ADDRESSING FERTILISER IMBALANCE IN INDIA

A DIAGNOSTIC STUDY OF THE SOIL HEALTH CARD SCHEME

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DATA. DECISIONS. DEVELOPMENT.

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EXECUTIVE SUMMARY

This paper presents the results of a qualitative, diagnostic study of the Government of India's Soil Health Card (SHC) scheme. This scheme provides farmers with crop-specific fertiliser dosage recommendations, in an attempt to address the imbalanced use of chemical inputs, improve soil health, and boost agricultural productivity. Across eight districts throughout India, we interviewed 37 key informants and 450 farmers to assess scheme implementation and to understand the reasons for farmers' non-adoption of recommendations.

We find considerable deficits in the resources available to maintain soil sample testing quality; low emphasis on dissemination of test results by extension workers; and farmers' non-adoption driven by a poor understanding of the card and limited trust in the recommendations. Most crucially, without significant modifications, our results suggest that the effect of the scheme in altering farmers' input use behaviour, and ultimately improving agricultural incomes, will remain limited. On the basis of these findings, this study presents three feasible recommendations to improve scheme implementation and farmer adoption: redesign the SHC, supplement in-person explanation of recommendations by extension workers with technology-based messaging, and build farmers' trust in the authenticity of their SHC recommendations.

INTRODUCTION

Since the 1950s, long-term agricultural productivity growth in India has averaged 3.0 percent and has improved only marginally to 3.5 percent since 2004 (World Bank 2012; World Bank 2014; NITI Aayog 2015). For most crops, output per hectare remains low, lagging far behind its competitors, (FAO 2015; Aadil et al. 2017) reflecting a considerable yield gap between realised and potential output (World Bank 2014; FAO 2015). Slow progress in agricultural productivity has significant welfare implications for the three-quarters of the population of rural India who are dependent on agriculture for their livelihoods (Food and Agriculture Organisation 2019), with the largest proportion of the low-income population in India found in the agricultural sector (NITI Aayog 2015). Over 80% of farmers, moreover, cultivate less than two hectares of land, inadequate to absorb production and price shocks, and hence remain exposed to income instability (FAO 2019). The successful implementation of strategies to accelerate productivity growth and increase farming incomes, therefore, remains of primary importance.

Alongside the use of other vital inputs, balanced fertiliser application is essential to achieve sustained growth in production and long-run agricultural sustainability (Himanshu 2015; Ward et al. 2016). Misapplication of chemical inputs, by contrast, is not only inefficient from an economic standpoint but contributes to the continual degradation of soil health, "*the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans*" (United States Department of Agriculture), and is one important contributor to stagnating agricultural productivity (Ongley 1996; Himanshu 2015; Fishman et al. 2016).

Agriculture in India has witnessed a dramatic increase in the use of chemical fertiliser, particularly from the Green Revolution era onwards, but growth in crop production has not kept up with the pace of input use increase (Fishman et al. 2016). Rather, fertiliser consumption data point to significant imbalance throughout the country. As a nationwide average, the over-application of urea has resulted in a highly skewed application ratio of nitrogen (N), phosphorous (P) and potassium (K), from an ideal ratio of 4:2:1, to 8.2:3.2:1 in 2013-14 (Ministry of Agriculture and Farmers' Welfare, 2015). In northern states, in particular, heavy subsidies have contributed to the over-application of urea, a major source of nitrogen, relative to phosphorous and potassium. For example, in Punjab, the NPK ratio reached 61.7:19.2:1 in 2015 – over fifteen times the recommended quantity of nitrogen-based fertiliser (Himanshu 2015). A distortion of similar magnitude was also recorded in Haryana, Rajasthan and Uttar Pradesh (Himanshu 2015), although over-application of urea is not universal (Cole et al. 2017). Similarly, application of other macronutrients varies widely across geographies: phosphorous consumption ranges from less than 1 kg/ha in Arunachal Pradesh to roughly 60kg/ha in Jharkhand and Punjab, whilst potassium ranges from less than 1 kg/ha in Rajasthan to roughly 30g/ha in Kerala and West Bengal (Ministry of Chemicals and Fertilizers 2013). The widespread misapplication of chemical fertiliser, moreover, is not limited to macronutrients. Farmers in India seldom apply either secondary nutrients (e.g., magnesium, calcium, and sulphur) or micronutrients (e.g., boron, gypsum, iron, copper and manganese) resulting in significant soil nutrient deficiencies, and further contributing to the stagnation of productivity growth (Fishman et al. 2016).

