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Do phone-based short message services improve the uptake of agri-met advice by farmers? A case study in Haryana, India

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ABSTRACT

Phone-based short message applications (also called SMS in common parlance) as a medium of sending agricultural information to farmers is considered important in the context of a developing country as it makes information accessible to a large number of farmers economically. However, the empirical evidence on the effect of agricultural information sent through SMS on varied farm outcomes is divided. Using a randomized control trial study design, the present study focuses on a particular agricultural information viz. agri-met advisories, and a particular channel of dissemination viz. SMS to understand the role of information and the medium of information in compliance with recommended information and improvement in farm outcomes. This paper asks two main questions: i) does provision of agri-met advisory via SMS lead to greater compliance with advisory recommendations by the farmers? and ii) Do farm outcomes such as yield differ for those who received the agri-met advisory via SMS?

The study is based on six districts in Haryana divided across three agro-climatic zones focusing on the wheat crop. The results showed positive and significant impact of SMS agri-met advisories on the farmers' compliance with advisory for the treatment group—particularly when the advisory was about agricultural cycles and processes with which they are familiar. However, for weather-related advisory, the results did not show a significant impact of SMS-based agri-met advice on the farmers' compliance, which was unexpected. The likely reasons for such a finding could be many—including unfamiliarity of the farmers with acting on weather advice, which suggests that future research is needed on factors affecting the uptake of SMS-based agri-met advice by farmers in developing country context.

1. Introduction

Climate variability is a significant source of fluctuations in crop yields and income streams for the agriculture-dependent rural households in India (Khan et al., 2009). About 80 per cent of rural agricultural households in India are subsistence (small and

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marginal) farmers (Dev, 2017). Weather shocks can have a severe impact on their income and exacerbate endemic poverty. Information about weather and climate is a vital input for efficient agricultural production (Stigter, 2011; Donovan, 2017; Cole and Fernando, 2016; Wood et al., 2014). Historically, the farmers mainly relied on the traditional knowledge passed down over generations to carry out various farm operations in tandem with the moderations in weather and climate (Roncoli et al., 2002; Zuma-Netshiukhwi et al., 2013). The knowledge and information from extension service was not imperative to beget expected yield from the nature. However, this scenario has changed with the rise of input-intensive modern agriculture, a decline in the use of traditional knowledge, and increasing variation in the weather and climatic conditions, limiting farmers' ability to respond to these changes with only traditional knowledge (Salite, 2019).

While there has been impressive technological development in generation and dissemination of weather and agrometeorological information, the challenge, however, lies in making information accessible to all the farmers, as small farmers still have limited access to information (FAO, 2019). In fact, farmers in general are still more reliant on their personal competence, experience and interaction with other farmers in the community (Nesheim et al., 2017). The agricultural extension system has limited reach even after decades of having been set up (Bachhav, 2012; Raghuprasad et al., 2016; Feder et al., 2010) and this calls for newer and more innovative methods which are also inclusive of wider dissemination of information.

Given the high penetration of mobile phones, the question that is of importance in the Indian and other developing countries context, where literacy levels are relatively low, is whether receiving information through SMS improves the decision-making of the farmers. The cost effectiveness of SMS, and its wider outreach theoretically, make it a more economically feasible mode of information dissemination rather than looking for a sophisticated and advanced technology which might be contextually impractical to use (Shiang-Yen et al., 2012). The evidence on this is contradictory in literature. Some studies did find that SMS advisories led to better farmer-level outcomes (Casaburi et al., 2014) and others find no impact of agriculture-related SMS on farmer-level outcomes (Camacho & Conover, 2010; Fafchamps & Minten, 2012).

The present study aims to shed further light on this by providing empirical evidence on the question whether weather and climate information sent to farmers through SMS makes a difference in their decision-making and farm-level outcomes. The particular SMS information that we studied are the agri-met advisories[1] sent by the India Meteorological Department (IMD) to the farmers via mass media (radio, print and TV), the internet, through extension service personnel, and through SMS on the farmers' mobile phones. The Agri-Met Field Unit (AMFU) located at Haryana Agricultural University, Hisar, has been putting together a database of farmers' mobile numbers in Haryana for disseminating SMS advisories, and claim to have a database of 150,000 farmers out of a total of about 1.1 million farmers in the state (personal communication with CCS Haryana Agricultural University). Advisories sent through SMS are expected to lead to a greater uptake. Therefore, the key research questions addressed by this study are:

Does provision of agri-met advisory via SMS lead to greater compliance with advisory recommendations by the farmers?
Does yield differ for those who received the agri-met advisory via SMS?

2. Background

There are multiple traditional as well as modern channels of information through which the farmers may obtain relevant information for their agriculture-related concerns, including climate information; however, efficacy of these channels vary. Extension services, for instance, are resource intensive (Aker, 2011), and have limited outreach, particularly for small and marginal farmers located in remote places. Extension workers appointed for extending agriculture services have shown to be biased in favour of progressive farmers, possibly because it is easier to reach them (Melkote, 1988). Sometimes, they have been seen to exhibit caste- or gender-based discrimination or exhibit, and often do not have resources for reaching large number of farmers (Bindlish and Evenson, 1997; Babu et al., 2012). Information from local input dealers may have legitimacy issues as the dealers may be providing information that serves vendors' interests over the farmers' (Aga, 2018). Yet many farmers—particularly small farmers—are still dependent on information provided by input vendors and progressive farmers (Birthal et al., 2015; Mittal, 2012).

The increasing penetration of mobile networks and phones, and steady evolution of the use of Information and Communications Technology (ICT) in extension services such as use of tele-centres, the internet, TV, radio broadcast, voice SMS, text SMS, videos and mobile applications are expected to play a promising role in making information widely available to farmers (Mittal, 2012). However, even these channels have their own peculiarities. Television and radio, which are traditional ICT channels, may have broader penetration but the broadcasting schedules of agricultural information may still restrict access to relevant information to the farmers (Benard et al., 2019). Smartphones may bring innovative ways of making specific information available to the farmers but the prerequisites—such as skills to operate and navigate smartphones and economic means to attain a working internet connection—may still exclude many resource-poor farmers from accessing information (Birthal et al., 2015). The more complex and comprehensive the information gets, the less likely it is that farmers will comprehend and follow the information (Shiang-Yen et al., 2012)—particularly in the context of developing countries like India, where a large proportion of farmers have low levels of formal education. The high penetration of mobile phones and the cost-effectiveness of SMS as a medium of information dissemination (Camacho & Conover, 2019)

[1] In June 2008, the India Meteorological Department, in collaboration with 130 Agri-Met Field Units, started providing agri-met advisories at the district level. The content of the advisories usually consists of concrete recommendations, for example, if it is going to rain in the next few days, then it would be good for the farmer to postpone the irrigation of his farmland. Thus, if the farmer would adhere to this recommendation, he may save irrigation costs and avoid potential damage that may arise if he irrigated while it is raining.

provide the flexibility to send information in different languages, offering a promising avenue to make information available to a large majority (Camacho & Conover, 2019; Shiang-Yen et al., 2012).

3. Empirical studies on provision of agriculture advice through SMS

Studies examining the role of information disseminated through SMS in improving farm outcomes broadly focus on two types of information: one is market- and price-related information, and the other is climate and weather information.

Studies that assessed the impact of provisioning of market and price information have *broadly* reported no significant impact on farm outcomes. Fafchamps & Minten (2012) studied 100 villages of Maharashtra through Randomized Control Trial (RCT) study design, wherein treated farmers got a one-year free subscription to private message service of Reuters Market Limited (RML). They found that even in the presence of market price fluctuations, provisioning of price information yielded no significant impact on net price, revenues and value added for the treated farmers compared to the control group farmers. Similarly, Camacho and Conover (2010) studied Colombian farmers and recorded no significant impact of SMS information related to crop prices on farm income or household expenditure of Colombian farmers. This finding was also consistent with their later study on the same sample of farmers (Camacho & Conover, 2019).

