	(0.0144)	(0.0208)	(0.0219)	(0.0170)	(0.0232)	(0.0256)
Treatment 2 (Loss aversion + Testimony)	-0.0158	0.00417	4.04e-05	-0.0165	-0.00905	-0.0167	-0.00268	0.0152	0.0117
	(0.0205)	(0.0317)	(0.0333)	(0.0135)	(0.0198)	(0.0208)	(0.0173)	(0.0252)	(0.0283)
Treatment 3 (Boost)	0.00429	0.0506	0.0546	0.00412	0.0131	0.0138	0.000703	0.0412	0.0422
	(0.0225)	(0.0315)	(0.0337)	(0.0160)	(0.0204)	(0.0216)	(0.0179)	(0.0263)	(0.0276)
Farmer's charactristics									
Number of fulltime member		0.00849	0.0125		0.0118	0.0173*		0.000925	0.000673
		(0.00868)	(0.0106)		(0.00803)	(0.00936)		(0.00619)	(0.00800)
Number of parttime member		-0.00478**	-0.00462**		-0.00208	-0.00214		-0.00119	-0.000958
		(0.00189)	(0.00206)		(0.00166)	(0.00181)		(0.00172)	(0.00186)
Total plannted area		0.000129	1.98e-05		0.000232	0.000156		-0.000128	-0.000164
		(0.000377)	(0.000359)		(0.000301)	(0.000284)		(0.000267)	(0.000263)
Paddy area		-0.00615	-0.00530		-0.00155	-0.00113		-0.00475	-0.00436
		(0.00521)	(0.00540)		(0.00316)	(0.00334)		(0.00470)	(0.00491)
Participation in community farming (YES)		0.0552	0.0410		0.100***	0.0960***		-0.0386	-0.0492
		(0.0508)	(0.0531)		(0.0136)	(0.0149)		(0.0503)	(0.0521)
Participation in community farming (NO)		0.0340	0.0327		0.0638***	0.0629***		-0.0239	-0.0287
		(0.0515)	(0.0545)		(0.0137)	(0.0144)		(0.0488)	(0.0510)
Percentage of income from rice cultivation		0.0417	0.0507		0.0362	0.0413		0.0101	0.0137
		(0.0366)	(0.0381)		(0.0270)	(0.0280)		(0.0262)	(0.0276)
Realized impact of climate change on rice farming (negative impact)		0.00317	0.00670		0.0400***	0.0382**		-0.0308	-0.0274
		(0.0277)	(0.0303)		(0.0152)	(0.0171)		(0.0259)	(0.0278)
Realized impact of climate change on rice farming (positive impact)		0.128	0.153		0.0902	0.107		0.0337	0.0393
		(0.0956)	(0.101)		(0.0610)	(0.0652)		(0.0721)	(0.0779)
Recognizing that rice paddies are a source of methane emissions (strongly)		0.0120	0.0150		-0.0177	-0.0136		0.0223	0.0246
		(0.0413)	(0.0433)		(0.0305)	(0.0323)		(0.0294)	(0.0310)
Recognizing that rice paddies are a source of methane emissions (to some extent)		-0.0298	-0.0352		-0.0446**	-0.0553***		0.00916	0.0168
		(0.0252)	(0.0267)		(0.0185)	(0.0192)		(0.0211)	(0.0224)
Leaflet check dummy		0.0214	0.0125		0.0639***	0.0556***		-0.0394*	-0.0395*
		(0.0281)	(0.0284)		(0.0213)	(0.0207)		(0.0202)	(0.0212)
Settlment's charactristics									
Welldrained area rate			-0.000430			-0.000319*			2.14e-06
			(0.000277)			(0.000191)			(0.000249)
Center elevation			3.07e-05			8.42e-05			-5.44e-05
			(0.000341)			(0.000188)			(0.000292)
Center inclination			-0.000687			-0.00731*			0.00631
			(0.00630)			(0.00380)			(0.00572)
Settlement's paddy area rate			0.00713			0.0263			-0.0443
			(0.130)			(0.0712)			(0.113)
Community farming dummy			0.0492*			0.0259			0.0256
			(0.0276)			(0.0164)			(0.0228)
Constant	0.158***	0.127*	0.0965	0.0727***	-0.0554	-0.0862	0.0900***	0.167**	0.188
	(0.0151)	(0.0723)	(0.149)	(0.00991)	(0.0343)	(0.0826)	(0.0122)	(0.0673)	(0.124)
Observations	2,525	1,061	990	2,523	1,060	989	2,523	1,060	989
R-squared	0.001	0.019	0.026	0.001	0.044	0.055	0.000	0.013	0.016
Robust standard errors in parentheses									
*** p<0.01, ** p<0.05, * p<0.1									