The government's Soil Health Card (SHC) scheme, launched in 2015, attempts to tackle misapplication of chemical fertiliser, soil degradation, and resultant low productivity, through the provision of crop-specific, fertiliser recommendations to each farmer throughout India. By targeting 100% penetration, this scheme is the first of its kind in the history of agricultural policy in India. On a two-year cycle, soil samples from select farmers' plots are tested across 12 parameters, and the results are used to generate fertiliser recommendations that are printed on SHCs and distributed to each individual farmer, for each plot they cultivate. The scope of this logistical endeavour is vast, with almost 50 million soil samples tested and over 180 million cards printed and distributed to farmers since 2015 (SHC Online Portal). It is hoped that by providing farmers with this information, the scheme will help to overcome entrenched fertiliser application practices. Yet, instilling this behaviour change, and hence achieving the scheme's primary objectives – to improve soil health, economise input use expenditure, and boost productivity – relies upon several conditions. It requires farmers to understand the recommendations on their card, and trust that adopting the recommendations will benefit them. It also presupposes that farmers' ability to adopt recommendations is not impeded by access to inputs or credit (Fishman et al. 2016; Cole et al. 2017).

The contribution of this qualitative, diagnostic study of the Soil Health Card scheme is fourfold. First, we assess the extent to which each of the above conditions required to achieve a change in farmers' fertiliser application hold. Most existing research that identifies low adoption of recommendations at the farmer-level does not comprehensively evaluate why this is the case (Fishman et al. 2016; Kishore 2018), whilst in other studies, the method of assessment of farmers' understanding is unclear (Reddy et al. 2016). Addressing these current gaps in the existing research is essential if the causes of non-usage are to be addressed, and hence for the scheme to achieve its objectives. To this end, we analyse the behavioural barriers impeding farmers' adoption, and show that farmers' poor understanding of their cards, and a lack of trust in the accuracy of recommendations, render most farmers unable and/or unwilling to use their SHC to inform their fertiliser application decision. We find these barriers to be much more significant in hindering adoption than liquidity constraints or a lack of access to recommended inputs.

Second, there is a dearth of empirical evidence assessing the current implementation of scheme processes, with only one notable study that attempts to do so (Reddy et al. 2016). Our research enriches this limited evidence. Through a combination of direct observation and stakeholder interviews, we provide a comprehensive assessment of the district-level execution of each SHC scheme process – soil sample collection, testing, fertiliser recommendation generation, and card explanation. Across districts, we find that a lack of infrastructure and sufficiently trained manpower undermine the quality of essential scheme processes. Most critically, the overburdening of extension workers hampers adequate in-person explanation of the card to farmers, with poor communication contributing both to farmers' limited understanding and lack of trust. Ultimately, by identifying the causes of unsuccessful implementation, we expect that the findings of this diagnostic can inform the future implementation of these processes. We also hope that our identification of district-level positive deviance in scheme implementation can contribute to an improvement in poorly performing districts.

Third, aside from one notable exception (Reddy et al. 2016), most existing research on the SHC scheme is limited by narrow geographical coverage, and hence findings may not be generalisable to other geographies. Experimental evidence on the effect of the scheme on altering farmers' fertiliser application (Fishman et al. 2016) and the efficacy of audio and video explanation on building farmers' understanding and eliciting trust in their SHC recommendations (Cole et al. 2017) are limited to Bihar and Gujarat, respectively. The agronomic, climatic and economic characteristics particular to these states may be underlying the results of these studies, and therefore findings may not be applicable elsewhere. We hope to address this shortcoming by assessing scheme implementation in eight districts, across eight states, characterised by differing agronomic, climatic and socio-economic conditions. In addition to district-specific findings, therefore, with increased geographical scope, we derive results representative across districts and states.

Finally, drawing directly from our findings, we shortlist three feasible and high impact recommendations that we believe the government should prioritise to improve scheme implementation and boost farmers' adoption of recommendations: redesign the Soil Health Card; supplement in-person explanation of the card by extension workers with ICT-based communication; and lastly, increase the cycle duration of the scheme, whilst decreasing the grid size used for soil sampling. Given the upcoming launch of the next cycle of the SHC scheme, we anticipate that providing a set of actionable recommendations can contribute to its on-going improvement. This study proceeds as follows: Section 2 describes the methodology used, and Section 3 presents our results. Section 4 summarises our policy recommendations. Section 5 concludes.

METHODOLOGY

SAMPLING

We conducted this qualitative, diagnostic study of the Soil Health Card scheme across eight districts, in eight states: Hamirpur (Himachal Pradesh), Baran (Rajasthan), Pakur (Jharkhand), Nandurbar (Maharashtra), Rajnandgaon (Chhattisgarh), Damoh (Madhya Pradesh), Balrampur (Uttar Pradesh) and Dhubri (Assam). Data collection for this study was conducted over a three-month period, during the summer of 2018. This study is split into two halves: the process-side, and the farmer-side. On the process-side, we interviewed 37 district-district-level key informants (lab-in-charges, lab technicians, extension workers, and Deputy Directors of Agriculture (DDAs)) responsible for scheme implementation at the district-level to assess current execution and identify the causes of implementation failure. On the farmer-side, we also interviewed 450 farmers (between 50 and 60 per study district), to understand prevailing knowledge levels, attitudes, and practices towards fertiliser application, and the reasons for farmers' non-adoption of SHC recommendations.