In case of weather and crop advisory information through SMS, we see contrasting findings. While Fafchamps & Minten (2012) found no systematic effect of SMS crop and weather advisories on farmers' behaviour and cultivation practices, Camacho and Conover (2010) found that weather information did contribute in reduction in crop losses in general, and also due to weather shocks. A later study by Camacho and Conover (2019), however, reported no significant reduction in crop losses attributed to the weather information. Casaburi et al. (2014) conducted a randomized evaluation study on Kenyan farmers to understand the impact of following proper timing of agricultural activities on productivity measured in terms of plot yield. Through the SMS, agricultural advice was provided to farmers about appropriate timing to perform agricultural tasks that need to be carried out. The study was conducted in two rounds; first in 2011–13, and second round in 2012–14, on two different samples. The authors found 8 per cent increment in the plot yield for treated farmers vis-à-vis control group farmers for the first round of intervention. However, they did not see significant increase in plot yield for the second round of intervention.

The contradictions in the findings of the above studies have several contextual explanations. Casaburi et al. (2014) reported that the impact of information was different for different set of farmers from the same region. This difference in the impact of information is not well understood, and is likely to be associated with the heterogeneity of the sample groups in these two rounds of intervention in terms of baseline yields, crop cycle, the harvest season and other farmer characteristics. In the study by Camacho and Conover (2010), Camacho and Conover (2019), the SMSs sent to the farmers provided information for three markets and eight typical crops grown in the region, and it could be possible that a farmer included in the study sample might not have grown those crops at all to derive any benefits. Similarly, the findings of Ali and Kumar (2011), though not based on SMS information but on broader set of ICT tools viz. ITC's e-Choupals, support that heterogeneity of different contexts can affect the impact of information and ICTs on desirable outcomes. Although they did find the impact of ITC's e-Choupal initiative on farm outcomes (better decision-making with respect to various agricultural practices), these results did not hold for the e-Choupal-user farmers who belonged to socially lower classes. This indicates that besides climatic factors, there are other factors—such as the socio-demographic characteristics of the users of information, level of income and size of landholding—that influence the farmers' decision-making ability. These factors were also suggested in Fafchamps and Minten (2012).

Another explanation for contradictory findings may lie in the way the farm outcome or the dependent variable(s) was conceptualized to assess the effect of information/SMS advisory in different studies. For instance, Camacho and Conover (2010), Camacho and Conover (2019) studied the effect of market information on farm income and household expenditure. These two farm outcome variables are not conspicuous, and the farmers in the developing world may purposefully underreport or not reveal the exact values because of economic and psychological reasons. For example, the farmers may exhibit such behaviour under the perception that this may help them benefit from schemes for the poor farmers. The outcome variables in the studies also include the crop losses avoided when weather information was provided to the farmers. Again, a farmer may simply be unable to actually measure the amount of losses that he/she incurred vis-à-vis in the past. Thus, these results need to be looked at very cautiously while reaching any conclusions.

4. Empirical studies on agri-met advisories (of India Meteorological Department) through SMS

Agri-met advisories are district-level (or in some cases sub-district) and crop-specific farm management information based on weather for various agricultural operations such as sowing, irrigation scheduling, fertilizers, weedicide and pesticide application, and harvesting (FAO, 2019). In the Indian context, generally, these advisories are issued weekly, and sometimes more frequently, providing updated weather information as per the local weather forecast and salient guidelines to orchestrate farming operations. Provisioning of information on various meteorological and weather parameters is recommended for farmers at every stage of crop production (Molua, 2002; Meera et al., 2004; Frisvold and Murugesan, 2013; Balaji and Craufurd, 2011) as weather forecast customized to the needs of the farmers and delivered timely as crop and location-specific agri-met advisories allow farmers to optimize the timings and decisions related to different agricultural operations such as sowing, irrigation, spraying, etc. and it would help farmers mitigate risks due to strong winds, frosts, droughts, pest attacks, etc., and hence improve their productivity (Donovan, 2017). It would also allow the farmers to exploit input-optimizing opportunities such as scheduling irrigation, and spraying of weedicides and pesticides efficiently around rain while avoiding windy days (George et al., 2011; Das, 2012).

Molua (2002) and Deressa et al. (2009) argue that the extension of agri-meteorological forecasts and advisories through SMS may reduce the information search costs to farmers. Maini and Rathore (2011), Jagadeesha et al., (2010), Vashisth et al. (2013), Saxena et al., (2015) found that use of agri-met advisory services (AAS) led to improved crop management by the farmers, and resulted in reduced input cost and increased yield and net profits compared to non-AAS farmers. However, most of these studies examine correlations between provision of agri-met advice and change in farm outcomes. We attempt to establish a causal relationship between the two by conducting an experiment using the methodology of RCTs. We primarily focus on a particular type of information and a particular medium of information dissemination, i.e. impact of *agri-met advisory* sent through *SMS* on the farmers' scheduling of agricultural operations.

5. Methods

In this section we present the study area, study design, sampling techniques, variables of interest and methods of data analysis.

5.1. Study area

The current study was conducted in the state of Haryana, which is situated in the north-western Trans-Gangetic plain region of India (see Fig. 1). Haryana has a total of 21 districts, out of which six districts were chosen (see Fig. 1) such that these districts represent the three agro-climatic zones and soil conditions of the state[2]. In Ambala and Panchkula districts, the average annual rainfall is 890 mm and the soil type is mainly calcareous in the region. Palwal and Mewat mainly have semi-arid to dry sub-humid climate, and the average annual rainfall is 561 mm and the soil type is alluvial. Jind and Hisar are from scare rainfall region, and have arid and extreme arid climate, with the annual rainfall at only 360 mm and the soil types being calcareous, sierozemic, alluvial and desert.

With the beginning of green revolution in mid 1960s, the production of wheat along with rice have been the keystone of India's agriculture and food security policies. Haryana is a major wheat-growing state, with 13.3 per cent share in the national wheat production and an average of four tonnes per hectare of productivity level (ICAR, n.d. (a)). The net sown area in Haryana is 80 per cent of the total geographic area as compared to the national average of 46 per cent, and with a cropping intensity of 181 per cent (ICAR, n.d. (b)) and the gross cropped area of 65 lakh hectares (DACMTD, n.d.). The major crops grown in Haryana are paddy, wheat, millets, mustard and cotton in the more recent years (Ohlan, 2012).

5.2. Study design: experimental design, sampling and data collection

To causally establish whether an SMS based agri-met advisory improves the farmers' decision-making or not, we designed an RCT as depicted in Fig. 2. The unit of analysis is individual farmer. We conducted a multi-stage cluster sampling. In the six study districts, we identified a list of all the villages, using the Government of India census 2011 data. From this list, we excluded all the villages where Agri-Met Field Unit at CCS HAU was already sending SMS advisories. The list of remaining villages (our sampling frame) were where the SMS advisories were *not* being sent. We randomly selected 10 villages from this list of villages from each district. If the location of the randomly selected village on the district map was contiguous to another selected village, we dropped that village from the sample and chose another one until we got all the villages which were non-contiguous so as to minimize contamination of control group by the treatment group during the intervention year.

Next, we selected a sample of 10 farmers from each of the 60 villages. We asked the village sarpanch (village head) to introduce us to a set of farmers across all different land size categories to ensure a representative sample for the study[3]. In this way, we obtained our initial sample of 640[4] farmers for the study from 58 villages[5] across the six districts in the period between April 2016 and July 2016 through face-to-face interviews. The power calculations for our main dependent variables (see Table S8 in supplementary material) show that the 58 clusters with each cluster size of about 11 farmers and a total sample size of farmers was adequate to achieve a power of 0.8 (1 minus the probability of a Type II error) and alpha of 0.05 (the probability of a Type I error).

