My opinion, your opinion – Do group norms and perceptions influence farmers' fertilizer practices?

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Abstract

Social norms and perceptions within farming networks can influence the adoption of new agricultural practices. In Indonesian rice farming communities, norms around the desired level of rice plant greenness are widespread, with some farmers valuing deep green plants. Since greenness levels depend on the content of chlorophyll in the plants, which in turn depends on nitrogen fertilizer inputs, these norms can lead to high usage of chemical fertilizer. This study uses a mixed-method approach to examine whether social norms, personal beliefs, and perceptions about peers' opinions influence rice farmers' fertilizer input decisions. We combine quantitative regression analyses with qualitative content analysis to explore these dynamics. Our findings show that farmers who are unaware of a saturation point for fertilizer application tend to use more chemical nitrogen and less organic fertilizer. These farmers are also less willing to experiment with new farming practices that might reduce plant greenness but improve soil health. However, second-order perceptions – beliefs about whether lower greenness levels lead to talking within the farming community – do not significantly affect fertilizer use or farmers' willingness to try new methods. A survey experiment further confirms that increasing the salience of potential talking has little effect on farmers' willingness to experiment with new practices. Dyadic regressions reveal that actual fertilizer adoption behaviors of neighboring farmers are more predictive of fertilizer input decisions than neighbors' greenness norms. This suggests that while social norms around plant appearance exist, farmers' decisions are more strongly influenced by their own knowledge and the observable actions of their peers.

Keywords: Agricultural networks, social norms, organic farming, technology adoption, mixed-methods, Indonesia

JEL-Codes: Q01, Q12, Q55, Q56

1. Introduction

Social networks and peer effects influence individual behavior and decision-making across various domains, including health, education, and agriculture (Banerjee et al., 2019; Kremer and Miguel, 2007; Munshi and Myaux, 2006; Songsermsawas et al., 2016; Zimmerman, 2003). In the context of agriculture, the structural organization of networks and the interactions among their members play an important role for agriculture-related decisions. Social networks function as information sources, since farmers often learn about new farming practices and technologies through observing or interacting with other network members (Foster and Rosenzweig, 1995). Consequently, individual adoption decisions are often influenced by the observed adoption decisions of other network members, and the diffusion rate of new agricultural technologies within a network often depends on the entry point of the technology, the individual's position within the network and the contents of conversations among the network members (Bandiera and Rasul, 2006; Beaman et al., 2021; Conley and Udry, 2010; Munshi, 2004; Van den Broeck and Dercon, 2011; Wang et al., 2023).

Other driving forces of agricultural decision-making include peer pressure, the desire for peer approval and social conformity within social networks (Maertens, 2017; Moser and Barret, 2006, Wollni and Andersson, 2014). For instance, Maertens (2017) studies crop adoption decisions in rural India and finds that social pressures, arising from the belief that the newly introduced crop has adverse environmental consequences, delayed individuals' adoption decisions. Moser and Barret (2006) analyze conformity desires in the context of a rice production technology in Madagascar and find that conformity desires significantly influenced the adoption decision alongside the "learning from others" effect. Wollni and Andersson (2014) demonstrate that farmers who believe their neighbors approve organic farming practices were more likely to adopt such practices. However, the latent nature of

such forces, in contrast to observable behaviors, has led to their relative understudy in the literature. Our study directly contributes to this body of research by examining social network effects, peer pressure, and compliance desires in the context of agricultural input decisions. Specifically, we investigate the presence of social norms, individual and peer perceptions with regard to farmers' fertilizer input choices and different levels of rice plant greenness, and assess whether such norms prevent farmers from substituting chemical fertilizer with organic fertilizer.[1]

Chemical fertilizer contains nitrogen which contributes to the dark green color of rice plants. However, while this relationship can be considered to be linear (the more nitrogen fertilizer, the greener the plants), the relationship between chemical fertilizer input and rice yields can best be described as an inverted U-shape; more nitrogen fertilizer increases yields up to a certain saturation point, after which further application of chemical fertilizer decreases soil health and thereby, in the long run, also yields (Ren et al., 2022; Zhang et al., 2018; 2019). Anecdotal evidence suggests the prevalence of norms and perceptions among farming communities that "greener plants indicate better yields", leading to overapplication of chemical fertilizer. In our study, we systematically investigate this dynamic and explore whether such norms and perceptions prevent farmers from experimenting with more sustainable farming practices, which usually require lower levels (or even no) chemical fertilizer application. We chose greenness levels of rice plants because this visual characteristic is observable by other farming community members, and can therefore be the cause of perceived (mis)conformity. Specifically, we address the following research questions:

1) Are lower greenness levels of rice plants (resulting from less chemical fertilizer

[1] Our study was pre-registered at the AEA RCT Registry (ID: 0011003). In this final manuscript, we deviate in some aspects from the pre-registered study protocol. We provide details on the deviations and reasons for them in a separate document available under the same registration number.

application and substituting chemical with more organic fertilizer) a subject of "talking"[2] within farming communities and are perceived as a signal of low farm management skills in rural Indonesia?

2) How do own opinions about greenness and second-order perceptions (i.e. perceptions about potential negative peer effects, such as talking) relate to farmers' actual fertilizer input decisions and their stated willingness to experiment with a new farming practice that might reduce rice plant greenness but increase soil health?

3) Are perceptions about greenness levels interrelated within farmer networks, and how do the effects of potential peer pressure compare with the effects of observed adoption decisions within these networks?

We use a mixed-method approach to provide an encompassing and in-depth picture of the relationship between peer perceptions and fertilizer use. We collected quantitative (via household surveys) and qualitative (via semi-structured interviews (SSIs) and focus group discussions (FGDs)) data on own and peer perceptions about the importance of greenness levels in the context of fertilizer input decisions. Additionally, we conducted a survey experiment, which allows us to derive causal evidence on the question of whether making social pressure and potential negative talking about greenness levels more salient influences farmers' willingness to experiment with sustainable farming practices.

With our study, we contribute to the agricultural economics literature by investigating a potential factor of farmers' technology adoption decision. Previous studies have extensively analyzed the role of information constraints (*[Reference anonymized]*; Kondylis et al., 2017), liquidity constraints (Giné and Yang, 2009; Karlan et al., 2014; Tarozzi et al., 2015) and (observable) peer behavior and replication (Bandiera and Rasul, 2006; Beaman

[2] We use the term "talking" throughout our study to not ex-ante assume that such talking can only be negatively connotated (e.g. gossip), but could also have a positive connotation (e.g. advice sharing).

et al., 2021; Conley and Udry, 2010; Munshi, 2004). In contrast, we shift the attention to more latent forces, in particular second-order perceptions, and investigate whether the fear of not complying with (perceived) social expectations can explain the choice of agricultural inputs.

Further, we contribute to the broader social network literature by investigating how such second-order perceptions are correlated within social networks by making use of a dyadic regression approach. Lastly, by relying on both quantitative and qualitative data, we can provide a richer understanding of social network effects in the context of agricultural technology adoption than the vast majority of previous studies which focus on quantitative insights.

The remainder of this article is organized as follows. In Section 2, we present contextual information. In Section 3, we outline the conceptual framework that guides our analysis. In Section 4, we describe the quantitative and qualitative data we collected. In Section 5, we present the results, ordered along the three research questions. In Section 6, we discuss our results and conclude.

2. Contextual Information

Our study is set on Java Island in the two regions Yogyakarta and Tasikmalaya (Figure 1). Rice is the most important agricultural crop in Java, contributing about 60% of Indonesia's total rice production. Since the 1970s, food security and increased rice productivity have been focal policy issues in Indonesia, promoted through "green revolution" technologies, including the heavy use of chemical fertilizer (Hazell, 2009). Today, the over-application of chemical fertilizer, particularly the nitrogen fertilizer urea, is widespread (Sukayat et al., 2023).

Figure 1: Study regions. *Notes:* The research areas are highlighted in orange: Yogyakarta and Tasikmalaya.

In intensive agricultural systems, nitrogen is the limiting element in most soils. While sufficient nitrogen supply is important, it is essential to match the supply with crop demand (in both timing and quantity) to avoid environmental degradation. Nitrogen pollution and soil degradation can occur not only from over-application but also from incorrect application timing (Norton and Roberts, 2015). Figure 2 shows a Leaf Color Chart (LCC) commonly used in Indonesia to determine the nitrogen fertilizer requirements of rice plants. It consists of multiple green color stripes that range from yellow-green to dark green. Comparing the greenness of the rice leaves with the LCC provides an indication of plants' nitrogen content

and potential over- or underuse of nitrogen fertilizer. Data collected in the study by *[Reference anonymized]* indicate significant over-application of chemical nitrogen fertilizer in our study region.