Heterogeneous Treatment Effect: Sub-group analysis

In Japan, farmers who participate in community farming are relatively small-scale farmers. Through collaborative activities, they can increase income and decrease labor hours by participating in community farming whereas those who do not participate in community farming are large-scale and self-supporting. In community farming organizations, meetings are held regularly to discuss local events, environmental conservation, water management, and other issues, where participants may have discussed the treatment materials of this experimental investigations.

Thus, the situation of farmers who participate in community farming differs significantly from that of other farmers, Table 4 details the estimated impacts of receiving any treatment in community farming participants only. Dependent variables of columns (1) to (3) refer to the implementation of prolonged MSD with subsidy, and (4) to (6) refer to the implementation without subsidy. The (4) to (6) column shows that the Treatment 1 intervention significantly improved prolonged MSD adoption without application for subsidies. Their degree of impact was ranging between 4.6% to 8.3% ($p<0.05$).

Figure 6 shows the prolonged MSD adaptation rate without application for subsidies for the sample categorized by whether or not they participated in community farming. The "other" category includes only a small number of respondents, such as agricultural corporations. Figure 6 shows that the prolonged MSD implementation rate of the control group was particularly low among those who participated in community farming, but treatment 1 was effective in improving the implementation rate. Contrary, the non-participants of the community farming had a high rate of MSD implementation overall, while The effect of the treatment cannot be confirmed for non-participants.

Furthermore, in agricultural settlements, there are distinctions between individuals who have seen the treatment material and those who have not. It is plausible that those who missed the flyer were subsequently informed during regional community meetings and thus participated in the prolonged MSD. This observation aligns with the findings presented in Chabé-Ferret, Le Coent, David-Legleye, et al. (2023) as "amplification effects".

Table 4. Average Treatment Effect : Prolonged MSD implementation (community farming participants only)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Prolonged MSD implement with application for subsidies			Prolonged MSD implement witout application for subsidies		
Treatments						
Treatment 1 (Social norm)	0.00823	0.0432	0.0340	0.0461**	0.0704**	0.0839***
	(0.0210)	(0.0310)	(0.0338)	(0.0216)	(0.0303)	(0.0322)
Treatment 2 (Loss aversion + Testimony)	-0.0254	-0.00267	-0.00717	-0.00116	0.00365	0.0134
	(0.0189)	(0.0273)	(0.0306)	(0.0201)	(0.0294)	(0.0336)
Treatment 3 (Boost)	0.0151	0.0286	0.0258	0.0238	0.0454	0.0504
	(0.0267)	(0.0318)	(0.0344)	(0.0242)	(0.0313)	(0.0317)
Farmer's charactristics						
Number of fulltime member		0.00748	0.0135		0.00241	0.00239
		(0.00844)	(0.0113)		(0.00642)	(0.00958)
Number of parttime member		-0.00142	-0.00166		-0.00193	-0.00182
		(0.00169)	(0.00182)		(0.00161)	(0.00176)
Total plannted area		-8.37e-05	-8.67e-05		8.68e-05	2.54e-06
		(0.000239)	(0.000249)		(0.000328)	(0.000321)
Paddy area		-0.00353	-0.00344		-0.00434	-0.00496
		(0.00405)	(0.00437)		(0.00565)	(0.00590)
Percentage of income from rice cultivation		0.0627	0.0699*		0.0195	0.0264
		(0.0382)	(0.0389)		(0.0319)	(0.0337)
Realized impact of climate change on rice farming (negative impact)		0.0429*	0.0418*		-0.0306	-0.0220
		(0.0227)	(0.0248)		(0.0327)	(0.0339)
Realized impact of climate change on rice farming (positive impact)		0.145*	0.165*		-0.0714	-0.0821
		(0.0826)	(0.0857)		(0.0587)	(0.0636)
Recognizing that rice paddies are a source of methane emissions (strongly)		-0.0190	-0.0177		-0.0138	-0.0157
		(0.0449)	(0.0474)		(0.0321)	(0.0339)
Recognizing that rice paddies are a source of methane emissions (to some extent)		-0.0632**	-0.0801***		0.000825	0.00440
		(0.0273)	(0.0285)		(0.0252)	(0.0267)
Leaflet check dummy		0.0522*	0.0436*		-0.00934	-0.00910
		(0.0266)	(0.0253)		(0.0236)	(0.0255)
Settlment's charactristics						
Welldrained area rate			-0.000190			7.98e-05
			(0.000263)			(0.000279)
Center elevation			1.31e-05			-0.000361
			(0.000256)			(0.000308)
Center inclination			-0.0101**			0.0111
			(0.00421)			(0.00714)
Settlement's paddy area rate			0.0127			0.271**
			(0.121)			(0.111)
Constant	0.0902***	0.0578	0.0686	0.0683***	0.121**	-0.113
	(0.0147)	(0.0428)	(0.126)	(0.0140)	(0.0583)	(0.119)
Observations	1,524	667	623	1,524	667	623
R-squared	0.003	0.040	0.053	0.005	0.015	0.025
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