The initial contact with the farmers was made face-to-face by visiting their village between January and July 2016. They were explained the objective of the study and their consent was taken for participating in the study as well. Data was collected for two consecutive Rabi season for the wheat crop—October 2016 to April 2017 (baseline data) and October 2017 to April 2018 (post-intervention/endline data). The tool for data collection was a detailed and structured questionnaire which was tested in the field before actual collection of the data. Because of the nature of data to be collected, frequent interaction with the farmers was required, and conducting face-to-face interviews was not economically feasible for the study. Therefore, after the initial face-to-face contact with the farmers, the data was collected through telephonic interviews where each farmer was contacted for a minimum of four to five times during the entire wheat crop season between October to April. Each telephonic interview lasted for an average of 20–25 min, wherein each farmer was asked about the time of scheduling and cost of relevant agricultural operations such as land preparation, sowing,

[2] The decision about choice of district was taken in consultation with the Agri-Met Field Unit at Chaudhary Charan Singh Haryana Agriculture University (CCS HAU), Hisar.

[3] We initially planned to conduct stratified random sampling to select sample of farmers based on the list of farmers and their landholding size we obtained from the district administration. However, the sample of farmers from the list often did not match farmers found in the villages actually.

[4] In some villages, we had collected data from more than 10 farmers (11 or 12 farmers) as the sarpanch had invited the farmers for interviewing with us, and a few extra farmers would allow for sample size to not reduce too much after attrition.

[5] We could not go to two villages in the sample in the district of Panchkula because of severe rains there during the data collection period.

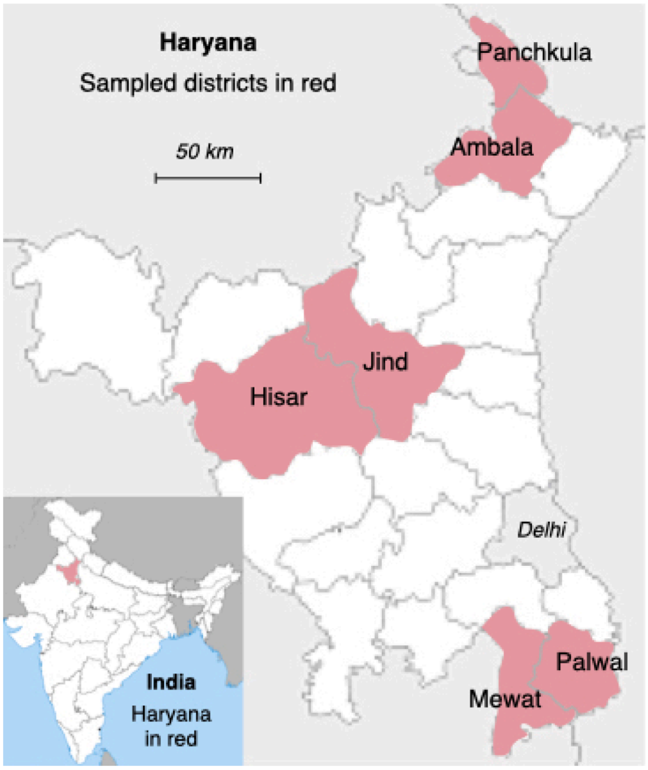

Fig. 1. Study area – study districts on map of Haryana.

irrigation, fertilizer application, and so on, at the time of calling.

For post-intervention data collection, the villages were allocated to the control group or the treatment group. The sample of farmers from each village would then be either treatment group of farmers or control group of farmers. A simple random allocation of villages to treatment and control groups may have led to some biases as all the villages were not exactly similar to each other in terms of size and demographics. Therefore, a matched pair of villages—i.e. two villages which are very similar to each other based on criteria such as the population of the village, total area, net sown area, number of literates, number of Scheduled Caste residents, number of farmers and agriculture labourers and total irrigated area—were identified (see supplementary material section A1 for a complete description of how matched pairs of villages were created). Out of the two matched villages, one was randomly assigned to a treatment group and other to the control group using the lottery method. Table 1 below presents whether the control and treatment groups were similar to each other in terms of demographic and other characteristics or not in the baseline year before the start of the intervention. The p-values for test of difference of means across control and treatment groups shows whether there is any significant differences in the farmer characteristics between the two groups viz. treatment and control group farmers.

In general, there is no statistically significant difference in farmer characteristics across the two groups. The mean average age of farmers in both the groups is approximately 45 years, having an average seven years of schooling. Farmers in both the groups on an average belong to the medium category of farmer owning approximately 5.5–6.2 acres of landholding and on an average cultivate 8.1–9.6 acres defined as operational landholding in this study. Similarly, nearly 75 per cent of the farmers in both the groups are primarily engaged in farming as primary occupation. Farmers across the two groups, however, differ in term of caste as the number of upper-caste farmers in the treatment group is 10 percentage point lower than the control group. About 27 per cent of the farmers do not receive any weather information at all.

5.3. The intervention

The intervention was the SMS-based agri-met advisory that was to be sent to the farmers in the treatment group (and not to the farmers in control group) by the Agri-Met Field unit located at CCS Haryana Agricultural University, Hisar, from October 2017 onwards[6]. Before the start of the intervention Rabi season (2017–18), phone numbers of the farmers in the treatment group were shared

[6] An MOU had been signed between CCS HAU, Hisar, and IIT Delhi to send SMSs to the treatment group of farmers for a period of the study. After the completion of data collection, the researchers at IIT Delhi enrolled all the farmers of the control group as well on the farmer portal of Haryana government so that they could start receiving the SMS agri-met advisories after the data collection for the intervention year was complete.