Whilst our study is not pan-India, due to the omission of southern states from our sample, we believe our findings are still representative across geographies for the following reasons. First, our district-level sampling strategy explicitly incorporated districts' capacity to implement the SHC scheme: six out of the eight districts selected are NITI Aayog-focus Aspirational Districts (as defined by the government's Transformation of Aspirational Districts Programme[i]), chosen on the basis of a resource index score[ii], designed to estimate districts' capacity to successfully implement the scheme. Hamirpur (Himachal Pradesh) and Rajnandgaon (Chhattisgarh) were chosen purposively, to observe implementation in higher-performing districts, which may be more representative of districts in southern states. District-level sampling also covers significant agronomic and climatic variation through the geographic dispersion of these eight districts. Second, utilising available data from the Agricultural Census (2011) online database, tehsil-level sampling ensured variation in irrigation and landholding size, both of which are likely to influence farmers' fertiliser application decisions (Sharma and Thaker 2011). Finally, selection of villages, and farmers within villages was purposive, to interview those farmers who had received their SHC and had, therefore, had an opportunity to adopt their recommendations. By covering considerable variation in key factors that affect both scheme implementation and farmers' adoption across India, our sampling strategy enhances the external validity of this study, and hence the generalisability of our findings beyond the eight study districts.

SURVEY INSTRUMENTS

To answer our research questions, this study used three survey instruments: in-depth key formant interviews, direct observation (process-side only), and vignette scenario interviews (farmer-side only). The specification of our survey instruments is summarised in Table 1.

Table 1. Survey instruments used

	Instrument	**Respondent**
Process-side	In-depth key informant interviews: one-on-one	Deputy Directors of Agriculture, extension workers, lab technicians, and lab-in-charge
	Direct observation using procedural checklists	Extension workers and lab technicians
Farmer-side	In-depth key informant interviews: one-on-one and focus group discussions (FGDs)	Farmers
	Vignette scenario interviews	

KEY INFORMANT INTERVIEWS

On the process-side, we designed one-on-one, in-depth interviews with stakeholders responsible for scheme implementation at the district-level (extension workers, lab technicians, lab-in-charges, and Deputy Directors of Agriculture (DDAs). These interviews assessed all stages of scheme implementation: soil sample collection, soil sample testing, card printing, and card explanation. On the farmer-side, we designed one-on-one interviews and focus group discussions (FGDs). Focus group discussions were chosen to complement one-on-one interviews due to farmers' willingness to talk openly about their fertiliser application behaviour and engage in meaningful discussions about the SHC scheme with other participants.

VIGNETTE SCENARIO INTERVIEWS

On the farmer-side, we designed vignette scenario interviews to uncover the behavioural barriers limiting farmers' adoption of recommendations and minimise the influence of social desirability bias[iii] in farmers' responses (Barter et al. 1999; Hughes and Huby 2004). Farmers were provided with scenarios where a fictional farmer had to make a decision whether to adopt their SHC fertiliser recommendations or not, based on certain constraints, e.g., the fictional farmer cultivates a small landholding or their recommendations are based on the test results of a soil sample from another farmers' plot, and so on. Respondents were then asked whether they thought the fictional farmer should adopt, and why or why not. By detaching the respondent from the decision, we expect this instrument enabled us to more successfully uncover respondents' attitudes, beliefs and perceptions towards adoption and the key considerations involved in fertiliser application decision-making (Barter et al. 1999; Hughes and Huby 2004). How respondents' advise a character in a vignette scenario to behave may, however, be a poor reflection of how that respondent would behave in practice (Hughes and Huby 2004). Yet, responses do reveal the extent to which attitudes towards adoption are favourable – a crucial precondition for actual adoption to occur.

OBSERVATIONAL CHECKLISTS

On the process-side, we designed observational checklists to assess scheme implementation for soil sample collection and soil testing. This decision was based on the assumption that directly observing behaviour is a better estimator of adherence to prescribed protocols than asking employees about their behaviour due to the effect of recall bias undermining data quality from self-reports (Foshay and Tinkey 2007; Abernethy 2015). Due to the likely presence of Hawthorne effects[iv], we assume that direct observation facilitates an estimation of participants' competence to perform prescribed procedures, rather than being indicative of actual performance (Foshay and Tinkey 2007). It is likely that study participants felt pressure to conduct their work according to stipulated guidelines, perhaps for fear of recrimination, and hence in the absence of observation, adherence to scheme protocol would be lower.

DATA ANALYSIS AND RESULTS

The process-side and farmer-side of this study utilised alternative qualitative analysis techniques. Given the importance of these analysis methods to the derivation of results, the following section is split by the process and farmer-side.

PROCESS-SIDE

TOP DOWN QUALITATIVE ANALYSIS

To analyse the processes underlying the Soil Health Card scheme, we adopted a "top-down" method of qualitative data analysis – deductive and analyst-driven, based on a preconceived theoretical framework of stage-wise scheme implementation, of soil sample collection, testing, fertiliser dose generation, and card explanation. This approach derived directly from the limited number of responses on the process-side of the study; aggregating upwards from so few data points would give too much weight to individual responses.