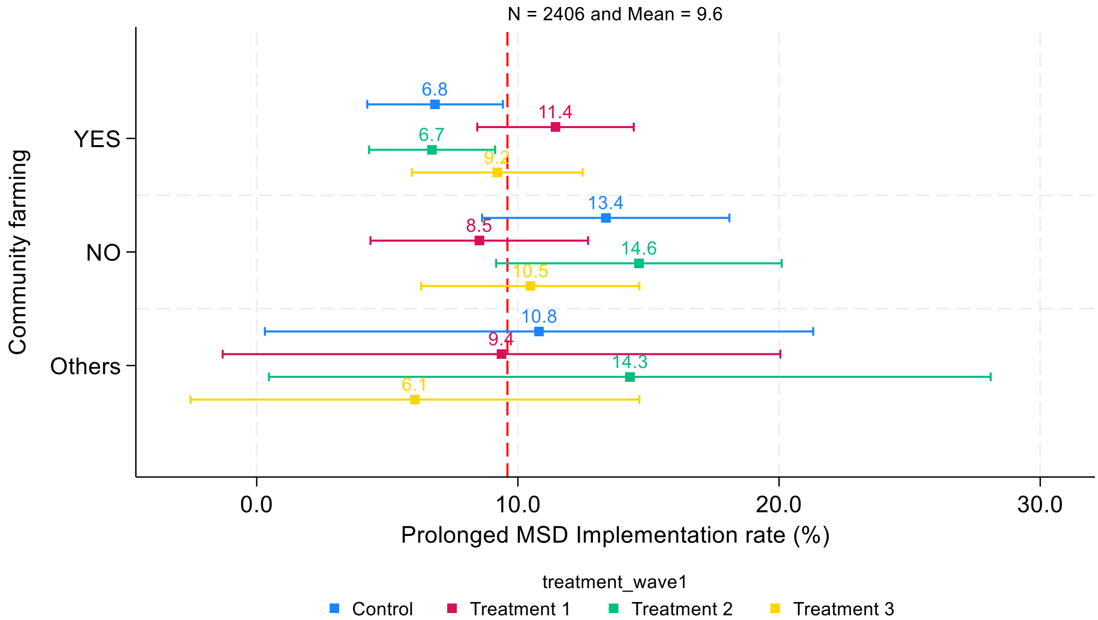

Figure 6. Prolonged MSD implementation rate (without application for subsidies)

Spillover Effect

'Behavioral spillover' has grown considerably in recent years. Spillover is where the adoption of one behavior causes the adoption of additional, related behaviors. In our experiment, we created an intervention material focused on the behavior of extending MSD. However, previous studies utilizing RCTs with consumers have reported that information interventions also induced pro-environmental behavior other than the targeted behavior. For example, Jessoe et al. (2021) is an experimental study that targets reductions in residential water use but reports that electricity use has also been altered. Similarly, Carlsson, Jaime, and Villegas (2021) report that social information campaign aimed at reducing water use causes a spillover effect on the use of electricity.