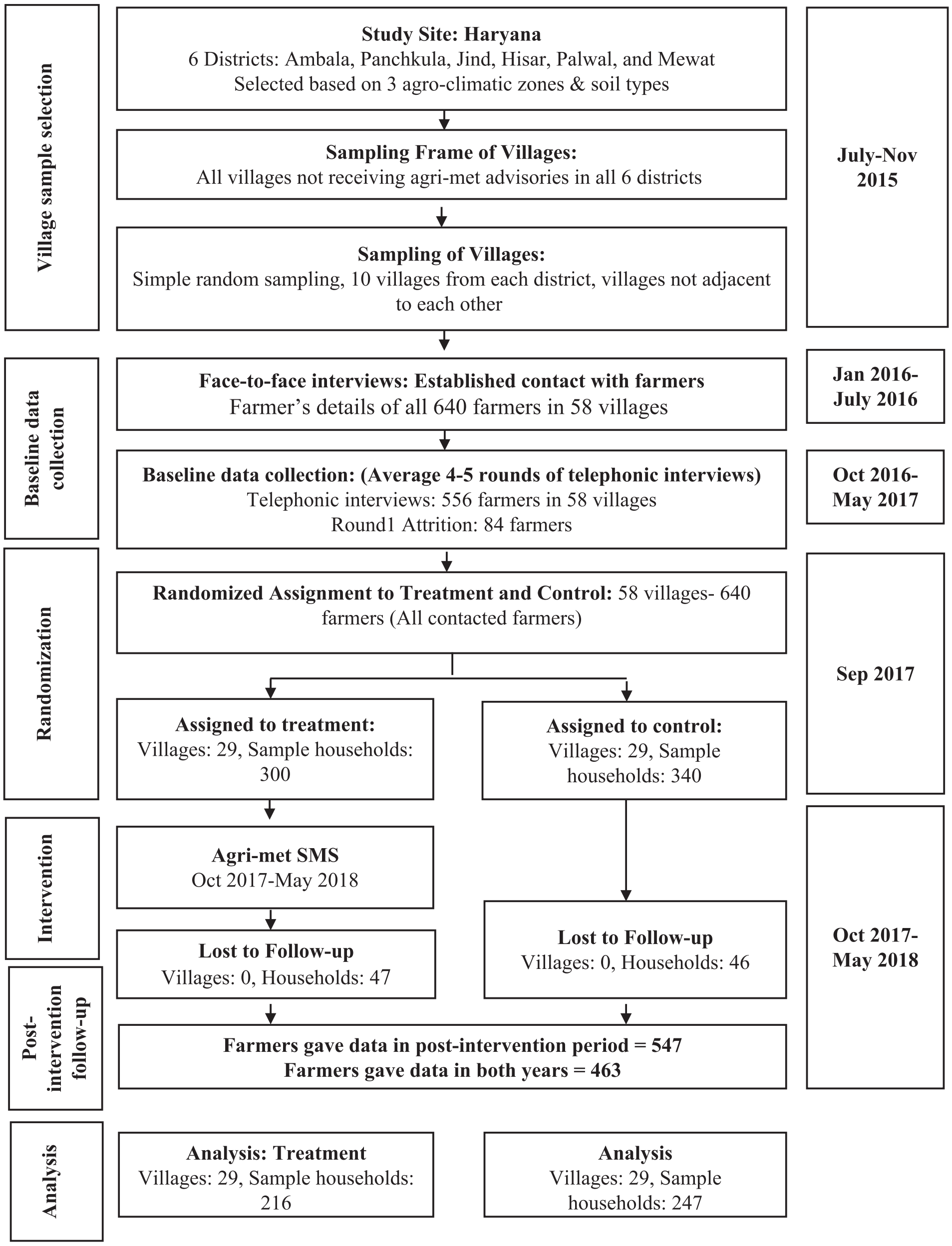

Fig. 2. Study Design.

with the Agri-met Field Unit at CCS HAU, Hisar. Table 2 presents some examples of the Agri-met advisories that were sent by CCS-HAU to farmers' mobile phones through SMS.

5.4. Description of variables

The crop advisory information once generated by Agri-met Field Unit is available to the farmers through various media such as television, radio, newspaper, extension agents, and the internet. Agri-met advisories are sent through mobile SMS to those farmers who have registered their mobile numbers for this service. This paper examines the causal relationship between the provision of SMS-based agri-met advisories to farmers on their mobile phones and the farmers' compliance with advisory for scheduling of different farming operations, specifically irrigation, fertilizers and weedicides application. Therefore, we are testing for efficacy of mobile SMS in increasing compliance of advisory by the farmers.

The scheduling of different operations is typically based on two criteria, i.e. Crop Growth Cycle (CGC) and the upcoming weather in the next few days. Each of these are discussed below. The dependent variable, i.e. the compliance of farmer with advisory

Table 1
Difference in Characteristics of Farmers in Treatment and Control Groups.

	Control (N = 247)	Treatment (N = 216)	Total (N = 463)	p value
Age in years				0.587
Mean (SD)	45.8 (12.6)	45.1 (13.5)	45.5 (13.1)	
Range	18–80	19–80	18–80	
Education in Years				0.900
Mean (SD)	7.6 (4.5)	7.71 (4.5)	7.68 (4.5)	
Range	0–17	0–17	0–17	
Area under operational landholding in acres				0.061
Mean (SD)	8.1 (8.1)	9.6 (9.3)	8.7 (8.7)	
Range	0.5–60	0.5–62.5	0.5–62.5	
Area owned by individual farmer in acres				0.196
Mean (SD)	5.5 (4.7)	6.2 (6.7)	5.8 (5.7)	
Range	0–30	0–55	0–55	
Engaged in more than 1 occupation				0.649
no	183 (74.1%)	164 (75.9%)	347(74.9%)	
yes	64 (25.9%)	52 (24.1%)	116 (25.1%)	
Caste				0.024
upper caste	109 (44.1%)	118 (54.6%)	227 (49.0%)	
other caste	138 (55.9%)	98 (45.4%)	236 (51.0%)	
Own a tractor				0.121
Yes	108 (43.7%)	110 (50.9%)	218 (47.1%)	
No	139 (56.3%)	106 (49.1%)	245 (52.9%)	
Weather information received through face-to-face channels				0.299
no	177 (71.7%)	164 (75.9%)	341 (73.7%)	
yes	70 (28.3%)	52 (24.1%)	122 (26.3%)	
Weather information received through mass media channels				0.710
no	141 (57.1%)	127 (58.8%)	268 (57.9%)	
yes	106 (42.9%)	89 (41.2%)	195 (42.1%)	
Weather information received through modern ICT channels				0.973
no	154 (62.3%)	135 (62.5%)	289 (62.4%)	
yes	93 (37.7%)	81 (37.5%)	174 (37.6%)	
Weather information received by farmer				0.96
no	66 (26.7%)	59 (27.3%)	125 (27%)	
yes	181 (73.3%)	157 (72.7%)	338 (73%)	

Table 2
Examples of Agri-meteorological Advisories.

Dates for which weather advisories were made available	Date of Circulation	Weather Warnings and Advisories Circulated by CCS Agriculture University, Haryana. #
14 and 15 Nov 2017	11 Nov 2017	Chances of weather change due to western disturbances starting 14th November. Light drizzling plausible at some places on 15th November. If possible, do not sow, or irrigate, or spray during this period.
6 Dec 2017	1 Dec 2017	Possibility of dry weather till 6th December. Must irrigate wheat at CRI (crown root initiation) stage which occurs 21 days after sowing as it is an important stage of irrigation.
11 to 13 Dec 2017	8 Dec 2017	Weather changeable from 10th December. Light to moderate rainfall during the 11 to 13 December. Postpone irrigation, spraying and sowing of late variety seeds of wheat.
11 to 13 Feb 2018	10 Feb 2018	On 11–13 February, due to western disturbances, possibility of light to moderate rainfall in some places. Temporarily postpone irrigation and spray in crops. Transfer the harvested fruits and vegetable to the market.

[#]Here, we present the translated version of the advisories send to the farmers of Haryana through SMS in Hindi by the CCS University.

recommendations, has many variants because we considered three operations viz. irrigation, fertilizer application and weedicide application, and two criteria discussed above on the basis of which advice is provided to the farmers. These are summarized in Table 2 (for greater detail on the formulation of these dependent variables (see Annexure 2 in supplementary material). Two other dependent variables considered are: 'Farmer's utilization of information about rainfall in advisory for irrigation' (as this would save on the economic cost of expending mechanical and human labour to extract scarce water resource) and 'Wheat yield (in quintals/acre)'. The main independent variable 'Treatment', and other independent variables which have mainly been used as controls are described and summarized in Table 3.

5.5. Hypotheses

A priori, we expect that the intervention (i.e. receiving agri-met advisory through SMS on phone) would lead to:

Table 3
Summary Statistics of Variables of Interest in the Study.