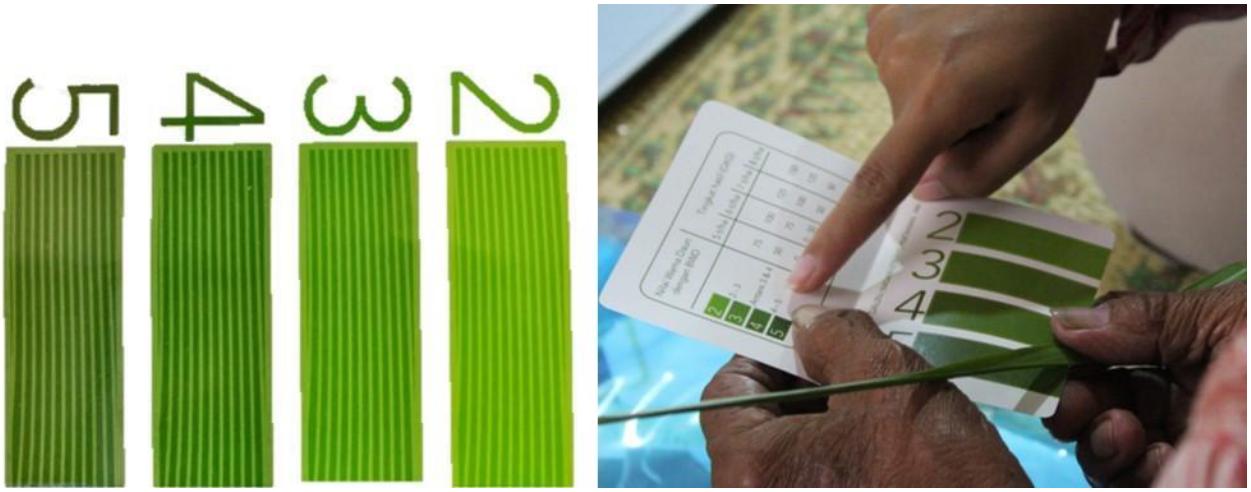

Figure 2: Leaf Color Chart. *Notes:* Leaf Color Charts are commonly used in Indonesia to determine the nitrogen fertilizer requirements of rice plants.

While reducing nitrogen application is often desirable to prevent long-term soil degradation, it can influence the appearance of rice crops due to lower chlorophyll levels, which in turn alter the plant's color (Yang et al., 2003). However, while the color might change, optimizing the amount and timing of chemical fertilizer application can even lead to increases in productivity. Ren et al. (2022) provide evidence that rice yields on around 10,000 smallholder plots in China could be increased between 10% and 19% while reducing nitrogen inputs by 15% to 19%. Similarly, Irawan et al. (2021) examined the benefits of using soil test kits for determining the dosage of rice fertilizer on 14,000 m^2 of rice plots in West Java and found that productivity increased by 6.2% to 13.2%, while chemical fertilizer use decreased by 15.5% to 48.4%, after following the soil test recommendations.

At the same time, the required amount of nutrients can also be provided by organic

fertilizer, without hampering productivity. For example, Rachman and Sudaryanto (2010) found that fresh rice straw or compost can provide the required nutrients that are otherwise provided through nitrogen, phosphorus and potassium fertilizer. Similarly, Susanti et al. (2024) demonstrated that recycling rice straw could reduce nitrogen application by 25-40 kg/ha per crop planting season. Hence, replacing chemical fertilizer with organic fertilizer can maintain or even increase productivity, while reducing nitrogen pollution.

We are therefore interested in the question of whether – despite the scientific evidence on the benefits of reducing chemical fertilizer when overapplication is present – prevailing norms and peer perceptions are a determinant of maintaining high levels of chemical fertilzer inputs in Indonesian rice farming communities.

Our study is embedded in the context of a previous study which assessed the causal impact of organic farming training on the adoption behavior of Indonesian rice farmers. While *[Reference anonymized]* provide evidence that training increased experimentation with organic farming practices, anecdotal qualitative data raised the question of whether a focus on greenness levels might have prevented other farmers from doing so. In qualitative interviews conducted two years after the training, farmers who began mixing organic fertilizer with chemical fertilizer to reduce the total amount of chemical fertilizer shared their experiences. Some respondents reported that while they observed an increase in soil quality and harvest, the resulting less green color of their fields led to gossip and talking within the farmer group. Others reported that deep green fields are still considered a quality indicator by many farmers and that these beliefs might affect farmers' willingness to experiment with "new" farming technologies.

The fear of social sanctions, comments, or negative views from peers about farmers' own farming practices could hence hinder the adoption of more sustainable farming practices. This can occur even if farmers understand that green fields are not necessarily a reliable

indicator of good farming management. In this study, we aim to systematically disentangle, quantitatively and qualitatively, the relationship between greenness levels, related opinions and perceptions, and how they influence fertilizer input decisions.

3. Conceptual Framework

We base our analysis on a conceptual framework, which is presented in Figure 3. Our framework is grounded in rational choice theory, which posits that farmers make decisions by balancing costs and benefits to maximize utility, here represented by yields and profits. In determining optimal fertilizer input, farmers strategically select a mix of chemical and organic fertilizer to minimize input costs and maximize returns. These decisions are shaped by farmers' personal opinion about the relationship between fertilizer use, plant greenness, and yields. For example, farmers who associate greener plants with higher yields will prefer higher chemical nitrogen input, while those who prioritize soil health may lean towards organic fertilizer.

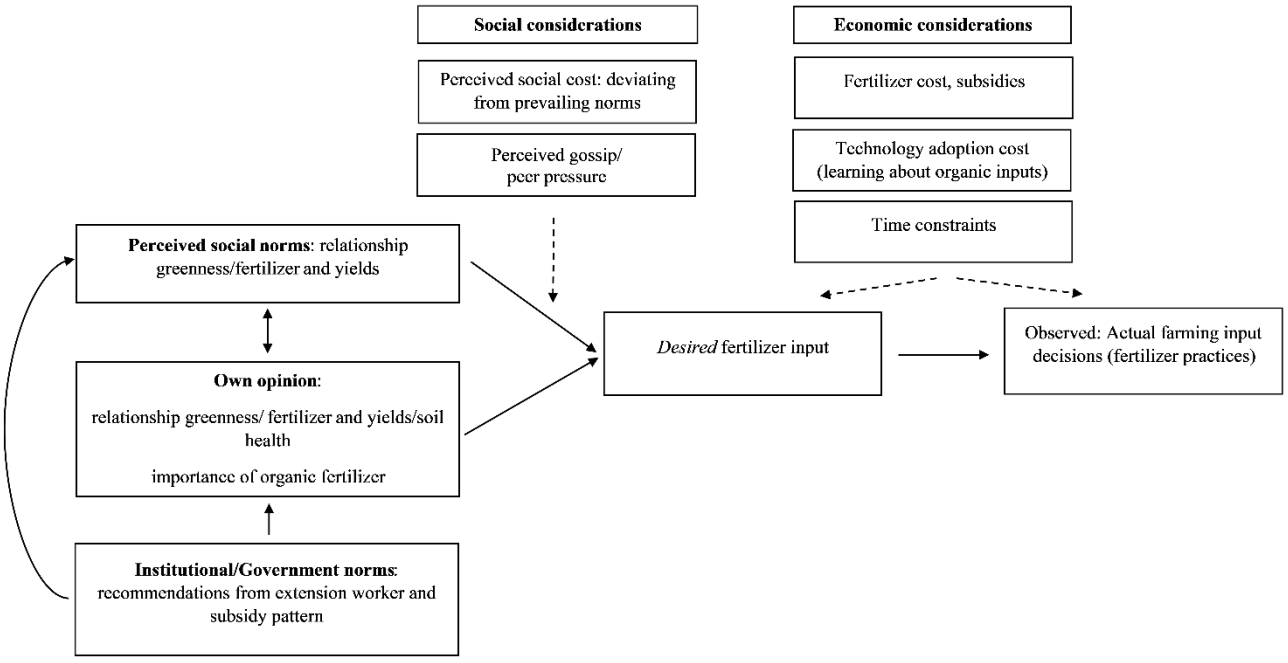

Figure 3: Conceptual framework. *Notes:* The conceptual framework presents the interplay between different determinants of fertilizer input decisions and practices.

Simultaneously, farmers' decisions are influenced by social norms, particularly perceptions of what their peers consider optimal plant greenness. Drawing on social norm theory, our framework suggests that farmers are influenced not only by their own preferences, but also by the perceived expectations of their farming network. These subjective norms, as shown in studies like Läpple and Kelley (2013) and Mzoughi (2011), can be a significant driver of adoption behaviors in agricultural practices. Thus, farmers may adjust their fertilizer use to conform to the community's expectations about ideal plant greenness, even when it contradicts their personal beliefs about yield optimization.

The strength of this influence further depends on the anticipated social costs of non-conformity. If deviating from the norm is socially penalized (e.g., being perceived as a less capable farmer and by leading to talking in the community), farmers are more likely to align their fertilizer input with community expectations. Conversely, if social costs are low, personal beliefs will dominate the input decisions.

Government norms, disseminated through subsidies and extension programs, can also shape both individual opinions and perceptions of social norms. These interventions, especially in group settings like farmer field schools, may shift farmers' beliefs about the optimal input mix or community standards around plant greenness.

Finally, economic factors such as fertilizer costs, subsidies, and technology adoption expenses influence farmers' ability to implement their desired fertilizer strategy. Constraints like financial limitations may prevent farmers from achieving their preferred input mix, even if they have the knowledge and desire to optimize their practices.

4. Methods and Data

To analyze the complex relationships between farmers' personal opinions and their perceived social norms regarding the optimal greenness levels of rice plants, we use a mixed-method approach. This approach combines quantitative data from two household surveys, including a survey experiment, with qualitative data from semi-structured interviews (SSIs) and focus group discussions (FGDs). For the quantitative data, we employ descriptive statistics and regression analyses. For the qualitative data, we use content analysis. The objectives of the qualitative data collection were to obtain contextual information regarding farmers' perceptions of greenness discussions and to triangulate findings from the quantitative evaluation.