We, therefore, also examined whether the letter's focus on prolonged MSD had an impact on the adoption of other eco-friendly farming practices besides MSD. The letter may have fostered farmers' awareness of global warming and induced other behaviors to reduce greenhouse gas emissions from agricultural land and the adoption of environmentally friendly farming methods (Carrico 2021). In the survey we distributed to farmers in October 2022, we also examined the adoption of various other eco-friendly agricultural practices recommended for implementation in the study area. In particular, "fall plowing" is attracting attention as an agricultural management for reducing greenhouse gas emissions as well as MSD. We decided to analyze the status of fall plowing because it does not require additional materials and does not require a lot of labor.

Figure 7 shows the percentage of fall plowing performed by the treatment group. Since the purpose of this subsection is to examine the spillover effects, only the implementation without subsidies with low switching costs of behavior change was mainly analysed. The results showed that there was a certain difference between the farmers who participated in community farming and those who did not. Specifically, treatment 1 increased 3.0% in the participation rate of farmers who participated in farming, which was statistically significant at the 10% level. The null hypothesis could not be rejected for any of the other coefficients.

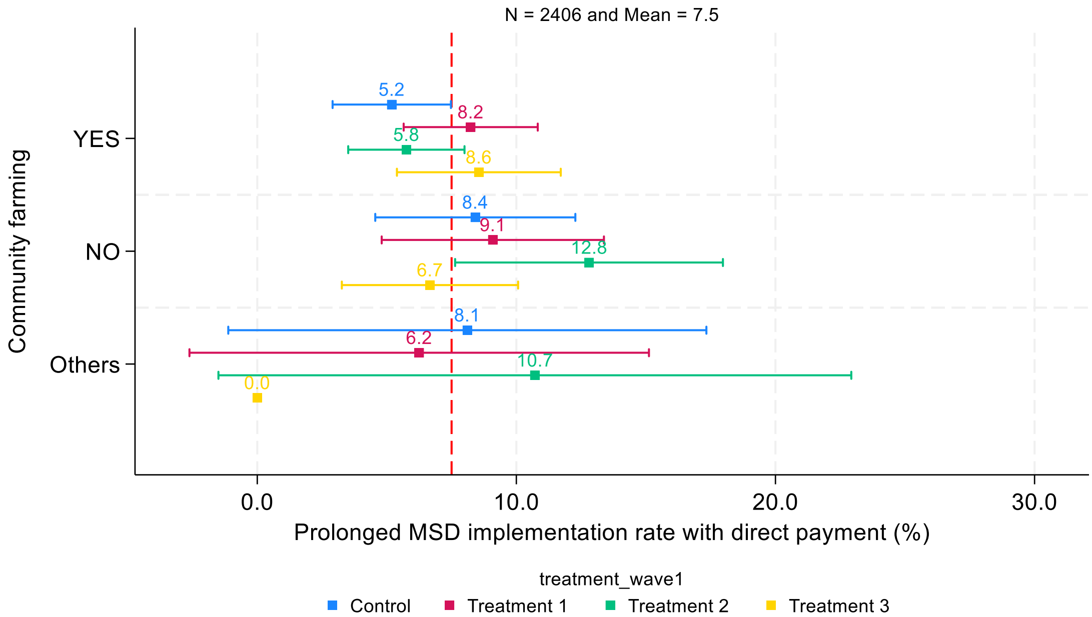

Figure 7. Fall plowing implementation rate (without application for subsidies)

Average Treatment Effects on behavioral intention and effect of repeated information provision

Table 5. indicate the number of farmers who received repeated information per group. About half of the farmers in Treatments 1, 2, and 3, as a subarm, received repeated informational leaflets. Figures 8 and 9 show the percentage of farmers who indicated their willingness to implement a prolonged MSD in the future after receiving the first stage treatments, and the percentage of farmers who are willing to implement as a result of the second treatment (reminder) in the second stage, respectively.