Variable name	Description of the variable	Descriptive statistics	
		2016–17 Frequency (percent) / Mean (SD) N = 463	*2017–18* Frequency (percent) / Mean (SD) N = 463
Treatment *(Main independent variable)*	*Treatment group*: SMS agri-met advisory sent to farmer	216 (46.7%)	216 (46.7%)
	Control group: SMS agri-met advisory not sent to farmer	247 (53.3%)	247 (53.3%)
Compliance with irrigation advice 1 based on Crop Growth Cycle *(Dependent variable)*	Difference (in days) between the actual date of irrigation and the due date of irrigation (calculated as 22 days after date of sowing) for a farmer	7.41 (8.29) NA = 2	9.46 (9.15) NA = 0
Compliance with irrigation advice 2 based on Crop Growth Cycle *(Dependent variable)*	Difference (in days) between the actual date of irrigation and the due date of irrigation (calculated as 45 days after date of sowing) for a farmer	13.07 (13.85) NA = 5	16.23 (13.69) NA = 5
Compliance with irrigation advice 3 based on Crop Growth Cycle *(Dependent variable)*	Difference (in days) between the actual date of irrigation and the due date of irrigation (calculated as 60 days after date of sowing) for a farmer	21.38 (17.88) NA = 43	22.28 (15.73) NA = 18
Compliance with fertilizer application advice based on Crop Growth Cycle *(Dependent variable)*	Difference (in days) between the actual date of urea application and the due date of urea application (calculated as midpoint of time window [−2, +5 days] from the date of irrigation) for a farmer	4.33 (9.257)	6.37 (10.179)
Compliance with weedicide application advice based on Crop Growth Cycle *(Dependent variable)*	Difference (in days) between the actual date of urea application and the due date of urea application (calculated as midpoint of time window 25 to 45 days after sowing viz. 30 days) for a farmer.	38.13 (25.712)	41.59 (24.202)
Compliance with Irrigation advice based on weather forecast *(Dependent variable)*	If the farmer did not comply with the advisory it was coded as ‘1’ and ‘0’ if the farmer complied, across 6 irrigations. A score of zero meant full compliance. Count of number of times a farmer did not comply is given below:	NA = 113	NA = 189
	0	84	64
	1	185	144
	2	66	44
	3	15	2
Compliance with Fertilizer advice based on weather forecast *(Dependent variable)*	Operationalization similar to above variable on irrigation	NA = 439	NA = 288
	Full compliance	18 (75%)	105 (60%)
	Non-compliance once or more	6 (25%)	70 (40%)
Compliance with Weedicide Application advice based on weather *(Dependent variable)*	Operationalization similar to above variable on irrigation	NA = 294	NA = 207
	Full compliance	142 (84.0%)	230 (89.8%)
	Non-compliance once or more	27 (16.0%)	26 (10.2%)
Whether Farmer utilized rain water for irrigation *(Dependent variable)*	Number of times a farmer reported using the forecast information on rainfall (received through the SMS agri-met advisory) to avoid irrigating his/her field		
	0	381	351
	1	77	79
	2	5	30
	3	0	2
	4	0	1
Wheat yield per acre *(Dependent variable)*	In quintals/acre	18.534 (3.209)	18.731 (3.531)
Agro climatic zones (ACZ) *(Control variable)*	Ambala-Panchkula	131 (28.3%)	131 (28.3%)
	Jind-Hisar	167 (36.1%)	167 (36.1%)
	Palwal-Mewat	165 (35.6%)	165 (35.6%)

a. Greater compliance by farmers with respect to advisories related to irrigation, fertilizer application and weedicide application based on crop growth cycle.
b. Greater compliance by farmers with respect to advisories related to irrigation, fertilizer application and weedicide application based on weather forecast.
c. Greater utilization of advisory about rain forecast in utilizing rain water for irrigation and avoiding conventional means of irrigation.
d. Greater yield for farmers.

5.6. Methods of data analysis

In this study we test for the effect of the intervention (providing SMS based agri-met advisories to farmers) on farmers' compliance with the advisory using the Difference-in-Difference (DID) technique. DID allows us to see the effect of the intervention by comparing the outcome over time between the two groups, one that received treatment and the other which did not. The double differencing helps in removing the biases that may be measured in the outcome variable if only the post-intervention outcomes are compared.

Equation-1 below is a standard DID equation that is estimated to measure the treatment effect (β_3). In this equation, d is the outcome variable representing compliance by a farmer*; Trt* is the dummy variable for treatment taking value 1 if farmer belongs to treatment group and 0 otherwise, *Yr* is the dummy variable for year taking value 1 for intervention year and 0 for baseline year; β_3 is the DID estimate showing the effect of intervention obtained through the double difference; *X* is a vector of other covariates included in the model that could influence the outcome variable.

$$d = \alpha_0 + \beta_1 Trt + \beta_2 Yr + \beta_3 Trt^{*} Yr + \beta_4 X + \varepsilon \tag{1}$$

Depending on the nature of the dependent variable, we used different regression models.

The first set of dependent variables on compliance of the farmer with respect to irrigation advice, fertilizer and weedicide application based on crop growth cycle are continuous variables representing the absolute distance (in number of days) between the actual and scheduled dates of the operations. Wheat yield per acre is also a continuous variable. Therefore, we used the linear model (OLS) while doing the DID. Compliance of the farmer with respect to weather advisory is a binary variable representing whether the farmer has made a mistake or not complied with the advisories (coded as 1) or not. Also, the variable on whether a farmer utilized rain forecast to use rain water to substitute surface/ground water irrigation is also a binary variable. Therefore, we used linear probability model while doing the DID. Covariates are the two farmers characteristics that remained unbalanced post random allocation of villages to control and treatment groups—(i) caste, and (ii) operational land of the farmer at baseline. The agro-climatic zones have been used as control for the area fixed effect across all models. Further, yield is a function of various inputs that go into the crop. Therefore, we also include seed variety and timing of sowing, number of irrigations, fertilizer application and weedicide applications as covariates in our DID estimations on wheat yield per acre. To check for robustness of DID estimates we also conducted Inverse Probability Weighted Treatment Difference in Difference (IPWT DID) analysis and Intention to Treat (ITT) analysis. We have reported the results of IPWT DID and ITT analysis in supplementary materials (see Tables S9 and S10 respectively).

6. Results

For each outcome (dependent variable), Table 4 summarizes (i) the DID estimate, (ii) the unit in which it is measured, and (iii) the mean of the baseline (2016–17) data in control group. The DID (treatment effect) estimates are displayed in Figs. 2a, 2b and 2c. The Tables S2, S4, S6 and S7 in the supplementary materials provide the full estimation results for the DID models for sample size of n = 463. In the sample of 463, there were 51 control group farmers who received SMSs in either pre- or post-intervention time period. This happened as there was a time lag between the time the farmers were enrolled in the experiment (between April and July 2016) and the time for collecting baseline data, intervention and the endline data collection. In the meantime, some farmers enrolled for the SMS service on the government's m-kisan portal to receive agri-met advisories. To get a true estimate of the average treatment effect on the treated (ATT), we excluded these 51 farmers and conducted the DID analysis also for the sample of 412. The Tables S3, S5, S6 and S7 present the full estimation results for DID models for sample sizes n = 412. However, the results presented in this section are for the sample size of 463.

6.1. *Farmer's compliance with advisory based on crop-growth cycle*

Table 4 (panel A) and Fig. 2a shows a significant and positive[7] effect of SMS on the farmers' compliance with irrigation, fertilizer and weedicide application advisory based on crop growth cycle (CGC), except in the case of 1st irrigation advice, where the sign of the coefficient is as expected (i.e. the intervention reduced the difference between scheduled and actual date of irrigation by about two days), though it is not significant. This is probably because the first irrigation about 22 days after sowing is an extremely important one and the farmers in both treatment and control group do not deviate too much from the schedule with respect to this irrigation. In fact, Table 4 does show that the mean difference between the schedule and actual date of irrigation for the first irrigation after sowing is only about eight days, and is the smallest compared to other irrigations. For the rest, the intervention has reduced the mean difference between scheduled and actual date of second and third irrigation, from 15 days to 10 days and from 22 days to 16 days respectively. Similarly, for fertilizer application, the mean difference between the scheduled date of application and the actual date of application has been reduced from about 5.5 days to 3 days; and the mean difference between the scheduled date of weedicide application and the actual date of application has been reduced from about 40 days to 32 days. Similar results hold for sample size 412 (see Table S3 in supplementary materials).

6.2. *Farmer's compliance with advisory based on weather forecast*

Table 4 (panel B) and Fig. 2b show no significant impact of the SMS on the farmer's compliance with the agri-met advisory with respect to irrigation and weedicides application, and fertilizer application based on weather forecast. Results for N = 412 are presented in Table S5 in supplementary materials. To be noted from the mean value for control group of farmers in the baseline years is that for fertilizer application 67 per cent (1–0.23 = 0.67) of farmers in the control group and for weedicide application 85 per cent (1–0.15 = 0.85) farmers complied with the advisory of not applying fertilizers or weedicide to their crop in case of a rain forecast.