4.1 Quantitative Data

Household Survey – Sample 1

The current study builds upon and closely relates to the work of *[Reference anonymized]* which employed a randomized controlled trial to evaluate the impact of organic farming training on smallholder farmers' knowledge and uptake of organic farming practices. In the original study, 1,200 respondents were randomly sampled from 60 villages in two administrative regions of Indonesia, Tasikmalaya district and Yogyakarta province.[3] In the context of a follow-up study with the same respondents in 2023, we systematically collected information about perceptions and the importance of rice plant greenness and how they might influence adoption decisions. We further collected detailed information on fertilizer inputs, particularly the amount of nitrogen fertilizer application per plot, the usage

[3] For more details on the original sampling and study design, we refer the reader to the study by *[Reference anonymized]*.

of organic fertilizer and the usage of organic manure. Figure A1 in the Appendix provides a schematic overview of the timeline of the original and follow-up study. In the present study, we use the data collected in 2023 from the follow-up study and refer to this as Sample 1.

Social Network Data

For this Sample 1, we also collected rich social network data. We used the *round-robin design* of social relations to collect the network data (Gleason and Halperin, 1975; Kenny et al., 2006), i.e., each farmer of the village sample was interacted with all other farmers sampled in the same village and information about social relations was collected from both sides ("nodes"). This approach allowed us to construct the village level $n \times n$ adjacency matrices of pairwise network links. The resulting dyadic data depict the agricultural networks among respondents within each village. Respondents were asked several questions, e.g., whether they engage in regular agricultural exchanges or whether they cultivate neighboring fields. In the current study, we focus on the geographical networks of neighboring fields; i.e. farmers are modeled as being connected nodes within a network if they cultivate neighboring fields.

Household Survey – Sample 2

In addition to Sample 1, we utilize data from a second household survey conducted as part of a study on the potential of individualized soil tests for smallholder farming in Indonesia. In this study, a sample of 1,104 rice farmers from 69 villages in Yogyakarta (distinct villages from Sample 1) were invited to participate in soil-health management training. Using the same survey questionnaire as for the Sample 1, we collected data on the importance and perceptions of greenness as well as information on fertilizer inputs during the post-training survey in 2023. In the present study, we refer to this dataset as Sample 2. Figure A2 in the

Appendix shows the timeline of this soil-health management study.

In total, our sample comprises 2,024 farmers from both studies (950 from Sample 1 and 1,074 from Sample 2 after attrition). We use the pooled sample (Sample 1 and Sample 2) for our main analysis and Sample 1 for analyses related to the social network data, since social network data was not collected for Sample 2.

Greenness variable description

For both samples, we used the following questions to explore greenness perceptions:

Perceived talking about greenness ("perceived talking"): To elicit individuals' beliefs about others' opinion, we asked: "Among your neighbors and other farmers in your village, are rice plants that are less green a point of talking?". Answer options to this question were (1) "yes, there is talking", (2) "yes, there is talking by some but not all" and (3) "no, there is no talking".

Own opinion about greenness ("own opinion"): To elicit individuals' opinion about how strongly they valued the greenness level personally and what they knew about the relationship between fertilizer application and resulting greenness levels, we asked: "According to you, what is the relationship between greenness and yield?". Answer categories were (1) "the greener the plants, the higher the yields", (2) "there is no strong relationship between greenness and yields" and (3) "crop yields increase as greenness of the plants increases, and then decreases when greenness passes a certain threshold". As explained above, the last answer category is considered the correct one and signals in-depth knowledge about the fertilizer-yields relationship, which follows an inverted U-shape (in the remainder of the paper, we use the term "inverted U-shape" to refer to answer (3)).

Survey Experiment

We also included a survey experiment in both samples to test whether making talking about greenness levels and related social pressure explicitly salient affects respondents' self-reported willingness to experiment with a new practice that might impact greenness levels. We used the following variable to elicit the influence of greenness on adoption willingeness:

Influence of greenness on adoption willingness ("greenness influence"): This variable measures the individual willingness to adopt a new farming practice if this farming practice is believed to be better for soil health, but lowers the greenness level of plants. Specifically, we asked the respondents: "There is a new farming practice that is thought to be better for soil health but might make your rice crops less green. Would the potential change in the greenness of your crops influence your decision to try this practice?". Answers were measured on a scale from 1 to 10, with 1 corresponding to "No, not at all" and 10 corresponding to "Yes, definitely". Hence, the higher the value of this variable, the stronger are individuals influenced by greenness levels in their choice of farming inputs.

We then randomized the order of the questions "perceived talking" and "greenness influence". The control group received the question about "greenness influence" *before* the "perceived talking" question. The treatment group, in contrast, received the "greenness influence" question *after* the "perceived talking" question. We hypothesized that highlighting the potential negative talks and discussions on greenness levels would make social norms and the potential costs of deviating from these norms more salient. We expected this to impact the extent to which respondents report to be influenced by potential changes in plants' greenness levels when deciding to adopting a new practice.

Table 1, Panel A presents the summary statistics of both samples including the greenness variables and fertilizer application rates.

Table 1: Summary statistics

	(1) Mean	(2) SD	(3) Min	(4) Max
PANEL A (Pooled sample, N=2,024)				
Demographics				
Gender (1=male)	0.84	0.36	0	1
Age	53.98	10.43	20	89
Marital status				
Married	0.90	0.30	0	1
Married but not living together	0.01	0.07	0	1
Divorced/Separated	0.01	0.11	0	1
Widowed	0.05	0.22	0	1
Never married	0.03	0.18	0	1
Education				
No elementary school	0.07	0.25	0	1
Elementary school	0.29	0.46	0	1
Junior high school	0.19	0.39	0	1
Senior high school	0.40	0.49	0	1
University	0.05	0.23	0	1
Household size	3.87	1.46	1	10
Greenness variables				
Talking perceptions				
Yes, there is talking	0.79	0.41	0	1
Yes, talking by some but not by all	0.05	0.22	0	1
No talking	0.16	0.37	0	1
Own opinion				
The greener the leaves, the higher the yields	0.41	0.49	0	1
No strong relationship	0.14	0.34	0	1
Inverted U-shape	0.45	0.50	0	1
Greenness influence	4.77	2.93	1	10
Nitrogen application (kg/ha)	146.29	85.01	0	368.75
Organic fertilizer last season (1=yes)	0.34	0.47	0	1
Organic manure last season (1=yes)	0.42	0.49	0	1
Sample (1= Sample 1)	0.47	0.50	0	1
Treatment status (1=received training in original RCTs)	0.59	0.49	0	1
PANEL B (Sample 1, N=950)				
Network variables				
# of total network members (neighboring plots)	2.06	2.50	0	18
# of network members applying organic fertilizer	0.88	1.41	0	10
# of network members applying organic manure	1.05	1.48	0	14
Average nitrogen application of network members	139.91	74.37	0	368.75
# of network members saying “yes, there is talking”	1.76	2.24	0	18
# of networks members saying “the greener, the higher the yields”	0.92	1.17	0	8
PANEL C (Sample 1, dyadic data set, N=14,444)				
Farmers cultivate neighboring rice fields	0.20	0.40	0	1
Farmers have the same perception about second-order talking	0.72	0.45	0	1
Both applied organic fertilizer	0.18	0.38	0	1
Both applied organic manure	0.29	0.45	0	1

Notes: This table presents the summary statistics of the pooled sample from Sample 1 and Sample 2 (Panel A), of the network variables which are only available for Sample 1 (Panel B), and for the dyadic data set constructed from the network variables for Sample 1 (Panel C). The average nitrogen application of network member is averaged only over the sample that has at least one network member besides the respondent.

The average input of nitrogen amounts to 146 kg/ha with a median of 136 kg/ha. About 38% of farmers apply more fertilizer than the upper level recommendation of the Indonesian Agricultural Ministry (161 kg/ha; Indonesian Agricultural Ministry, 2022). Thirty-four and 42% of the farmers applied organic fertilizer and organic manure in the last season, respectively. Panels B and C further present the summary statistics of the network data. Panel B presents the network statistics at the individual level. Since we focus on geographical networks, farmers are considered to be in the same network if they cultivate neighboring plots. On average, each farmer shares a plot border with 2.06 other farmers, of which 0.88 apply organic fertilizer and 1.05 apply organic manure. The average nitrogen application of neighboring farmers is 139.91 kg/ha. Moreover, of the average 2.06 neighboring farmers, 1.76 hold the opinion that less greenness levels lead to talking and 0.92 hold the opinion “the greener the plants, the higher the yields”. Panel C presents the network statistics at the dyad level (i.e., two connected nodes/farmers form a dyad). The panel shows that 20% of all possible node-connections are neighboring farmers, 72% of all possible node-connections share the same opinion about perceived talking, and 18% and 29% of all possible node-connections are pairs of farmers that both apply organic fertilizer and organic manure, respectively.

4.2 Qualitative Data

In addition to the quantitative surveys, we conducted 18 SSIs (10 from Sample 1 and 8 from Sample 2) and 6 FGDs (all from Sample 1).

The sampling procedure for the SSIs was purposive to ensure diverse responses and experiences. We selected SSI respondents based on variations in greenness questions and the adoption of organic farming practices, both derived from the quantitative data. The interviews lasted between 30 to 60 minutes and were conducted in Indonesian. Respondents were asked open-ended questions about their perceptions of community

discussions and comments around plant greenness as well as their reasons for choosing specific fertilizer.

Each FGD included 5-6 participants and lasted between 1-2 hours. The discussions focused on greenness and farmers' experiences with adopting organic fertilizer. Specifically, we asked farmers about the preferred greenness level in their community, the frequency of discussions about greenness, and whether greenness is seen as an indicator of farming ability.

Trained enumerators conducted all SSIs and FGDs, with one of the authors attending all sessions. All interviews and FGDs were recorded with the respondents' consent and later transcribed into Indonesian.

