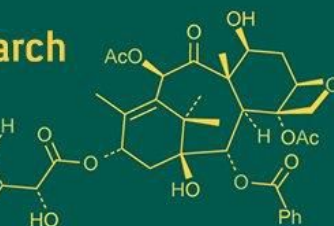
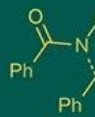


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Constraint analysis in adoption of soil health card recommendations among farmers in Karimnagar district of Telangana state

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Abstract

The Soil Health Card (SHC) initiative represents a significant agricultural policy intervention by the Government of India to promote evidence-based nutrient management and sustainable soil stewardship. Despite nationwide implementation and distribution of over 270 million cards, the translation of SHC recommendations into actual farming practices remains constrained by multiple barriers. This investigation systematically examined the multidimensional constraints affecting SHC adoption among beneficiary farmers in erstwhile Karimnagar district of Telangana State. Using an ex-post facto research design, data were collected from 120 purposively selected SHC recipient farmers across 24 villages through structured personal interviews. The analytical framework categorized constraints into four dimensions: technical, operational, socio-personal and psychological. Descriptive statistics including frequency, percentage, mean score and Garrett ranking technique were employed for data analysis. Results revealed that technical constraints constituted the primary impediment, with inadequate information on micronutrient deficiencies (Garrett Mean Score 65.82, Rank I) and delayed issuance of cards (GMS 62.45, Rank II) emerging as critical bottlenecks. Operational constraints were dominated by non-availability of recommended micronutrients in local markets (GMS 68.34, Rank I) and prohibitive fertilizer prices (GMS 64.21, Rank II). Among socio-personal factors, difficulty in comprehending and interpreting soil test reports (GMS 63.56, Rank I) significantly hindered utilization. Psychological constraints reflected lack of motivation (GMS 66.78, Rank I) and inadequate educational background limiting understanding (GMS 61.89, Rank II). The study underscores critical implementation gaps in service delivery, extension support systems and input supply chains. Strategic recommendations include institutional strengthening of soil testing laboratories for timely reporting, development of farmer-friendly interpretative aids in vernacular languages, capacity building through pre-seasonal training programs, enhancement of extension follow-up mechanisms, establishment of village-level nutrient banks and convergence with input supply cooperatives to ensure affordable access to recommended fertilizers.

Keywords: Soil health card, adoption constraints, Garrett ranking, extension barriers

Introduction

Agricultural sustainability and food security fundamentally depend on maintaining optimal soil health status. However, Indian agriculture faces a paradoxical situation where decades of input-intensive farming have simultaneously increased production while systematically depleting soil quality. The persistent imbalance in fertilizer application patterns, characterized by disproportionately high nitrogen use relative to phosphorus and potassium, has created widespread multi-nutrient deficiencies across agroecological zones (Ohlan *et al.* 2025) [7]. This nutrient mining, coupled with declining organic carbon content and micronutrient depletion, poses serious threats to long-term productivity and environmental sustainability (Singh *et al.* 2023) [1].

Recognizing these challenges, the Government of India introduced the Soil Health Card scheme as a transformative policy intervention on February 19, 2015. The scheme's conceptual foundation rests on providing farmers with individualized, soil test-based nutrient management recommendations to replace the prevailing blanket fertilizer prescriptions. Through systematic soil sampling, laboratory analysis of 12 critical parameters (NPK macronutrients, sulfur as secondary nutrient, five micronutrients including Zn, Fe, Cu, Mn,

B, and physicochemical properties pH, EC, OC) and generation of crop-specific fertilizer advisories, the SHC mechanism aims to optimize input efficiency while enhancing soil fertility (PIB 2025). The scheme envisions complete coverage of India's 14 crore farm holdings through triennial soil testing cycles, with technological enhancements including GIS-integrated portal systems and mobile applications facilitating sample collection and card distribution.

The scheme's implementation has achieved substantial quantitative milestones, with cumulative distribution exceeding 270 million soil health cards across multiple cycles. Recent technological interventions in 2023 revamped the SHC portal with Geographic Information System integration, while the establishment of 665 Village-Level Soil Testing Laboratories across 17 states by February 2025 has decentralized testing infrastructure (PIB 2025) ^[9]. Additionally, the innovative School Soil Health Programme has engaged 125,972 students in 1,020 schools, creating awareness among future farming generations. These achievements notwithstanding, empirical evidence increasingly reveals significant disconnects between card distribution and actual adoption of recommendations by farming communities.

Recent research across diverse agroecological contexts consistently documents this awareness-adoption gap. Madhuri *et al.* (2024) ^[6] reported that while 82% of paddy farmers in North Coastal Andhra Pradesh demonstrated awareness of the SHC scheme, only 48% actually implemented the recommended fertilizer applications. Similarly, Kumar (2025) ^[4] identified that 57% of farmers in Madhya Pradesh reported minimal usage of SHC recommendations despite receiving cards. This implementation deficit stems from multifaceted constraints operating across technical, operational, socio-economic and psychological dimensions. Technical barriers include delayed report generation, inadequate information on emerging nutrient deficiencies and sampling methodology errors. Operational constraints encompass input availability challenges, price disincentives and weak market linkages. Socio-personal factors involve educational limitations affecting comprehension of technical advisories, while psychological barriers reflect motivational deficits and skepticism regarding perceived benefits.