That means that even in the baseline year, the compliance with weather advisory is quite high. However, this is not true for irrigation where one notices that compliance with the weather advisory for not doing irrigation when rain is forecast is quite low at

[7] The coefficient of the DID is negative because lesser the distance between the scheduled and actual date of a particular operation, the better it is. The negative sign of the coefficient implies that the effect of intervention on treatment group is positive.

Table 4
Impact of SMS Advisory Intervention on the Farmer's Compliance with SMS Advisory, Utilization of Rain Forecast for Avoiding Irrigation and Yield.

Panel A	Compliance with SMS advisory based on Crop Growth Cycle (difference in days between scheduled and actual date of operation)				
Units	Irrigation-1 (Days)	Irrigation-2 (Days)	Irrigation-3 (Days)	Fertilizer (Days)	Weedicide (Days)
Effect of SMS advisories	−2.02	−5.04**	−7.94***	−2.57*	−8.41**
SE	1.36	2.04	2.25	1.43	3.78
Mean (control group baseline year)	7.37	12.28	19.98	4.04	35.86
Panel B	Compliance with SMS advisory based on weather forecast			Whether farmer utilized rain water for irrigation	
	Irrigation (Yes/No)	Fertilizer (Yes/No)	Weedicide (Yes/No)	(Yes/No)	
Effect of SMS advisories	0.06	−0.09	0.08	0.09**	
SE	0.07	0.17	0.06	0.04	
Mean (control group baseline year)	0.79	0.23	0.15	0.19	
Panel C Units	Wheat yield per acre (Quintals/acre)				
Effect of SMS advisories	0.19				
SE	0.37				
Mean (control group baseline year)	18.31				

Note: ***p < 0.01, **p < 0.05, *p < 0.1; SE reported are clustered SE; (N = 463).

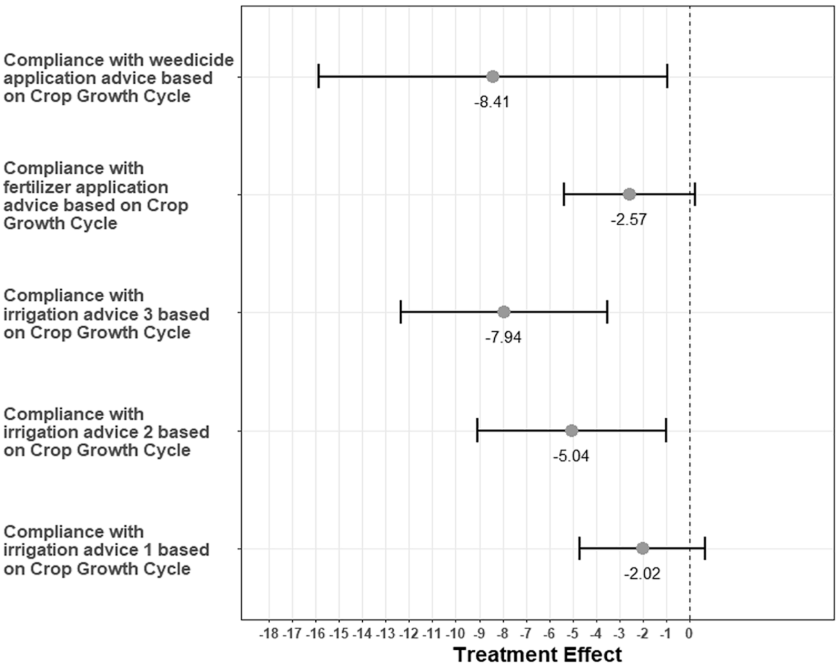

Fig. 2a. Impact of SMS agri-met advisories on farmers' compliance with crop growth cycle-based advisory.

only 21 per cent (1 − 0.79 = 0.21) in the control group of baseline year. The SMS-based agri-met advisory intervention did not significantly affect compliance to weather-based advisory by the farmers. The possible reasons for such unexpected results are discussed in section 4 on Discussion.

6.3. Farmer's utilization of rainfall forecast information in advisory for irrigation

Table 4 (panel B) and Fig. 2b also presents the results for the effect of SMS-based agri-met advisories on the number of times the farmer was able to substitute rainfall for ground/surface water irrigation. The results show that at 95 per cent confidence level, the SMS does increase the utilization of rainfall information in the weather forecast by 9 percentage points. See Table S6 in supplementary materials for N = 412, which has similar results.

6.4. Effect of SMS-based agri-met advisory on per-acre yield

Table 4 (panel C) and Fig. 2c shows that the SMS-based agri-met advisories intervention had no significant impact on the yield per-

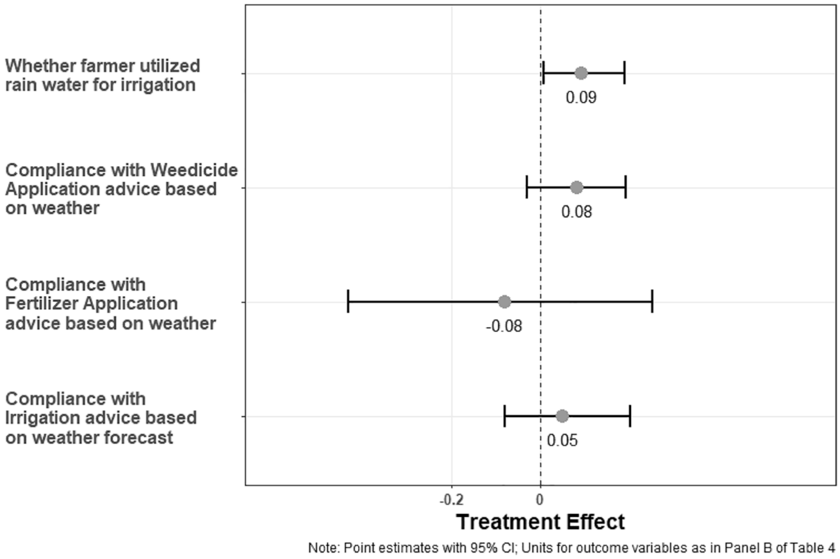

Fig. 2b. Impact of SMS agri-met advisories on farmers' compliance with weather-based advisory.

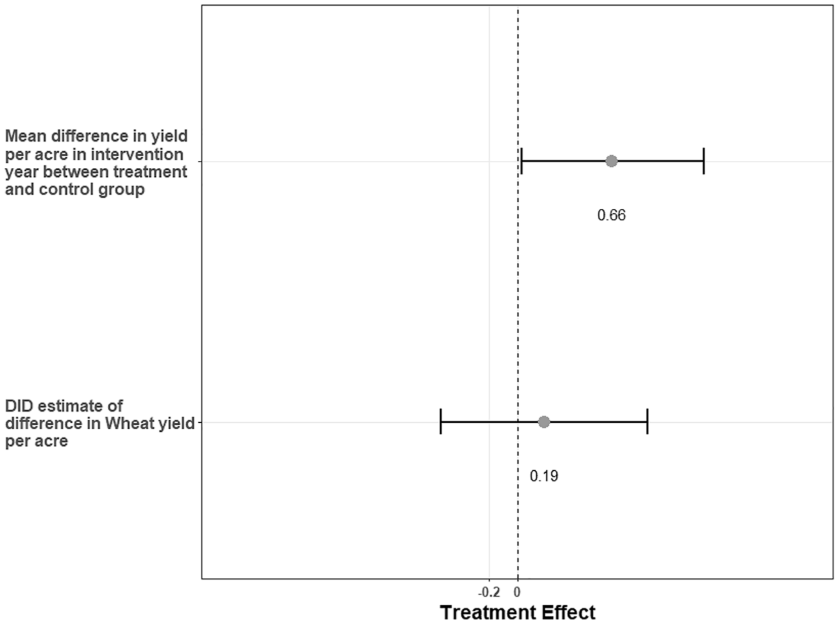

Fig. 2c. Impact of SMS agri-met advisories on the farmers' yield.

acre of the farmers even after accounting for other factors that could influence the crop yield by including them as controls in the model (see Table S7). However, also depicted in Fig. 2c are the mean differences between the yield of the treatment and control group in the endline year which is significantly different for both the groups. Similar results hold for N = 412, see Table S7 in supplementary materials, though for this sample the magnitude of the DID estimate increases 0.19 (for n = 463) to 0.35 (for n = 412) and the level of significance improves, though the effect is still insignificant.