5. Results

5.1 Are lower greenness levels of rice plants perceived as a signal of low farm management skills and subject to talking?

We begin by presenting descriptive evidence on whether farmers perceive greenness levels as a topic of talking and how these perceptions overlap within villages. Assuming a simple scenario where there either is or is no talking about greenness levels within a village, one might expect that farmers within a village have uniform perceptions about the occurrence of talking. However, in practice, talking may be restricted to subgroups, and respondents may differ in their subjective perceptions. Figure 4 compares the share of respondents who answered (1) "yes, there is talking", (2) "there is talking among some" and (3) "no, there is no talking" about plants' greenness levels within their community. If all respondents within one village shared the same perceptions about talking related to greenness, we should only observe shares of 1 (100 percent). Figure 4 shows that this is not the case in our data.

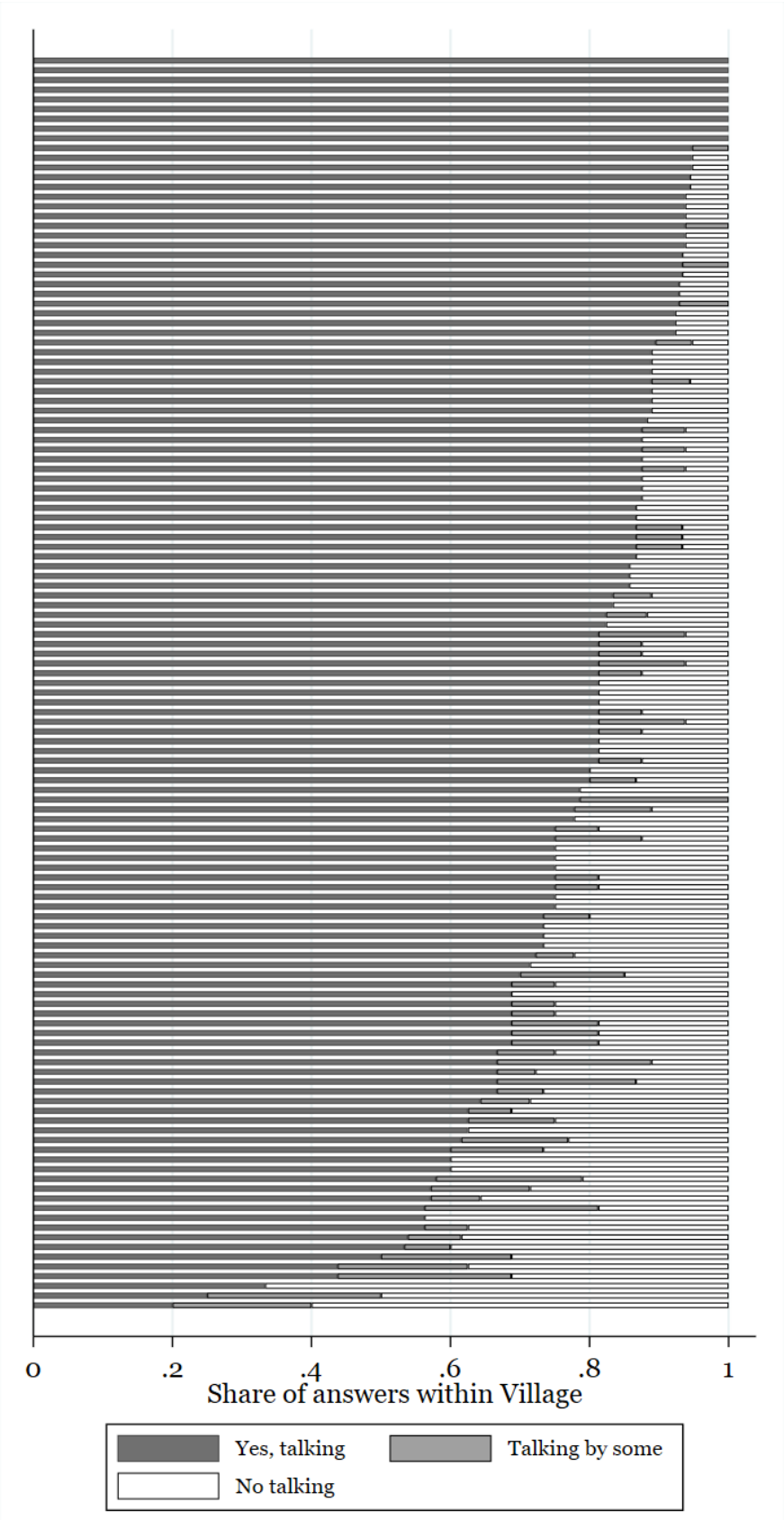

Figure 4: Perceptions about the existence of talking within one's own village. *Notes:* Figure 4 presents per village the share of farmers who mentioned that there is (1) talking, (2) talking by some or (3) no talking about the greenness level of rice plants.

In only seven villages, all respondents share the perception that “yes, there is talking”. In most villages, however, beliefs about talking are mixed. Notably, however, perceived talking about greenness is present in all villages. In fact, in all villages at least 50% of respondents report that there is talking about greenness levels.

The qualitative data supports the quantitative evidence regarding the existence of talking about greenness. SSIs and FGDs confirm that leaf color is a common topic of discussions, with discussions often taking place in the fields. One SSI respondent in Tasikmalaya explained that farmers compare the greenness of their rice plants when they meet in the fields: “*Farmers ask ‘Why is that one green like that, why is mine yellow?’, like that. ‘What is the seed?’. It is just like that. We like to chat about it*.”

Results from both, SSIs and FGDs reveal different perceptions concerning the connotation of “talk” about leaf greenness. In an FGD in Yogyakarta, participants highlighted the importance green leaves have for them. They also confirmed the prevalence of talking among farmers, noting that light green fields might lead to speculations about financial constraints in purchasing fertilizer. One participant stressed the importance of plants being green by the 40-day mark after planting, explaining that it is a “wow” factor and commented on by others. The participants explained that greenness is seen as a sign of quality since their parents’ generation and even non-farmers walking by the field comment on and judge the greenness of the rice crops. This sentiment is reiterated by an SSI respondent, who said “Y*eah, sure. It definitely becomes a topic of conversation – when just going around people say ‘Oh, this one is from Mister [.], how come that the yellow plants weren’t fertilized correctly?’”*. Another SSI respondent recounted other farmers commenting on the color of his rice plants after he reduced the amount of urea he applied. He explained that “*sometimes people say ‘Oh, how come that the plants aren't green enough, fertilize them again’”*.

Other SSI respondents confirmed that farmers talk about greenness but stressed that they do not perceive this as talk with the negative connotations associated with gossip. Two respondents in Tasikmalaya explained that while there is talking about greenness, they see it as simply confiding in each other. When asked about their decision-making process for urea application quantities, the respondents mentioned that they follow neighboring farmers and extension worker recommendations. Thus, while they do not view talk negatively, they tend to be influenced by other farmers' behavior. The notion that comments and talk are not perceived negatively was also echoed by FGD participants in Tasikmalaya. They described the talk and commenting as confiding in each other and seeking advice. According to them, farmers pay attention to greenness and ask each other about how much fertilizer was applied.

Comparing discussions across FGDs reveals that some farmer groups talk and comment mainly on yellow-green leaves while in other groups, farmers comment on both yellow and excessively dark green leaves. One participant, for example, said greenness is always a topic of conversation among friends and that farmer group members might comment "*Why is yours darker, brother? Why does it look like it hasn't been taken care of properly*?". During their discussion about greenness and whether it leads to talking, participants mentioned a lack or unevenly applied fertilizer but also addressed excess fertilizer when fields are green but results are unsatisfactory.

When asked whether less green plants signal less farming ability, some farmers describe leaf color as a marker of farming ability, suggesting the existence of a perceived norm regarding greenness and judgment if this norm is not met. For example, one FGD participant in Yogyakarta mentioned that yellow-green leaves are a sign that farmers do not take proper care of their plants. However, participants in this FGD also noted that a farmer field school taught them that visual appearance is not a definite marker of farming

ability or dedication. Participants in another FGD in Tasikmalaya outlined various reasons for less green fields, including cultivation methods, a lack of fertilizer, unevenly distributed fertilizer, and limited resources to purchase fertilizer. Other farmers rejected the idea that greenness reflects farming ability, arguing that greenness can be influenced by factors beyond farmers' control, such as pests.

To conclude, the topic of rice plant greenness seems to be an important point of talking among rice farmers in Indonesia. Leaf greenness is evaluated and discussed and farmers link greenness levels to fertilizer usage. Qualitative data show that farmers notice less green or yellow plants, but some also addressed dark green leaves as a sign of over-fertilization. Evidence on whether less green plants are perceived as signal of low farming ability is mixed. While some farmers agree that this can be a sign of not taking sufficient care of the rice plants, other farmers also emphasize reasons that are beyond the farmers' control.

We further explored farmers' own opinions about the relationship between greenness and yields to understand individuals' motivations for applying high amounts of chemical fertilizer. This allows us to later explore to what extent farmers' own opinions or their second-order perceptions drive actual input decisions. Figure 5 compares the share of farmers who answered (1) "the greener the plants, the higher the yields", (2) "there is no strong relationship between greenness and yields" and, (3) "inverted U-shaped relationship". We observe that farmers within the same village hold diverse opinions regarding the relationship between greenness and yields. The variation of these opinions is much higher than that of the perceived existence of talking about greenness levels, indicating that own opinions and perceived talking may not be strongly correlated.