Table 5. Number of farmers who received repeated information per group

	Settlement	Farmers	Non-repeated information provision	Repeated information provision (reminder)
Control	103	634	–	–
Treatment 1 (Social norm)	103	675	387	288
Treatment 2 (Loss aversion +Testimony)	101	642	321	321
Treatment 3 (Boost)	101	574	300	274

This result indicates that Treatment 3(Boost) is effective, in contrast to previous findings where the 'implementation rate' was the measured outcome. Additionally, it has been observed that providing information repeatedly can enhance the implementation rate. Specifically, the proportion of respondents expressing willingness to implement prolonged MSD with subsidies was notably higher in the treatment groups 3. This increase was statistically significant at the 1% level following the repeated provision of information. Thus, nudges and boosts differ in the outcomes that show their effects, and repeated provision of information is found to be effective.

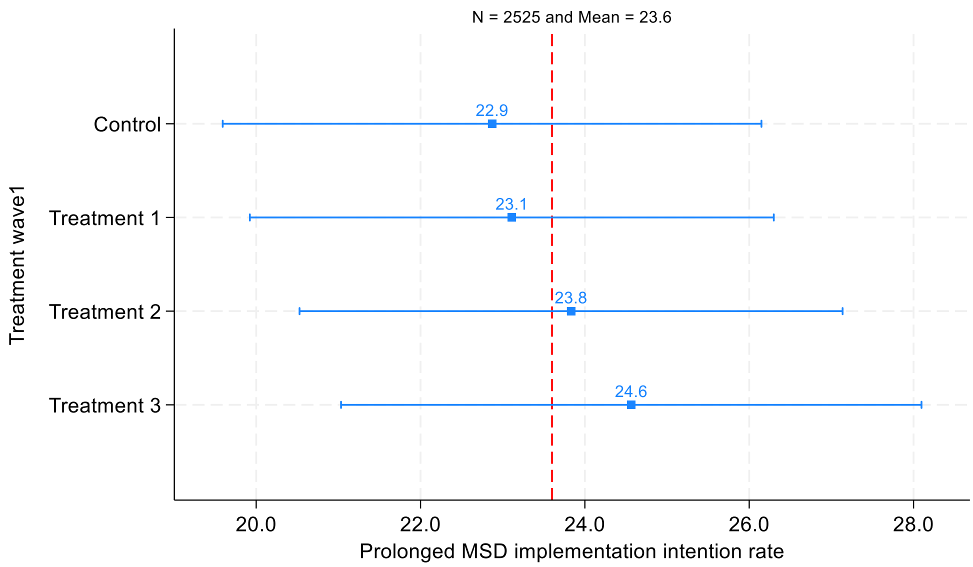

Figure 8. Prolonged MSD implementation intention rate by first-wave treatment

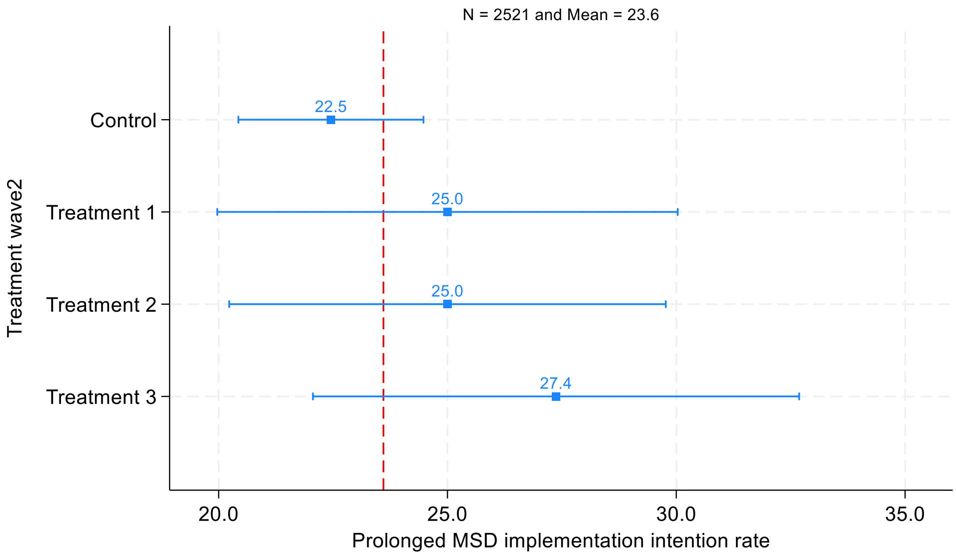

Figure 9. Prolonged MSD implementation intention rate by second-wave treatment (reminder)