The key question on the process-side is how well districts adhere to the SHC scheme's stipulated implementation procedures. To answer this, we directly observed each stage of scheme implementation from soil sample collection through to card explanation. Through a review of the literature, and discussions with key stakeholders, *a priori*[iv] we identified four indicators that influence how accurately districts are following stipulated procedures: (i) the availability of resources, ii) the quality of available resources, (iii) the ways in which these resources were managed and (iv) the coordination of resources. Each stage was assessed according to these indicators. Table 2 (below) illustrates an example of this approach.

The secondary question was the extent to which these indicators influenced districts' implementation of the scheme. To do so, we used fuzzy set qualitative comparative analysis (fsQCA). fsQCA is a technique used to identify potential causal relationships despite having a small number of cases to study, and without strict, binary rules of set membership, e.g., being a member of the set of districts that have adequate resources available to implement the Soil Health Card Scheme. This methodology allowed us to use logical inference to determine the necessary and sufficient conditions for successful implementation of the scheme, despite the limited sample size of key informants across districts. For a thorough explanation of this technique, see Elliott (2013). Although emerging initially from political science literature, qualitative researchers have since used this technique across various fields such as business (Linton et al. 2017; Olya et al. 2017) education (Stevenson 2013), environmental science (Basurto 2013), and health (Blackman 2013).

Table 2. Stage-wise Process Analysis

Indicators*	**Metric**	**Instrument**
Resource availability	Time	Interviews
	Human Resources	
	Equipment	Direct observation and interviews
Resource capacity	Training	Interviews
	Qualification	
	Experience	
Resource management	Monitoring	
	Incentives	
Resource coordination	Accuracy	Direct observation and interviews
	Efficiency	

* Assessed for each of the four stages SHC scheme implementation.

PROCESS-SIDE RESULTS

On the process-side, we assessed implementation sequentially, according to each of the four stages of the scheme: soil sample collection, testing, fertiliser dose generation and card explanation.

Stage 1: soil sample collection

We find that across districts, the manpower available to collect soil samples is insufficient. On average, at the time of interview, almost half of sanctioned extension worker posts were vacant across our sampled districts. This has led to the overburdening of extension workers. The extension workers we interviewed, moreover, were also under-trained and unaware of the steps that have to be followed whilst collecting soil samples, specifically for the creation of grids for sampling. Inaccurate grid creation can lead to farmers receiving recommendations that are not applicable to their plots, which undermines trust in the authenticity of recommendations.

For soil sample collection, Baran and Pakur were the most poorly performing districts, with extension workers' displaying only limited knowledge of the correct procedures to follow, particularly with respect to grid creation. By contrast, extension workers in Rajnandgaon did adhere to procedures for soil sample collection. Rajnandgaon was also the only district where resource management for soil sample collection was sufficient, with strong monitoring methods in place (for example, weekly meetings, monthly targets, and cross-district checks). These strategies for resource management help to ensure adherence to guidelines for accurate soil sample collection, but were absent from all other study districts.

Stage 2. Soil sample testing

Across districts, we find that there is a shortage of resources available for soil sample testing procedures – infrastructure (e.g., electricity and water supply), machinery (e.g., fully-automated AAS machines) and human resources (approximately half of all lab technician posts were vacant at the time of interview)[vi]. These problems were especially acute in Balrampur and Damoh, severely limiting the capacity of the district labs to meet their soil testing targets. By contrast, we find significant inter-district variation in resource capacity, driven primarily by differences in the qualifications and experience level of lab staff. Lab technicians were the most under-qualified and inexperienced in Pakur, increasing the likelihood of deviance from soil testing protocol.

Across districts, we also find that there is a lack of coordination between extension workers and labs, which means that the supply of samples from the field is irregular. Labs are either overstretched when a large number of samples come in at once or operate below capacity when samples fail to come in from the field during the onset of soil sample collection. In Hamirpur and Damoh, the cost of transporting samples is borne by extension workers. As a result, most choose to deposit soil samples at the labs less frequently but in larger numbers per trip. This causes a bottleneck on the supply of soil samples to labs, preventing labs from operating optimally.

Stage 3: fertiliser dose generation

We find substantial cross-district variation in the level of adherence to procedures for fertiliser recommendation generation. Whilst some districts are performing adequately, with data enterers accurately generating recommendations (Hamirpur, Baran, and Rajnandgaon), we also identify significant issues in others (Pakur, Balrampur and Damoh). Challenges facing these districts include cards printed in non-local languages, duplication of recommendations, contextually irrelevant fertilisers, and handwritten cards, which are often illegible and/or error-prone. In Pakur and Damoh, an absence of dedicated data enterers means field staff, often with little computing experience, are responsible for data entry. In these districts, not only were field staff less efficient but also more prone to making data entry errors. In Balrampur and Dhubri, moreover, where data entry and card printing processes are outsourced, an absence of monitoring or quality checks results in a high prevalence of cards printed with errors. Errors not only undermine the likelihood that recommendations, when adopted, improve soil health and boost productivity, but also further erode farmers' trust in the scheme.

Stage 4: card explanation

Across districts, emphasis on card explanation is low. In particular, we find that incentives for extension workers to explain the cards to farmers are inadequate. Prevailing resource management practices place little emphasis on ensuring extension workers adequately explain cards to farmers, with performance management, targets and monitoring overwhelmingly geared towards card distribution rather than explanation. This is symptomatic of the centre's limited prioritisation on adoption of recommendations at the farmer-level, and rather, the preoccupation with supply-side output targets.