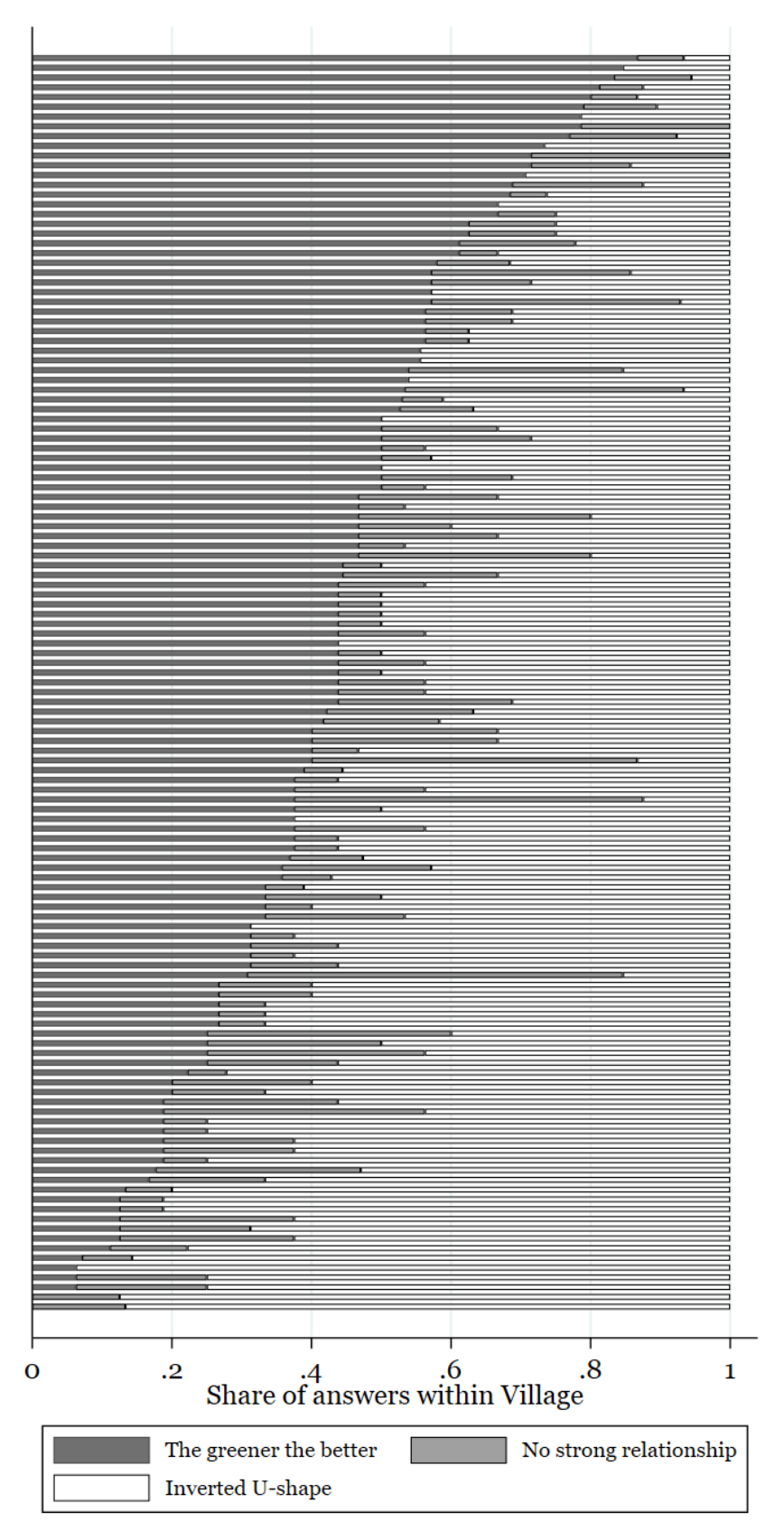

Figure 5: Opinion about the relationship between greenness of rice plants and yields. *Notes:* Figure 5 presents per village the share of farmers answered (1) “the greener the plants, the higher the yields”, (2) “there is no strong relationship between greenness and yields” and, (3) “inverted U-shaped relationship”.

To explore this further, we plot the average perception of talking about lower greenness, i.e., the share of respondents who believe that lower greenness is a topic of talking, against the share of respondents per village who reported “the greener the leaves, the higher the yields” (Figure 6). While agreeing with “the greener the leaves, the higher the yields” does not necessarily imply that the respondent would also engage in talking about other farmers’ fields, it provides some insights into how one’s own perceptions about greenness might overlap with perceptions about others’ opinions on greenness. Figure 6 shows no strong correlation between respondents’ own opinions and their perceptions about talking. This indicates that perceptions about whether lower greenness levels lead to talking, and thus perceptions about other people’s opinions, may not strongly correlate with their own opinions on greenness. This raises the question of whether it is one’s own opinion or the anticipation of talking about less green fields that drive actual fertilizer input decisions.

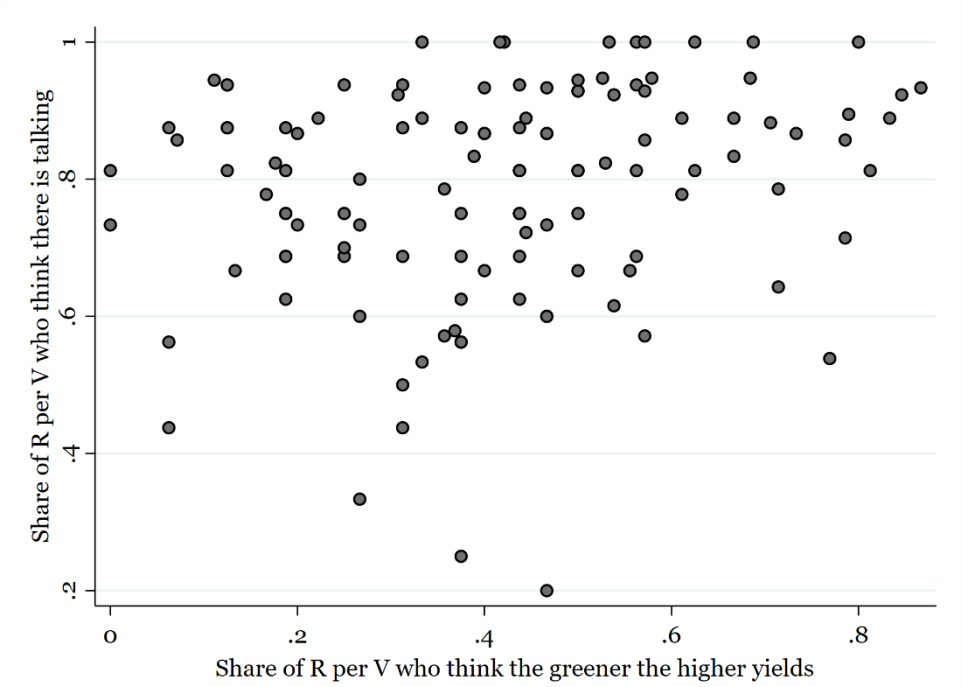

Figure 6: Correlation between one’s own opinion about the importance of greenness and perception of talking prevalence within villages. *Notes:* Figure 6 plots for each village the share of respondents that think that lower greenness levels result in talking against the share of respondents that think that the greener the rice plants are, the higher the yields.

5.2 Do own opinion or (second-order) perceptions about possible talking influence farmers' fertilizer input decisions?

Having established that greenness levels of rice plants are an important point of discussion within villages and farming networks, but that the perceptions of talking do not strongly correlate with own opinions on the importance of greenness for yields, we now explore how talking perceptions and own opinions influence stated and actual adoption decisions. Specifically, we investigate whether talking perceptions and own opinions are correlated with (1) the stated willingness to adopt a new farming practice if this practice would reduce plant greenness and with (2) actual agricultural input behavior. To investigate this, we conduct regression analyses to examine the effects of own opinions and second-order perceptions on: (1) the stated willingness to adopt a new farming practice (i.e., the variable "greenness influence" as described above), (2) actual nitrogen application from chemical fertilizer, (3) actual organic fertilizer usage, and (4) actual fermented manure usage. We use organic fertilizer and manure usage as a proxy for sustainable farming practices that closely relate to the hypothetical practice we introduce in the "greenness influence" question. In our quantitative data, we only observe farmers' actual input decisions and not desired input decisions (which are considered separately in our conceptual framework). However, we believe that actual input decisions serve as a good proxy for desired input levels. We estimate the following equation:

$$Input\ behavior_i = \alpha + \beta OwnOpinion_i + \gamma TalkingPerceptions_i + \delta X_i + \mu_i \quad (1)$$

The outcomes of interest $Input\ behavior$ are measured as: (1) the influence by changes in plant greenness of a new practice on willingness to adopt ("greenness influence"; 1: no influence, 10: very high influence), (2) as a continuous variable of kg nitrogen used per hectare by farmer *i* in the last planting season, (3) as binary variable equal to 1 if farmer *i* reports to have used organic fertilizer in the last planting season, and (4) as binary variable

equal to 1 if farmer *i* reports to have used fermented manure in the last planting season.

The variables $OwnOpinion$ and $TalkingPerceptions$ are constructed as explained in Section 3.1. $\boldsymbol{X}_i$ contains individual-level control variables (age, gender, education, marital status, household size, assets). It also includes farmers' treatment status in the original training interventions (i.e., whether farmers were invited to a training on organic farming or soil health management). μ_i is the village-level clustered error term.