7. Discussion

Agri-met advice is considered an important means to improve farm outcomes by aiding decision-making of the farmers about various operations (such as irrigation, sowing, fertilizer application and plant protection). While this information is potentially available through many channels—such as face-to-face contact with extension agents, friends and neighbours, mass media channels like radio, television and newspaper, and newer ICT tools such as the internet on mobile phones and computers—the reach of SMS is potentially likely to be highest, given the penetration of mobile phone in rural Haryana. Hence, it is important to examine whether an SMS agri-met advisory sent to a farmer's mobile phone helps the farmer make better decisions.

This paper attempts to examine whether agri-met advice sent through SMS on the mobile phone of the farmer leads to greater compliance by the farmers for that advice and better farm outcomes such as yields. To understand this, we studied compliance with respect to irrigation, fertilizer application and weedicide application advice provided to the wheat-growing farmers in six districts of Haryana. These three inputs are considered to be a major driver of variations in yields for wheat farmers, and the timing of these operations are critical in affecting yield. The compliance of the farmers with the advice was assessed for two kinds of advisories: one was on timing of an operation (irrigation or weedicide or fertilizer application) based on crop growth cycle, and the other was not doing a particular operation because of upcoming weather conditions. The third outcome assessed was the farmer's ability to take advantage of the rain forecast and avoid groundwater/surface water irrigation, thereby saving that cost. Lastly, we also looked at the per-acre yield to test whether it significantly differs for those who received SMS-based agri-met advice.

We find that the timing of all three operations for advice based on crop growth cycle improves for the treated farmers. The farmers irrigate their field closer to the date when it is scheduled, and also apply urea and weedicide closer to the scheduled dates for the treatment group. We find the significant effect of SMS advisories on the farmers' compliance with respect to crop growth cycle advice intriguing, as the farmers are usually well aware of maintaining these time intervals for different operations. Despite this fact, it is evident that SMS agri-met advisories improved the scheduling of agricultural operations—particularly irrigation and fertilizer application significantly for those who received agri-met advisories. Our finding resonates with the study by Maredia et al. (2018), where they find that for technologies that the farmers were already aware of, animated video shown on the mobile phone (the intervention in their study) was also as effective as live demonstration in inducing adoption. Similarly, the weekly push content delivered through voice messages to the farmers worked as a reminder to follow the information availed through calling services in the Cole and Fernando (2016) study. Likewise, the agri-met advisories turned out to be a reminder for the farmers that reinforced the importance of following the crop calendar while scheduling the agricultural operations. This indicates that nudging the farmers about following good practices that he/she already knows may render benefits over time.

However, the more surprising finding is with respect to the farmers' compliance with weather advisories. The SMS agri-met advisories had no significant effect on the farmers' compliance with weather advisories. We can think of two possible reasons behind these unexpected results. The first reason for such a finding could be the unfamiliarity of the farmers with the weather advisories about not doing an operation on certain dates as compared to the agri-met advisories related to scheduling of operations based on crop growth cycle. Most farmers are generally aware of the crop cycle, and most farmers in our sample had never received an SMS agri-met advice before the intervention.

A second possible reason could be related to the specificity of the advisory message. SMS advisories are not very specific about the amount or quantity of rainfall that is expected (see Table 2). The amount is mentioned in qualitative terms, such as light to moderate showers, for example. In the absence of information about how much rain to expect, a farmer may not comply with the advisory about not irrigating; he/she feels that the amount of rainfall that occurs may not be sufficient for their crop. In fact, comments by some farmers in our sample do corroborate this point. One of the farmers said, '…they were waiting for rain to occur after receiving the advisory, but when scanty rain occurred, they irrigated their fields as usual, as the crop needed water at the time.' Therefore, we find that for irrigation, the compliance with advisory about not to irrigate is relatively much lower. Also, since we have considered only those cases of compliance where irrigation was due for that farmer during the time-window when the advisory advised against irrigating, the insufficiency of rain makes the case of non-compliance (farmer irrigating despite the advice to not do so) more explainable. This is, perhaps, also the reason why we find a relatively less number of farmers being able to utilize that rainfall forecast to substitute groundwater or surface water irrigation.

A point to note is that compliance with agri-met advisory with respect to weedicide application and fertilizer application is rather high, as there are very few cases of non-compliance in the sample for both baseline and endline years (see Table 3). Since compliance is high even in the baseline year and irrespective of the treatment, it is another reason we do not see a very significant effect of SMS advisories that advice against application of weedicide and fertilizers in the event of rainfall. This means that when farmers learn that there may be rain in the near future (about which they could learn from channels other than SMS advisory, such as television), they do not apply weedicides or fertilizers. Most farmers understand that the weedicides applied would be simply washed off even if the rainfall is scanty. Weedicides are also expensive, and therefore, the farmers are cautious about losing them to a rain shower.

Despite the lack of specificity in the advisory, one significant impact of the SMS advisory observed in our dataset is that treated farmers are more likely to use information on rain forecast to take advantage of the same, and avoid irrigating their fields using groundwater through tube-wells, and sometimes canal water. The use of rainfall for irrigation reduces cost of irrigation per acre for the farmer, as both groundwater and surface water use incurs cost for the farmer. This cost of irrigation can be substantial, particularly when the groundwater has to be extracted using expensive diesel engine tube-wells or have to be purchased from another farmer.

The SMS agri-met advisories intervention did not have a significant effect on the yield of the farmers, though the coefficient of the DID estimate is positive for the sample size of 463 (see Table 4), and the sample size of 412 (see Table S7), inverse probability weighted (IPW) DID (see Table S9), and in the full sample of 640 in which we imputed missing values for Intention to Treat (ITT) analysis (see Table S10)—it is insignificant in all the four cases. If we simply consider the difference between treatment and control group yields in the endline year, we do find a significant difference between the yields (see Table S1). While the better scheduling of operations would ideally affect yields, the same is also affected by a number of other factors—all of which have probably not been captured here. In addition, while the SMS agri-met advisories have improved the scheduling of advisories, the scheduling in the treatment group is still far from perfect. Perhaps, a greater familiarity and use of advisories would improve scheduling further for the framers, and then the effect on yield may become more visible.

Overall, we find in this study that SMS can be effective in compliance by the farmers to agri-met advisories for many scheduling decisions, if not all. We also found while interviewing the farmers over the phone that the majority of the treated farmers did show a preference for receiving information through SMS. They said that they found it useful to receive the agri-met advisory over their phones. Fafchamps and Minten (2012) stated that even when no statistically significant benefits of the agricultural information emerge in their empirical study, those farmers who reported making changes in their practices did list RML SMSs as one of the drivers influencing their decision-making.