Most concerning, across districts, many extension workers report experiencing difficulties in understanding the cards themselves. We find that the design of the card itself has a significant impact on extension workers' understanding of the fertiliser recommendations and on their ability to accurately relay this information to farmers. In particular, most extension workers struggled to interpret the multiple columns for macronutrients, demonstrating a poor understanding that multiple columns represent alternative fertiliser combinations, depending on local access and availability. Extension workers reported that cards with larger fonts and simpler formatting (such as the one used in Baran, Rajasthan) were easier to understand than the generic soil health card. Finally, Rajnandgaon was the only district where we observed extension workers explain the card adequately. Given extension services are the primary channel of scheme communication, this failing has significant implications for farmers' understanding of their cards, and hence their ability to adopt.

FARMER-SIDE

FARMERS' BACKGROUND CHARACTERISTICS

There was substantial cross-district variation in the socio-economic and agronomic characteristics of the farmers we interviewed. Differentials in landholding size were especially stark, with farmers in Baran on average cultivating landholdings over 20 times[vii] larger than those cultivated by farmers in Pakur or Dhubri, where the landholdings of farmers we interviewed ranged between only 0.5-1.5 hectares in size. Farmers in districts cultivating the smallest landholdings, moreover, also reported facing substantial subsistence pressure, often consuming almost all of their produce. Irrigation remained a major issue in Hamirpur and Pakur, and therefore a key consideration in fertiliser application decisions. These differences are likely to contribute to the inter-district variation of farmers' ability and willingness to adopt their recommendations.

FARMER-SIDE: BOTTOM-UP QUALITATIVE ANALYSIS

On the farmer side, we used a "bottom-up" approach to data analysis – inductive and data-driven, without trying to fit responses into a pre-defined coding frame. This approach derived directly from the large volume of farmer responses we had, with sufficient data points, therefore, to identify the relative frequency of responses, and recognise thematic patterns. By question, we coded responses to organise, refine, and synthesise the data. To do so, we used open codes, emerging from the data directly, to distil the main concepts and ideas in farmers' responses. Codes were aggregated upwards to create broader sub-themes or "buckets," analysed together to infer the overarching themes relating to farmers' decision to adopt or not adopt the fertiliser recommendations on their SHC.

FARMER-SIDE RESULTS

Knowledge, attitudes and practices towards fertiliser application

We find farmers' knowledge of the consequences of incorrect fertiliser application, and the resulting impact on soil health varied widely between districts: knowledge was weakest in Pakur and Damoh, and strongest in Baran, Rajnandgaon, and Balrampur. Particularly for the over-application of chemical fertiliser, most farmers were able to describe changes to soil quality and appearance – such as texture (e.g., dryness, cracking and hardness), colour (e.g., whitening), and reduced water absorption. Farmers with the highest knowledge levels were also able to describe specific changes caused by over-application of nitrogen-based fertiliser, such as to soil pH. Across districts, knowledge of the consequences of under-application of chemical fertiliser, however, centred overwhelmingly on the negative impact this may have on output, rather than specific changes to soil or crop characteristics.

We find that across districts, roughly two-thirds of the farmers were willing to increase chemical fertiliser application based on SHC recommendations, whilst almost all farmers were willing to decrease. This result counters Aadil et al. (2017) study that suggests concerns about productivity prevent farmers following recommendations that decrease application. We find farmers in Baran were the least willing to increase, whilst farmers in Rajnandgaon were the least willing to decrease. In Rajnandgaon, farmers' aggregate application was lower than the quantities recommended on SHCs. An awareness of prevalent under-application may be driving this unwillingness to decrease further. In Damoh, Pakur, and Baran, farmers' perceived the risk of changing fertiliser application to be greater if the land was rented or the landholding was small. Risks were perceived to be greater if the land was unirrigated in Hamirpur, Nandurbar, and Rajnandgaon. Overall, however, these findings are largely indicative of favourable attitudes towards altering fertiliser application practices – a result which is reassuring for the potential efficacy of the Soil Health Card scheme.

Application of micronutrient fertilisers, in particular, is severely limited. Zinc was the most frequently reported micronutrient applied, with the application of other micronutrients extremely low and irregular. Difficult to disentangle, this finding may result from both a lack of awareness of the impacts of micronutrients on yield and crop quality, as well as a decision not to apply, even when micronutrients are known about. This finding reiterates the necessity of the SHC scheme to improve awareness on the importance of micronutrient application, to ultimately increase farmers' micronutrient application. Across districts, farmers rarely attributed not applying other micronutrients to a lack of access to purchase these inputs.

Behavioral barriers limiting Soil Health Card Scheme adoption

We identify three primary reasons why farmers are currently not adopting the recommendations on their SHC, applicable across districts: poor understanding of the card, inadequate communication by extension workers, and a lack of trust in the accuracy of recommendations. By contrast, credit constraints or limited access to inputs was infrequently reported as a reason for non-adoption. It is possible, however, that these constraints may emerge as increasingly important after the initial barriers of understanding and trust have been bridged.