Table 2 displays the results for each of the four outcome variables. Column (1) shows that farmers' own beliefs about the greenness-yield relationship significantly correlate with how much a potential change in leaf greenness influences their stated willingness to adopt a new farming practice. Farmers who reported "there is no strong relationship between greenness and yield" or "inverted U-shape relationship" indicated they would be less influenced by a potential lower greenness level and, therefore, more willing to experiment with a new practice described as better for soil health but potentially reducing plants' greenness level. In contrast, there is no significant correlation between second-order perceptions about talking and influence by greenness on farmers' (stated) willingness to adopt a new practice.

Column (2) displays the relationship between farmers' own beliefs about the greenness-yield relationship and their actual nitrogen fertilizer application. Since nitrogen fertilizer application closely correlates with plants' greenness levels, we expected that farmers who believe "the greener, the higher the yields" would apply higher quantities of nitrogen fertilizer compared to those who do not hold this belief. This is confirmed in the analysis. Our regression results show that farmers who answered "there is no strong relationship between greenness and yields" apply 22 kg/ha less nitrogen than those who reported "the greener, the higher the yields". Farmers who reported "there is an inverted U-shaped relationship" apply about 10 kg/ha less nitrogen than those who answered "the greener,

the higher the yields". Similar to the stated adoption decision, we observe no significant correlation between second-order perceptions about talking and actual nitrogen application. While the coefficient for those stating "yes, there is talking" is positive and hence in line with the expectation that perceived talking increases nitrogen fertilizer application, the effect is small (1.39 kg/ha) and very imprecisely measured.

Table 2: Correlation between own opinion, second-order talking perceptions, and fertilizer input behavior

	(1)	(2)	(3)	(4)
	Influence of changes in greenness levels on adoption decision (1 low, 10 high)[a]	Nitrogen application (kg/ha)	Organic fertilizer usage last season (=1)	Manure usage last season (=1)
Own Perception/Knowledge				
Reference: The greener, the higher the yields				
No strong relationship	-1.171***	-22.267***	0.045	0.065*
	(0.213)	(6.181)	(0.035)	(0.037)
Inverted U-shape	-1.068***	-9.564**	0.069***	0.061**
	(0.168)	(4.315)	(0.025)	(0.026)
Talking perception				
Reference: No				
Yes, by some	0.314	10.425	0.013	-0.013
	(0.349)	(9.485)	(0.047)	(0.060)
Yes	0.186	1.394	0.056*	-0.016
	(0.170)	(5.374)	(0.031)	(0.034)
Observations	2,021	1,914	1,985	1,985
R-squared	0.045	0.047	0.058	0.047
Controls	Yes	Yes	Yes	Yes
Survey fixed-effects	Yes	Yes	Yes	Yes
Control mean	4.76	146.29	0.38	0.42

Notes: [a] The variable "greenness influence" is constructed from the question: "There is a new farming practice that is thought to be better for soil health but might make your rice crops less green. Would the potential change in the greenness of your crops influence your decision to try this practice?". Answers were measured on a scale from 1 to 10, with 1 corresponding to "No, not at all" and 10 corresponding to "Yes, definitely". Hence, the higher the value of this variable, the more are individuals influenced by greenness levels in their choice of fertilizer inputs. Robust standard errors are clustered at the village level and shown in parentheses. All regressions control for individual characteristics (age, gender, education, marital status, household size, assets), treatment status in the training interventions and survey fixed-effects. *** p<0.01, ** p<0.05, * p<0.1.

Columns (3) and (4) show similar results for organic fertilizer usage and manure usage in the last agricultural season. Farmers who reported "there is an inverted U-shaped relationship" are 6.9 percentage points more likely to have used organic fertilizer and 6.1

percentage points more likely to have applied manure in the last season compared to those stating “the greener, the higher the yields”. However, we again observe no significant correlation between second-order perceptions about talking and organic fertilizer and manure usage – if at all, there is a counterintuitive, marginally significant positive correlation between perceived talking and organic fertilizer application. These results are similar when including own opinion and talking perceptions separately in the regressions, as shown in Table A1 in the Appendix.

We further explore whether other people’s perceived opinions about greenness and talking influence fertilizer input decisions in our qualitative interviews. When asked directly, many SSI respondents and FGD participants stated they are not influenced by others’ opinions or comments about plant greenness. One SSI respondent, who primarily uses organic fertilizer with minimal chemical inputs, noted that while the plants in his mostly organic fields are slightly lighter in color, comments from other farmers do not concern him. He recounted that some farmers have said, “*If you rely only on organic fertilizer, like goat manure, it’s not very stable – try ours, the green is great.”* However, for him, the important factor is the harvest quantity, not the color of the plants. Participants in two FGDs highlighted the awareness they gained through a government training program, explaining that before the training, they chased greenness and received praise if their fields were dark green.

Some respondents and FGD participants acknowledged that discussions among farmers do influence their practices to some extent. In one FGD, participants noted that less-green fields often receive comments, prompting a discussion on strategies to achieve darker greenness levels. One SSI respondent, who believed the greener the plants, the higher the yields, noted that he adjusts his fertilizer based on conversations with other farmers. He described these interactions as collaborative discussions where farmers jointly identify

and address issues, thereby supporting each other.

Regarding the influence of community opinions on other farmers, respondents provided diverse answers. Some were unsure, some stated they believe others are also not influenced and some explained that others are influenced. One SSI respondent noted that some farmers prioritize achieving high greenness levels and disregard the advice of other farmers or extension workers, indicating indifference to the opinions of those who believe they use excessive fertilizer. Conversely, another respondent explained that some farmers use excessive urea because they believe greener plants lead to better yields, but they are also influenced by comments on the greenness of their plots. He stated, "*Sometimes people say, 'Oh, why are your plants not green?' So they [the other farmers] fertilize them again."* Another SSI respondent who stated he is not concerned about comments on his plants' greenness, explained that sharecroppers often use more urea, because they worry about the owners' opinions on field appearance.

Survey experiment

While the results presented above are descriptive, our survey experiment aimed to introduce some exogenous variation in exposure to potential negative talking to provide causal evidence on its effect on adoption decisions. We varied the order of the questions related to greenness and talking to make potential talking consequences more salient to the treatment group. We then analyzed whether this influenced respondents' answers to the question of how much a change in plant greenness affects their decision to adopt a new farming practice that would improve soil health but potentially reduce greenness levels. The results in Table 3 suggest that our treatment (i.e., randomizing the question order and making potential gossip more salient) did not significantly affect farmers' reported influence by greenness level changes. This aligns with the previous results,

indicating that although (negative) talking about greenness levels is present in our study context, it does not lead to farmers adjusting their actual farming input behavior.

Table 3: Results of the survey experiment

	(1)	(2)	(3)
	Influence of changes in greenness levels on adoption decision (1 low, 10 high)[a]	Influence of changes in greenness levels on adoption decision (1 low, 10 high)	Influence of changes in greenness levels on adoption decision (1 low, 10 high)
Treatment	0.006	0.020	0.018
	(0.134)	(0.132)	(0.131)
Observations	2,024	2,024	2,024
R-squared	0.000	0.160	0.162
Village fixed-effects	No	Yes	Yes
Controls	No	No	Yes
Control mean	4.76	4.76	4.76

Notes: [a] The variable "greenness influence" is constructed from the question: "There is a new farming practice that is thought to be better for soil health but might make your rice crops less green. Would the potential change in the greenness of your crops influence your decision to try this practice?". Answers were measured on a scale from 1 to 10, with 1 corresponding to "No, not at all" and 10 corresponding to "Yes, definitely". Hence, the higher the value of this variable, the more are individuals influenced by greenness levels in their choice of fertilizer inputs. Robust standard errors are clustered at the village level and presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Another reason why we might not capture significant effects in our survey experiment is the little variation in the variable of perceived talking. Our data show that almost all respondents (80%) believe there is talking about greenness. Therefore, varying whether individuals received this question before or after the question about influence from greenness might not have led to any measurable differences. Making this simply more salient does not seem to introduce further changes in respondents' stated influence levels.

5.3 How are perceptions about greenness levels interrelated within farmer networks and how do perceived peer pressure effects compare with the effects of observed adoption decisions?

We are further interested in how greenness perceptions are interrelated within farmers' geographical networks (i.e., farmers with neighboring plots within villages). Since our

previous results indicate that perceptions of talking do not seem to drive input decisions, we analyze whether observable fertilizer input decisions of plot-neighbor network members are more strongly correlated with one's own input decisions. For this assessment, we rely on the network data collected for Sample 1, which builds on neighboring plots, i.e., farmers who cultivate neighboring plots[4] are assumed to be part of the same network. We base the definition of a plot neighbor network on the assumption that input decisions on neighboring plots are easily observable. For each village, we can then construct the network of neighboring plots, exemplified in Figure 7. In this Figure, circles represent different "nodes" (farmers) within one village. The lines indicate that the connected farmers have neighboring rice fields. Unconnected farmers have remote fields and have no neighboring fields with other framers.