5. Discussion and Conclusion

This paper builds on the existing economics literature utilizing RCTs to explore the effects of behavioral interventions such as Nudges (including social norm and loss aversion interventions) and Boosts. Our experimental results show notable differences in the effectiveness of basic communications from the local government (Control group) versus those enriched with social norms messaging focusing on methane emission from paddy fields (Nudge). Specifically, we find a clear positive effect of social norm messaging on self-reported prolonging MSD for farmers participating in community-based agriculture. On the other hand, farmers who did not participate in community farming had higher rates of prolonged MSD with and without nudges. Participation in community farming depends on local conditions and individual farmers' management policies. For example, farmers may not participate in community farming for the following reasons. (1) Large-scale farmers have their own management strategies and may not be efficient to cooperate with other farmers. (2) If the share of income from community farming is lower than their own management, they have less incentive to participate. Thus, those who prefer farming based on their own free strategy will not participate in community farming. In addition, our research shows that targeted technical advice (Boost), which addresses common concerns about changing traditional farming practices, significantly influences farmers' future intentions to adopt methane mitigation techniques, although it did not lead to behavioral change in the experimental year. Additionally, the impact of repeated information provision on future implementation intentions was statistically positive.

It is fascinating that in our experiment, while the letter to farmers informed only about global warming and the methane reduction benefits of prolonged MSD, a noticeable increase in autumn plowing was observed in the treated group. Just as effective at reducing methane emissions from paddy fields, autumn plowing, which entails tilling the soil after harvest and mixing in rice straw and stubble, can markedly decrease methane output. Past experimental studies with consumers have shown spillover effects in behavioral interventions, impacting areas beyond the intended treatment. Interestingly, we found a similar phenomenon in farmers' behaviors.

This behavioral intervention and its results constitute an important contribution to the behavioral insights literature. Specifically, we provide novel evidence regarding the efficacy of nudge and boost interventions implemented among farmers rather than consumers. The study underscores the importance of combining nudges, which subtly alter the external choice architecture, with boosts that empower farmers' decision-making capabilities and counter cognitive biases, to effectively steer behavior towards environmentally sustainable practices.

Our work most directly builds on Hrozencik et al. (2023), Chabé-Ferret et al. (2019) and Chabé-Ferret, Le Coent, David-Legleye, et al. (2023) which implemented field experiments with farmers in developed countries. In terms of the effect of social comparison nudge, Hrozencik et al. (2023) and Chabé-Ferret et al. (2019) found a positive significant effect (reducing annual groundwater use) while some studies (Chabé-Ferret, Le Coent, David-Legleye, et al. 2023) found adding a social comparison nudge cause negative impact (decreases farmers' PES contracts). Although the results of social comparison nudges in recent field experiments with a large number of farmers in the U.S. and Europe are mixing, our experimental result is consistent with the former in which social comparison messaging can influence the behavior of agricultural producers toward prosocial outcomes.

Our experimental setting is, under the condition of existing the small amount of subsidy program for MSD, it was left to the farmers to decide whether to receive this subsidy and implement MSD or not (since it is less labor-intensive management). This situation is likely to occur in agri-environmental direct payment programs in other countries, and our experiment shows that social comparisons are effective in changing behavior. We also confirmed that Boost can change the future behavioral intentions of farmers who are hesitant to change their behavior, indicating that the combination of nudges and boosts, rather than nudges alone, is effective in promoting farmers' sustainable agricultural choices.

Finally, important questions remain regarding the persistence of treatment effects over time, and the external validity of the project to regions other than Shiga prefecture, which has been advanced in tackling environmental problems.

Although the nudges identified in this study have only stimulated behavioral change in a very small percentage of farmers, their cost-effectiveness is significant. Although paper-based information was provided in this study, in several developed countries, sending messages to individual farmers is becoming easier and less expensive at an accelerated pace, as applications for subsidies are now available online. In Japan, MAFF has developed a service (commonly known as eMAFF) that allows online applications for subsidies and grants as well as applications based on the laws and regulations under its jurisdiction. It will be possible to implement nudges easily by displaying the necessary on mobile devices. The combination of effective top-down information provision through digital technology and technology dissemination activities by Extension Centers that exist throughout the country in response to local conditions will be effective.

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