Most farmers do not understand their card

We find that barriers to card comprehension prevent the vast majority of farmers from understanding how to apply the recommendations printed on their card. To measure farmers' comprehension of their SHC, we asked farmers to interpret various features of the card and then explain the fertiliser recommendations. We assessed comprehension according to the accuracy of their responses. We find that farmers' interpretation of SHC recommendations is constrained by limited functional literacy; limited awareness of the conversion rate from hectares (the standard land unit used on the generic SHC) to local land units; limited functional numeracy to calculate fertiliser quantity per local land unit; a poor understanding of scientific language; and a poor understanding that multiple columns on the card represent alternative fertiliser combinations. The difficulty farmers face in interpreting the recommendations written on their card, therefore, is determined not only by structural barriers, such as low literacy and numeracy, but is exacerbated by the poor and complex presentation of information on the card, and the inclusion of superfluous detail that creates confusion.

Across districts, identifying farmers who could overcome these comprehension barriers was challenging. Only in three districts were farmers able to calculate the unit conversion for fertiliser quantities in hectares to their local land unit (Baran, Nandurbar, and Rajnandgaon). Only in Nandurbar did we observe farmers who were able to interpret multiple columns of macronutrient fertilisers as representing alternate combinations, one of which should be applied. Throughout all eight districts, farmers who could accurately interpret the fertiliser recommendations on their SHCs were virtually non-existent.

Communication of recommendations by extension workers is insufficient

Overburdened extension services, the main channel of SHC information dissemination, contribute significantly to farmers' poor understanding of the card. Extension workers often distribute cards centrally in a village, with farmers then circulating cards amongst themselves. In these instances, farmers miss out on receiving an explanation of the card from the extension worker, essential for understanding where functional literacy and numeracy are limited. Even when farmers do receive an explanation of their card from an extension worker, moreover, many illiterate farmers expressed difficulty remembering how to interpret their recommendations at a later date. Particularly for those who cannot refer back to their card without assistance, this reiterates the need for recommendations to be explained to farmers on multiple occasions.

Finally, we also infer that the absence of frequent communication from a relatively well-trusted agricultural official[viii] exacerbates perceptions of the irrelevance of the card and limits the formation of positive attitudes towards adoption, such that farmers believe using their card will benefit them. Not only are farmers then unable to use their cards but often also unwilling to adopt their recommendations.

Most farmers do not trust recommendations unless a soil sample from their own plot is tested

The scheme applies grid-based soil sampling strategy, such that one sample is drawn from a grid of 2.5 hectares for irrigated land or 10 hectares for unirrigated[ix], with test results and fertiliser recommendations extrapolated to all farmers across the grid. Yet, over three-quarters[x] of farmers reported that they would be unwilling to trust SHC recommendations if they were based on a soil sample taken from another farmer's plot. Aversion to adopting recommendations if a sample from their own plot was not tested was strongest in Baran, where the farmers we interviewed cultivated the largest landholdings on average. We speculate that such large average plot sizes further exacerbate distrust in the accuracy of the grid-based sampling and its ability to capture sufficient variation in soil types. Aversion to adopting if a sample from their own plot was not tested was weakest in Hamirpur, although scepticism of the current grid-based sampling strategy was evident across districts. For the vast majority of farmers, having a sample from their own plot tested was a prerequisite to adopting the fertiliser recommendations. Those farmers who were willing to trust the recommendations, moreover, would do so only on the basis of certain similarities between their own plot and the source of the soil sample: e.g., soil type, fertilisers applied, crops grown, and distance. The lack of site-specificity of the test results undermined farmers' ability to evaluate whether the soil sample on which their recommendations are based would be similar enough to their own plot to be applicable. As a consequence, it also increased farmers' uncertainty about the reliability of the recommendations printed on their cards.

We also find that roughly two-thirds[xi] of farmers were unwilling to trust SHC recommendations based on composite samples[xii]. Many farmers believe that by mixing together soil from several different plots, the test results and resultant recommendations would not be applicable to their plot. Across districts, farmers often collect soil samples jointly with the extension worker, with farmers, therefore, witnessing the creation of a composite sample. For farmers who are sceptical of the validity of test results derived from composite sampling, this further erodes trust in their recommendations and hence their willingness to adopt.

Jointly, these findings suggest that regardless of the scientific representativeness of the scheme's grid-based and/or composite sampling procedures, farmers' deeply held beliefs about the inaccuracy of the recommendations limits adoption across districts. It is clear that distrust in the authenticity of results is strong, irrespective of the actual scientific validity of either method.

DISCUSSION

SYNTHESIS OF FINDINGS

PROCESS-SIDE

On the process-side, three main conclusions, applicable across districts, can be drawn from the above findings:

1. A lack of available manpower for soil sample collection undermines adherence to the stipulated guidelines, with the most significant departures from protocol arising in grid creation processes during soil sample collection.
2. A lack of available resources (infrastructure, machinery, and manpower) for soil testing procedures undermines the quality of the scientific testing and the ability of districts to meet their targets.
3. Extension workers' explanation of the card is not incentivised by management practices. Rather, targets are geared towards the distribution of cards. Hence, the low prioritisation of extension worker communication is reflected in the absence of monitoring mechanisms to ensure cards are adequately explained to farmers.