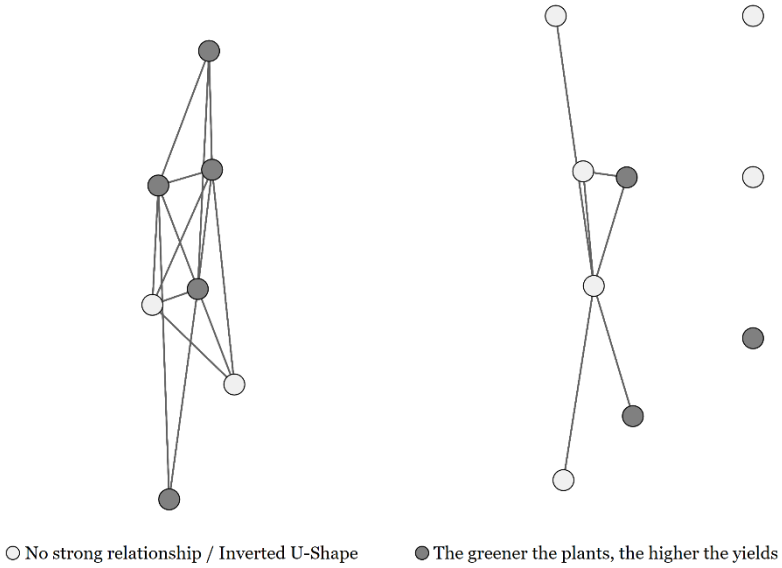

Figure 7: Networks of neighboring rice fields. *Notes:* Circles represent different "nodes" (farmers) within one village. The lines indicate that the connected farmers have neighboring rice fields. Unconnected farmers have remote fields/ have no neighboring fields with other framers. Dark grey nodes represent farmers who believe "the greener the plants, the higher the yields", light green nodes represent farmers that do not share this belief.

[4] Whether farmers cultivate neighboring plots was defined based on respondents' self-report, i.e. we did not map the rice fields in the villages. This is also because "neighbors" do not necessarily need to share a direct plot border, but also fields that are close by one's own plot and are passed by regularly can be perceived as "neighboring".

Based on this network data, we construct a dyadic dataset and estimate whether farmers cultivating neighboring plots are more likely to share the same opinion about the relationship between greenness and yields, share the same second-order talking perceptions, and whether both apply organic farming techniques. Specifically, this approach measures the probability that two neighboring farmers share the same opinion or both apply organic farming practices compared to two randomly chosen farmers in the same village who do not cultivate neighboring plots. The dyadic regression equation reads as follows

$$Y_{ij} = \theta + \vartheta Neighbor_{ij} + \rho(X_i - Z_j) + \epsilon_{ij} \quad (2)$$

where the outcome Y_{ij} is a binary variable equal to one if farmers *i* and *j* (1) share the same opinion about the relationship between greenness and yields, (2) share the same second-order perception about talking about greenness[5], (3) both have used organic fertilizer, or (4) both have used manure in the last harvesting season. $Neighbor_{ij}$ is a binary variable equal to one if farmers *i* and j cultivate neighboring plots[6], X_i and Z_j are farmers' *i* and *j* individual characteristics (i.e., we control for differences in age, gender and education of the two individuals), respectively, and ϵ_{ij} is the error term clustered at the dyad level.

The results of this analysis are presented in Table 4. We do not find any significant correlation between cultivating neighboring plots and sharing the same opinion about the relationship between greenness and yields (Column (1)). However, we do find that second-

[5] For both opinion variables, we limit the definition of "same opinion" to the extreme values, since in both cases only very few farmers chose the middle option. This means for the own opinion about the relationship between greenness and yields we assign the value 1 to a dyad if both farmers either respond "the greener the leaves, the higher the yields" or both farmers responded "Inverted U-shape". Similarly, for the second-order talking perception we assign the value 1 to a dyad if both farmers either respond "yes, this is perceived as sign of low quality and leads to talking" or both farmers respond "no, there is no talking".

[6] In the main analysis, we define $Neighbor_{ij}$ as equal to 1 if either farmer *i* or farmer *j* reported that they cultivate neighboring fields. In a robustness analysis in Table A2 in the Appendix, we repeat the analysis with $Neighbor_{ij}$ only being equal to 1 if both farmers report to cultivate neighboring fields. For the latter case, only the observable adoption decisions of applying organic fertilizer remains statistically significant.

order talking perceptions are correlated within networks (Column (2)). Specifically, two farmers within a village who cultivate neighboring plots are 2.2 percentage points more likely to share the same talking perceptions compared to two farmers who do not cultivate neighboring plots. This indicates that while talking perceptions seem to be a social construct within networks, opinions about how greenness levels relate to yields are rather individualistic and not necessarily identical within networks. Together with the finding that individual opinions significantly correlate with actual fertilizer input decisions, but talking perceptions do not, this suggest that talking about greenness is rather a socially relevant activity, but does not influence practical individual decisions.

Table 4: Correlation of opinions, second-order perceptions and adoption within networks

	(1) Same opinion about relationship greenness and yields (=1)	(2) Same perception about second-order talking (=1)	(3) Both applied organic fertilizer (=1)	(4) Both applied organic manure (=1)
Farmers have neighboring fields (=1)	0.016	0.022**	0.027***	0.021**
	(0.012)	(0.010)	(0.009)	(0.010)
Observations	14,444	14,444	14,444	14,444
R-squared	0.090	0.162	0.214	0.269
Mean	41.90%	72.10%	17.50%	29.10%
Village fixed-effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Notes: The variable *Neighboring fields* takes the value 1 if either farmer *i* or *j* of a dyad reports to cultivate neighboring fields. Robust standard errors are clustered at the dyad level and presented in parentheses. All regressions control for differences in age, gender and education of the two farmers. *** p<0.01, ** p<0.05, * p<0.1

Yet, we find that observed adoption decisions are replicated within networks. The probability that two plot neighbors have both applied organic fertilizer or manure in the last season is significantly higher by 2.7 and 2.1 percentage points, respectively, compared to

the probability that two farmers without neighboring plots both applied it.[7] In relative terms, this correlation is larger than the correlation of similar second-order talking perceptions.

To compare the role of observed fertilizer decisions with network opinions, we additionally regress fertilizer input decisions (nitrogen application levels, organic fertilizer application and manure application) and "greenness influence" on the number of network members that use organic fertilizer and on the number of network members who believe "the greener the leaves, the higher the yields". The latter indicates the network's preferences regarding greenness and may thus serve as a proxy for potential peer pressure. If peer pressure exists within networks where members prefer dark green leaves, we would expect to see a positive correlation with the "greenness influence" and nitrogen application.

The results presented in Table 5 confirm that observed adoption decisions seem to be more important than potential peer pressure. While we find that the influence by greenness levels on (stated) adoption willingness is influenced by both observed adoption decisions as well as the network's greenness preference (Columns (1) and (2)), for actual organic fertilizer application, only observed adoption decisions matter. Specifically, each member within a network that uses organic fertilizer increases one's own probability of applying organic fertilizer by 7.9 percentage points (Column (4)). In contrast, it does not matter how many network members state "the greener the leaves, the higher the yields" for one's own organic fertilizer adoption (Column (5)). Similarly, the higher the average nitrogen application within one's network, the higher is one's own nitrogen application (Column (9)), but again, it is not significantly correlated to the number of network members saying "the greener, the higher the yields" (Column (8)).

[7] The concern that potential negative spillovers from neighbors' chemical fertilizer explain this effect (i.e., neighbors use only organic fertilizer if they don't risk that their neighbors' chemical fertilizer spoil their fields) should not apply in our context, since farmers never apply 100% organic inputs in our sample, but always mix it with chemical inputs.

Table 5: Network effects on influence by greenness on (stated) adoption and fertilizer inputs

	(1) Influence of changes in greenness levels on adoption decision (1 low, 10 high)[a]	(2) Influence of changes in greenness levels on adoption decision (1 low, 10 high)	(3) Influence of changes in greenness levels on adoption decision (1 low, 10 high)	(4) Organic fertilizer usage (=1)	(5) Organic fertilizer usage (=1)	(6) Organic fertilizer usage (=1)	(7) Nitrogen application (kg/ha)	(8) Nitrogen application (kg/ha)	(9) Nitrogen application (kg/ha)
# of NW members using organic fertilizer	-0.235*			0.079***			-0.993		
	(0.138)			(0.021)			(4.338)		
# of NW members saying "the greener, the higher the yields"		0.570***			0.028			-5.298	
		(0.132)			(0.020)			(4.253)	
Average nitrogen kg/ha among NW members			-0.002			-0.000			0.318***
			(0.002)			(0.000)			(0.076)
Observations	946	946	720	946	946	720	875	875	680
R-squared	0.030	0.046	0.048	0.107	0.092	0.094	0.052	0.054	0.113
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: [a] The variable "greenness influence" is constructed from the question: "There is a new farming practice that is thought to be better for soil health but might make your rice crops less green. Would the potential change in the greenness of your crops influence your decision to try this practice?". Answers were measured on a scale from 1 to 10, with 1 corresponding to "No, not at all" and 10 corresponding to "Yes, definitely". Hence, the higher the value of this variable, the more are individuals influenced by greenness levels in their choice of fertilizer inputs. NW means network. The sample size varies when average nitrogen in kg/ha among network members is used as explanatory variable, since this variable cannot be calculated for farmers with 0 network members. Similarly, the sample size is smaller when Nitrogen application (kg/ha) is used as outcome variable, since some farmers don't cultivate rice plots (only other vegetables) and the amount was averaged only over rice plots. Robust standard errors are clustered at the village level and presented in parentheses. All regressions control for individual characteristics (age, gender, education, marital status, household size, assets) and treatment status in the training intervention. *** p<0.01, ** p<0.05, * p<0.1.

6. Discussion and Conclusion

Our study aimed to advance the existing research on social networks in agriculture by investigating how individual farmers' opinions and second-order perceptions about the greenness of rice plants influence their stated willingness to adopt and the actual adoption of sustainable farming practices, specifically fertilizer application. Both the quantitative and qualitative data revealed that the greenness level of rice plants is a prevalent topic among Indonesian smallholder farmers, with many associating less green plants with poor farm management skills.