Some limitations of the study relate to the fact that the study is focussed only on the wheat crop, and not all the crops that the farmers grow. For the farmers who grow vegetables and fruits—which are usually even more weather-sensitive than the cereals—agri-met advisories sent through SMS on the farmers' mobile phone could be even more useful. A second limitation of this study is that it is located in the state of Haryana, where most farmers have access to some source of irrigation, whether surface or groundwater. Studying the impact of SMS agri-met advisories in case of states and areas that are dryland regions and not necessarily well-irrigated could reveal far greater usefulness of agri-met advisories, as rain-fed areas are likely to find weather forecasts and associated weather advice far more useful than irrigated areas. A third limitation of the study is that it assesses the uptake of SMS-based agri-met advisories by the farmers in only one season. This was the first time many of the farmers ever received an SMS agri-met advisory. Repetition of the study over a number of seasons may have resulted in greater familiarity and uptake of advisory by the farmers. The limitation of scope in terms of crops, geographic area of study and the time-duration of the study can be attributed to budget and cost limitations at the first author's end.

The findings of this paper make contributions in two distinct yet related domains, i.e. one to adaptation to climate risk domain, and two to the ICTs in agriculture. An important question in the literature related to adaptation to climate change is regarding the role of information in enhancing the farmers' ability to respond to climate risk. Empirical evidences have revealed that weather and climate information has positively contributed in enhancing the ability of the farmers to respond to climate risk and improving farm outcomes such as increased crop yield and cost saving (Stigter, 2011; Donovan, 2017; Cole & Fernando, 2016; Nesheim et al., 2017; Wang & Cai, 2009), likely increase in water saving by improving irrigation decisions (Wang & Cai, 2009), and improved farm revenue (Birthal et al., 2015). In fact, farmers with access to weather and climate information are more likely to make on-farm changes (Wood et al., 2014) that may result in better farm outcomes. Our study also provides supporting evidence on the positive role of relevant information in enabling the farmers to better respond to climate risk and make improvements in the scheduling of their farming operations.

However, an important question is that if information is so useful to the farmers' capacity to adapt, then why is it not used extensively, and by all farmers? Our data shows that 27 per cent of the farmers did not report any source or channel of information for receiving weather-related information (see Table 1). One possible explanation could be that the transaction cost involved in obtaining relevant information is often non-negligible (De Silva and Ratnadiwakara, 2008). According to the IPCC report (IPCC, 2014, pp.955), information acquisition cost can significantly affect the exposed unit's ability to adapt to climate risk. This could be either when weather and climate data are costly to obtain or difficult to access. Moreover, the report says that since information is public good, there is under-provision of information. Consequently, such farmers tend to resist adaptation measures which otherwise could have been possible, had the information been available with ease (Bradshaw, et al., 2004; Pannell, et al., 2006; Deressa, et al., 2009). Public interventions to provide relevant information to the farmers on their mobile phones through SMS, like the one in this study, then is an important step in the direction of improving capacity of the farmers to respond to climate risk.

A second contribution of the study is in the domain of ICTs for agriculture. Though the importance of ICTs in agricultural performance is widely recognized, efforts towards a rigorous impact assessment of the use of ICTs on the outcomes from farming have been limited. Our study attempts to add to this strand of literature by examining a particular ICT, i.e. SMS on mobile phones of the farmers, and its impact on farm outcomes. An important unresolved question in the arena of agricultural extension is the method of outreach to all the farmers in the face of shortage of staff. A promising avenue since the penetration of mobile phones in the rural hinterland is through SMS. Our study provides causal evidence on efficacy of SMS sent on mobile phones of the framers in getting them the information and significantly affecting their decisions. Also, SMS is a relatively cheap medium of information dissemination, especially compared to extension agents (Karanja et al., 2020; Soyemi & Adesi, 2018). Our study shows that SMS has the potential to be an important medium of outreach to the farmers with relevant information.

Our study also highlights some directions for future research in this area. From the perspective of the quality of information, further research in this arena needs to focus on the credibility and salience of the agri-met advisories. When this study started, we had registered six mobile numbers of the project team for each of the districts in order to receive the SMS agri-met advisories, particularly for wheat crop. We maintained a catalogue of advisories received on each of these numbers, and noted that there was often not much difference in the advisories across the districts, with only slight variation in the timing of circulation of the advisories. This raises serious concern over the salience of the advisories affecting the trust of the farmers who received them. Our study also points towards the need for future research in the characteristics of information such as accuracy, specificity and reliability that would match the needs of the farmers. While there is ample research related to the characteristics of the warning information and how it affects public response to warnings (see annotated bibliography by Mileti et al., 2006), such research on message, channel, source characteristics of weather and climate forecasts, and their impact on response of the farmers to this information is scant.

From the perspective of ICTs, further research is needed on which features of the phone would be most useful to disseminate information to the farmers. For example, voice messages maybe be preferred more by the farmers than text messages through SMS. Different mobile phone applications may provide better ways of providing relevant information to the farmer. Studies have found that SMS is less preferred over phone calls by the farmers. For instance, according to (Wyche & Steinfield, 2016), the farmers in rural Kenya face SMS challenge, meaning there is a steep learning curve involved in the usage of SMS for communication. Similar findings were stated by Crandall (2012), that farmers in Kenya find calling easier than sending and receiving text messages, which also requires some practice. But given the cost-effectiveness of sending an SMS compared to voice messages (particularly for cash-strapped Agri-met Field Units in India), keeping it a non-paid service for the farmers, and the ability to reach them without smart phones through an SMS, implies SMS (particularly SMS in local language) is still important and relevant in the developing country context, where majority of the farmers are small and marginal farmers, and are often not able to afford a smartphone. However, with functional literacy rates being low among small and marginal farmers in the developing country context, the challenging question is how to make farmers more adept in checking the SMS information received.

In terms of implications for policy, SMS Agri-met advisories are useful and should be promoted by the government, especially in the short to medium term. While there is quite a bit of optimism regarding the use of applications more modern than the SMS and use of GPS-supported technology to conduct farming in many parts of the world—including India, it will be a while (perhaps another 10 years as a new generation enters farming) before the potential of the modern ICTs is fully explored and exploited by the farmers in India. In the short term, SMS is likely to remain an important channel of communication for the farmers. The main reasons being—one, for most of the apps and GPS technology that may aid farming, a smartphone is needed. A majority of farmers in India are small and marginal land holders, and often do not have a smartphone. Haryana, our study state, is among the more affluent states in India. Even in our sample, only about 25 per cent of the sample had smartphones. Smartphone usage in India as of 2018 was 27 per cent of the population (McKinsey Global Institute, 2019). The population in rural India that does use smartphones are often richer farmers and other professionals, and typically not small and marginal farmers (Dev, 2017). The distribution of smartphones by landholding in our study sample also illustrates this.

Second, in case of ordinary (non-smart) phone, SMS is the main tool to push written content, other than voice calls (which a farmer needs to make and often does not). Even if every farmer can afford to purchase a smartphone, still, every farmer does not have the capacity to use all the features of a smartphone. This is also illustrated in our sample, which showed that a majority of the farmers (70 per cent) could open and read an SMS, but only a small minority could do other more sophisticated tasks on the phone, such as use online apps or make online transactions using the mobile phone. This is the case when the average literacy level in rural Haryana is about 80 per cent, and higher than the national average. Even among those who are illiterate, they may not be able to read an SMS on their own. But given that agri-met SMSs are sent in regional languages and not English, many illiterate farmers are able to ask their children to read out the message to them, as was reported in our study sample.

While face-to-face communication and exchange through their trusted groups will continue to be important for the farmers, even the trusted groups need to get their information from somewhere. The sources are numerous (TV, radio, etc.), but SMS is still important because it is delivered to the trusted group (another farmer) right on his/her phone, and can be read at the farmers' convenience. With TV and radio, the comments of the farmers in our sample revealed that accessing information at the farmers' convenience is difficult.

Given the fact that ordinary, non-smart phone, at the moment, have made the largest penetration in rural areas and particularly less affluent farming communities, SMS does seem to be still very important. It may not be the ideal form of communication, given the current potential of ICTs, but it still is a very important form of communication for rural parts of India. The government's investments in the agri-met advisory programme should be bolstered to strengthen the capacity of agri-met field units to send district and sub-district level, and crop-specific advisories.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crm.2021.100321.

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