FARMER-SIDE

On the farmer-side, two main conclusions, applicable across districts, can be drawn from the above findings. Adoption of fertiliser recommendations is fundamentally constrained by:

1. Farmers' poor understanding of their recommendations, which renders the majority of farmers unable to use their card, even if they would like to. Two primary channels cause farmers' poor understanding: first, limited comprehension of the card itself, exacerbated by complex design. Second, farmers' poor understanding is also caused by the ineffective and inadequate explanation of recommendations by trained extension workers, primarily due to

overburdening, and at times, extension workers' own limited understanding of the card.

2. Farmers' low level of trust in the fertiliser recommendations on their card means many farmers are unwilling to use their card. Likewise, two primary channels cause this lack of trust: first, farmers' trust is undermined by the poor communication of SHC science to farmers, resulting from complex card design, and inadequate explanation by extension workers. Second, trust is further eroded by inefficiencies in scheme processes, and scepticism of the scientific accuracy of recommendations extrapolated across the grid.

RECOMMENDATIONS

Drawing directly from our findings, and after incorporating input from key stakeholders, we developed a set of recommendations to improve the scheme. Based on the feasibility of execution and the potential impact of implementation, we prioritise three to address the current challenges afflicting the scheme. Note that we have not commented on the cost-effectiveness of each recommendation: this depends on many unknowns including the scale of implementation, and hence is beyond the scope of this study.

REDESIGN THE CARD

By utilising insights from behavioural science, cards should be redesigned to improve farmers' comprehension of their recommendations, as well as boost farmers' willingness to use their card. Our results, in addition to the findings of iterative user-testing research in Bihar (Singh et al. 2017), suggest that card redesign should ensure: the volume of information is streamlined, unnecessary scientific jargon, is removed, and fertiliser quantities are printed in local land units and available trade names. Additional formatting changes should also be made to display alternative fertiliser combinations more intuitively. The use of fertiliser images and coloured icons to indicate nutrient deficiency levels could simultaneously improve comprehension and boost the aesthetic appeal of the cards. Lastly, the cards should clearly display the number of a SHC helpline that farmers can call for assistance using their card.

While state governments have the autonomy to implement a card of their choice, most states adopt the generic design available on the SHC portal. The Centre, however, cannot scale a generic card that is too expensive operationally. Further research is required, therefore, to optimise card design within the constraints of financial feasibility.

We foresee **two potential benefits** of card redesign:

i) Improve comprehension, particularly for farmers who have some functional literacy to read the card, but are currently overwhelmed by the volume of information, scientific jargon and unintuitive presentation.
ii) Improve extension workers' understanding and ability to explain the card to farmers effectively. This is essential for the information on the card to be successfully conveyed to farmers.

SUPPLEMENT IN-PERSON EXPLANATION OF THE CARD BY THE EXTENSION WORKER WITH TECHNOLOGY-BASED EXPLANATIONS OF RECOMMENDATIONS

Existing literature suggests that video and audio messages are as effective as in-person extension at improving farmers' understanding of SHC recommendations and eliciting trust in their validity (Cole et al. 2017). In-person explanation by extension workers should, therefore, be supplemented with technology-based messaging to reinforce card explanation. This will increase the frequency and timeliness of messaging, in addition to increasing exposure to SHC messaging from a range of communication channels.

Potential channels for technology-based SHC messaging include SMS reminders; participatory videos; Interactive Voice Response calls; including a toll-free helpline on the card that farmers can call to receive a verbal explanation of their card.[xiii] Crucially, these channels do not rely on extension worker capacity to implement and hence would not exacerbate the current overburdening of extension services. In order for information to be actionable for farmers, technology-based explanation of recommendations should be timely, provided before the start of the sowing season. The impact of a variety of technology-based mediums on farmer adoption, as well as their operational feasibility and cost-effectiveness, however, requires further assessment.

We expect that supplementing in-person communication of SHC recommendations with additional, tech-based mediums will have **three potential benefits**:

i) Enable the provision of information on how to use the card at a time when it is most actionable for farmers – before the sowing season.
ii) Improve farmers' understanding of how to use their card, irrespective of farmers' literacy level.
iii) Build farmers' trust in the validity of the recommendations, due to improvements in understanding and exposure to SHC messaging from multiple channels.

INCREASE THE CYCLE DURATION OF THE SHC SCHEME, WHILST REDUCING THE GRID SIZE

Providing each farmer in the country with a SHC every two years is a hugely resource-intensive undertaking, which contributes significantly to the overburdening of extension services. Given the slow rate of change in soil nutrient composition, moreover, providing farmers with recommendations on a two-year cycle is most likely unnecessary. Second, given the apparent prevalence of farmers' distrust of grid-based sampling, reducing the grid size is likely to reduce scepticism in the accuracy of recommendations extrapolated across the grid. The resource outlay incurred by a reduction in the grid size could feasibly be offset by simultaneously increasing the cycle duration. This is likely to help maintain sample collection and testing quality, although these dynamics require further assessment. A cycle of four years could be appropriate with a grid size of five hectares, for both irrigated and unirrigated areas. Overall, the Centre should determine the optimal combination of cycle duration and grid size to simultaneously alleviate the burden on extension services whilst improving farmers' trust in grid-based sampling.