We built our conceptual framework on the assumption that a farmer's desired fertilizer input level and actual input decisions are influenced by their individual opinions, prevailing social norms, and their perceptions of these norms. This aligns with previous research on farmers' perceptions and input adoption decisions (Läpple and Kelley, 2013; Mzoughi, 2011; Wollni and Andersson, 2014). However, our regression estimates only partly support this framework, showing that it is primarily one's own opinion that matters for fertilizer input decisions, whereas second-order perceptions play a limited role. Specifically, our results indicate that farmers who personally associate darker plant greenness with higher productivity are less willing to adopt a (hypothetical) sustainable farming technique that may reduce plant greenness. This belief is also reflected in lower actual adoption of sustainable inputs (such as less organic fertilizer and manure and more nitrogen fertilizer), highlighting the significant impact of personal opinions on input decisions.

Contrary to our conceptual framework, the regression results show that second-order perceptions – farmers' beliefs about what others think – do not significantly affect their stated willingness or actual adoption of sustainable farming inputs. Our survey experiment supports this finding, demonstrating that emphasizing the topic of "perceived talking" does not alter farmers' willingness to adopt practices that might reduce plant greenness. This result

diverges from Wollni and Andersson (2014), who found that second-order perceptions significantly influence farming input adoption decisions.

Our in-depth interviews and FGDs provide further insights, revealing that “talking” about greenness levels can be perceived both positively and negatively by farmers. This dual perception likely contributes to the lack of a statistically significant relationship between second-order perceptions and both stated willingness and actual input decisions. Additionally, the lack of variation in the measurement of the second-order perception variable could explain the precision issues in our estimates (Agresti, 2012). This highlights the need for further research into the measurement of social norms, perceived peer pressure and second-order perceptions.

Our social network analysis reveals that the observed adoption decisions of other network members are strongly related to farmers’ individual adoption decisions and their stated willingness to adopt new farming practices. This aligns with Wang et al. (2023), who combined spatial proximity with farmers’ tendency to consult peers and found that farmers’ willingness to adopt a pesticide-free wheat production program increases as peer adoption rises. However, our results indicate no significant relationship between neighboring farmers’ opinions about greenness and individual farmers’ actual input decisions. This suggests that while farmers consider the actions of their neighbors, the opinions of their neighbors do not substantially influence their input decisions. As indicated in our conceptual framework, another reason why actual input decisions are strongly related to those of other network members is that these farmers are likely subject to the same external influences, particularly advice from extension workers and farmer groups, as well as availability and access to (subsidized) fertilizer.

In summary, the green color of rice plants is a significant factor in the agricultural decision-making process among Indonesian smallholder farmers. While personal opinions about

greenness are strongly correlated with adoption decisions, second-order perceptions do not show a similar correlation. Leveraging peer networks by encouraging early adopters to share their experiences could, hence, create a positive feedback loop, fostering broader adoption. A nuanced understanding of the role of social networks and perceptions in the adoption of sustainable farming practices can inform the development of more effective agricultural policies and programs, ultimately leading to more sustainable and productive farming systems. Further research to explore these dynamics in greater detail will provide deeper insights and more robust evidence to guide policy interventions aimed at promoting sustainable agriculture.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGTP in order to shorten the manuscript and to improve the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Appendix: Additional tables and figures

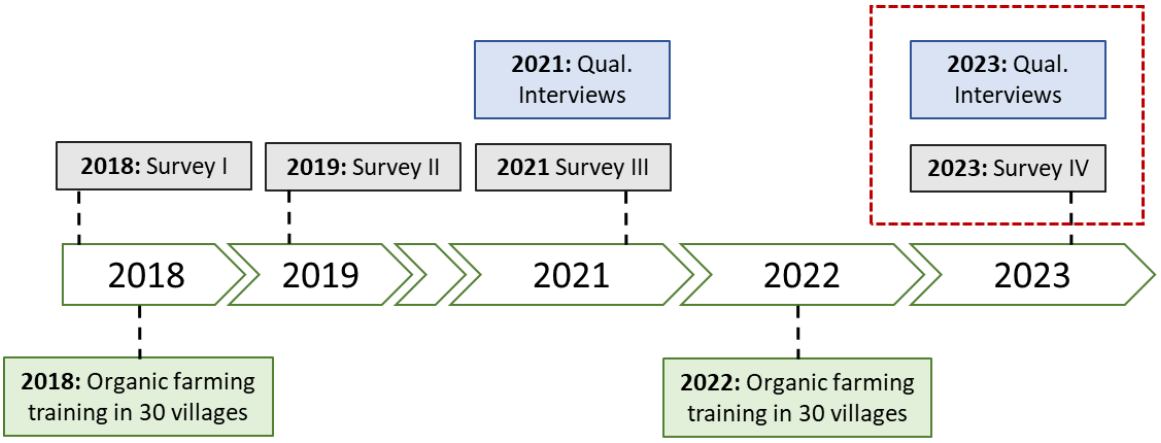

Figure A1: Overview of the original organic farming training study *([Reference anonymized]).* *Notes:* Data collected in household survey 4 and in the qualitative interviews in 2023 are used in this study and referred to as "Sample 1".

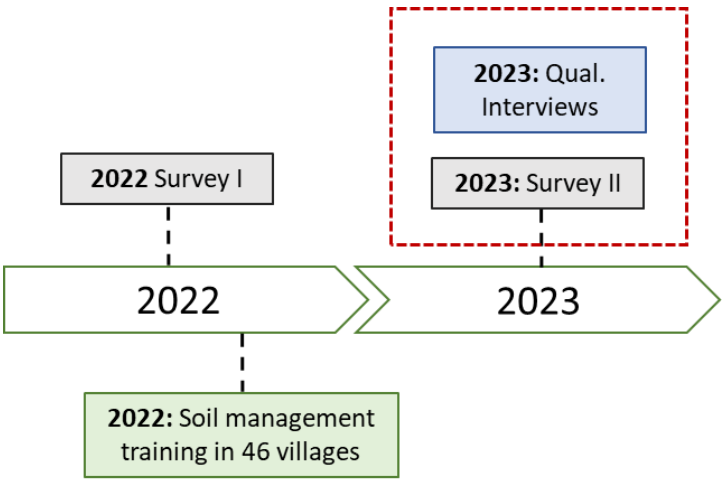

Figure A2: Overview of the soil-health management training study. *Notes:* Data collected in household survey 2 and in the qualitative interviews in 2023 are used in this study and referred to as "Sample 2".

Table A1: Correlation between own opinion, second-order talking perceptions, and fertilizer input behavior – Separate regressions

	(1) Influence from greenness level (1 low, 10 high)[a]	(2) Influence from greenness level (1 low, 10 high)	(3) Nitrogen application (kg/ha)	(4) Nitrogen application (kg/ha)	(5) Organic fertilizer usage last season (=1)	(6) Organic fertilizer usage last season (=1)	(7) Manure usage last season (=1)	(8) Manure usage last season (=1)
Own Perception/Knowledge								
Reference: The greener, the higher the yields								
No strong relationship	-1.171***		-22.045***		0.043		0.065*	
	(0.212)		(6.177)		(0.035)		(0.037)	
Inverted U-shape	-1.063***		-9.246**		0.068***		0.061**	
	(0.166)		(4.277)		(0.025)		(0.026)	
Talking perception								
Reference: No								
Yes, by some		0.163		8.693		0.024		-0.003
		(0.359)		(9.373)		(0.046)		(0.060)
Yes		0.197		1.681		0.056*		-0.017
		(0.177)		(5.279)		(0.031)		(0.033)
Observations	2,021	2,021	1,914	1,914	1,985	1,985	1,985	1,985
R-squared	0.045	0.013	0.046	0.039	0.058	0.056	0.048	0.045
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control mean	4.76	4.76	152.8	152.8	0.38	0.38	0.42	0.42

Notes: [a] The variable "greenness influence" is constructed from the question: "There is a new farming practice that is thought to be better for soil health but might make your rice crops less green. Would the potential change in the greenness of your crops influence your decision to try this practice?". Answers were measured on a scale from 1 to 10, with 1 corresponding to "No, not at all" and 10 corresponding to "Yes, definitely". Hence, the higher the value of this variable, the more are individuals influenced by greenness levels in their choice of fertilizer inputs. NW means network. The sample is smaller when Nitrogen application (kg/ha) is used as outcome variable, since some farmers don't cultivate rice plots (only other vegetables) and the amount was averaged only over rice plots. Robust standard errors are clustered at the village level and shown in parentheses. All regressions control for individual characteristics (age, gender, education, marital status, household size, assets), treatment status in the training interventions and survey fixed-effects. *** p<0.01, ** p<0.05, * p<0.1.

Table A2: Correlation of opinions, perceptions and adoption within networks - Robustness

	(1) Same opinion about relationship greenness and yields (=1)	(2) Same perception about second-order talking (=1)	(3) Both applied organic fertilizer (=1)	(4) Both applied organic manure (=1)
Farmers have neighboring fields (=1)	0.010	0.024	0.039***	0.007
	(0.018)	(0.016)	(0.014)	(0.015)
Observations	14,444	14,444	14,444	14,444
R-squared	0.089	0.161	0.214	0.269
Mean	41.90%	72.10%	17.50%	29.10%
Village fixed-effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Notes: The variable *Neighboring fields* takes the value 1 if both farmers *i* and *j* of a dyad report to cultivate neighboring fields. Robust standard errors are clustered at the dyad level and presented in parentheses. All regressions control for differences in age, gender and education of the two farmers. *** p<0.01, ** p<0.05, * p<0.1.