We anticipate **three potential benefits** of implementing this recommendation:

i) Improve the quality of soil sample collection and testing, given an increase in time per sample.
ii) Reduce extension workers' workload, thereby increasing their capacity to adequately explain the card to farmers.
iii) Build farmers' trust in the accuracy of recommendations extrapolated across all plots in the grid.

CONCLUSION

Agriculture is the primary source of livelihood for over three-quarters of rural India, and 82% of those are small and marginal farmers, blighted by landholding fragmentation and stagnating growth in productivity. The slow transformation of the agricultural sector to generate higher output and higher incomes has contributed to ongoing agrarian distress across India.

Amongst many required reforms, addressing deteriorating soil health, caused by imbalanced application of chemical fertilisers, is one strategy that has the potential to improve productivity, input use efficiency, and ultimately boost farmers' income. Soil Health Cards are intended to provide farmers with usable, crop-specific fertiliser recommendations to promote a change in farmers' fertiliser application decision making, and encourage more judicious usage.

This qualitative, diagnostic study of the SHC scheme, in eight diverse districts across eight states, however, identified significant failings in execution that currently limit the success of the SHC scheme, and restrict the accomplishment of its primary objectives. First, the scheme's processes – such as soil sample collection, testing, recommendation generation, and card distribution – are undermined by limited infrastructure and a lack of sufficiently trained manpower. The overburdening of extension services, in particular, compromises the quality of vital procedures, such as accurate soil sample collection, and prohibits extension workers' adequate explanation of the card to farmers.

At the micro-level, we find that the majority of farmers are unable to adopt their SHC recommendations, even if they would like to, due to poor understanding. Barriers to comprehension are caused not only by structural problems such as low literacy and numeracy but are also exacerbated by unnecessarily complex and unintuitive card design, in addition to extension workers' poor communication of the science to farmers. Amongst the farmers who are able to understand the recommendations on their card, moreover, many are not confident that following the recommendations could lead to benefits, and hence willingness to adopt remains low. This lack of trust derives largely from scepticism in the accuracy of the scheme's grid-based sampling method and is further exacerbated by limited exposure to extension services as a trusted source of agricultural information and advice.

From the findings of this study, it is clear that the failures of scheme processes and the causes of farmers' non-adoption are often entwined, and thus must be addressed simultaneously for the scheme to achieve its objectives. Yet, both sets of challenges are also fuelled by the centre's preoccupation with output targets. Given the impressive record of distribution already achieved in the first two cycles, the government must now refocus its attention to monitor the quality of implementation, and most crucially, promote farmers' adoption of recommendations. By doing so, the centre can provide a mandate for states to do the same; this is vital if meaningful changes are to be made at the state and district level.

To this end, three prioritised measures are essential for the government to improve the scheme: redesign the card, supplement existing in-person explanation of the card by the extension worker with ICT-based communication channels, and reduce the grid size whilst increasing the cycle duration.

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NOTES

[i] Prime Minister Narendra Modi launched the Transforming Aspirational Districts Programme. “Aspirational Districts” are ranked on 49 key performance indicators across Health & Nutrition, Agriculture & Water Resources, Financial Inclusion & Skill Development, Education, and Basic Infrastructure, to identify strategies to improve socioeconomic performance, and measure districts’ progress.
[ii] Variables included in this district index score were: the number of blocks; the number of farmers; the number of soil testing labs per sample; the number of lab technicians in district-level labs; the number of shifts in district-level labs; and Atomic Absorption Spectrometry devise (AAS) availability.
[iii] Social desirability bias occurs when respondents alter their responses based on what they anticipate surveyors would like to hear or to portray the self in a positive, norm-abiding light.
[iv] Hawthorne effect refers to the alteration of the behaviour of study participants caused by being observed.
[V] Reasoning deriving from theoretical deduction, rather than empirical observation.
[vi] Subject to change around hiring drives.
[vii] Note that estimates are approximate.
[viii] We assessed farmers’ trust of extension workers through vignette and in-depth interviews. Across districts, farmers were more willing to trust information provided by an Extension Worker than from a progressive farmer.
[ix] Grids are drawn using GPS devices and revenue maps.
[x] 67/85 farmers from vignette interviews. This question was asked across all eight districts. This finding was also supported by farmers’ responses during Focus Group Discussions.
[xi] 34/60 farmers from vignette interviews. This question was asked across five districts, which explains the smaller number of responses. This finding was also supported by farmers’ responses during Focus Group Discussions.
[xii] Composite soil samples combine multiple soil samples across the same grid.
[xiii] The relative efficacy of various tech-based message mediums requires further assessment.