Garrett ranking methodology provides a robust analytical framework for hierarchically prioritizing these constraints based on farmers' perceptions, enabling evidence-based policy formulation. Previous applications of this technique in agricultural technology adoption studies have successfully identified critical intervention points. However, constraint analysis specific to SHC adoption in Telangana State, particularly in districts with intensive implementation like Karimnagar, remains inadequately documented. Erstwhile Karimnagar district represents an appropriate research locale given its agricultural predominance, diverse cropping systems encompassing paddy, cotton, maize and pulses and active engagement of Krishi Vignana Kendras and District Agricultural Advisory and Transfer of Technology Centres (DAATTCs) in extension service delivery.

Understanding constraint hierarchies from farmers' perspectives is imperative for designing targeted

interventions that enhance scheme effectiveness. Whereas earlier studies have examined adoption patterns and impacts, systematic analysis of implementation barriers using standardized ranking procedures remains sparse. This knowledge gap undermines evidence-based policy refinement and extension strategy formulation. Therefore, the present investigation was conceived with specific objectives: (i) to profile the socio-economic and psychological characteristics of SHC beneficiary farmers; (ii) to identify and prioritize technical constraints limiting SHC recommendation adoption using Garrett ranking technique; (iii) to analyze operational barriers affecting implementation; (iv) to examine socio-personal and psychological factors hindering utilization; and (v) to formulate evidence-based suggestions for strengthening scheme implementation and enhancing adoption levels among farming communities.

Materials and Methods

Research design and rationale of the Study

An ex-post facto research design was employed for this investigation, given that the Soil Health Card scheme had already been operationalized and the phenomenon under study constraints in adoption occurred naturally without researcher manipulation. This non-experimental design enabled systematic examination of existing relationships between farmer characteristics and constraint perceptions in authentic field settings, thereby enhancing external validity and policy relevance of findings. The retrospective nature of constraint assessment allowed farmers to reflect on their cumulative experiences across multiple cropping seasons since receiving SHC, providing comprehensive insights into persistent barriers rather than isolated incidents.

Research locale and sampling procedure

The study was conducted in Erstwhile Karimnagar district of Telangana State, which was purposively selected based on three criteria: (i) substantial coverage of farm holdings under SHC scheme implementation; (ii) active engagement of Krishi Vignana Kendras in facilitating scheme operations; and (iii) representative agrarian characteristics including diverse cropping patterns and predominance of small and marginal landholdings typical of the region. A multi-stage stratified random sampling procedure was adopted to ensure adequate representation. In the first stage, six mandals were randomly selected from erstwhile Karimnagar district. In the second stage, four villages were randomly chosen from each selected mandal, resulting in a total of 24 villages. In the final stage, from each village, 05 farmers who had received Soil Health Cards were randomly selected, making a total sample size of 120 respondents. This sample size aligns with statistical adequacy norms for constraint analysis studies in agricultural extension research (Patel *et al.* 2023) ^[8].

Primary data were collected through face-to-face personal interviews conducted, coinciding with the post-Rabi harvest period when farmers had adequate time for interaction. A pre-tested structured interview schedule was developed following established psychometric procedures. The instrument comprised three sections: (i) socio-economic profile characteristics including age, education, farm size, farming experience, training exposure and extension

contact; (ii) adoption-related variables including awareness, understanding and implementation of SHC recommendations; and (iii) constraint statements across four dimensions-technical (8 items), operational (7 items), socio-personal (7 items) and psychological (7 items). The constraint statements were developed through extensive literature review, consultation with soil scientists, extension specialists and KrishiVignana Kendra officials, followed by pre-testing with 15 non-sample farmers to ensure content validity, comprehension clarity and response variability. Each constraint item was evaluated by respondents on its severity using Garrett ranking continuum. Supplementary qualitative information was gathered through informal discussions and field observations to contextualize quantitative findings.

Operationalization and measurement of variables

Profile variables were operationalized using established scales. Age was recorded in completed years and categorized as young (up to 35 years), middle (35-50 years) and old (above 50 years). Education was measured as years of formal schooling completed, classified into six ordinal categories from illiterate to post-graduation. Farm size was assessed in hectares and grouped according to official landholding classifications. Farming experience was computed as years of active agricultural engagement. Extension contact was measured using a composite index incorporating frequency of interaction with various extension agencies, participation in training programs, and attendance in farmers' meetings, following Singh and Sharma (2004) [14]. Psychological constructs including scientific orientation, achievement motivation, economic motivation, and innovativeness were assessed using standardized scales with demonstrated reliability coefficients exceeding 0.75.

Garrett ranking technique for constraint prioritization

Constraints were prioritized using Garrett ranking technique, which converts ordinal ranks assigned by respondents into numerical scores amenable to statistical comparison. Respondents ranked each constraint based on perceived severity from most serious to least serious. These ranks were converted to percent positions using the formula: $\text{Percent Position} = 100(R_{ij} - 0.5)/N_j$, where R_{ij} represents the rank assigned by the i th respondent to j th constraint, and N_j denotes total number of constraints in that category. The percent positions were then converted to Garrett scores using Garrett table of score conversion. For each constraint, the Garrett Mean Score (GMS) was calculated by summing individual Garrett scores and dividing by number of respondents. Constraints were hierarchically ranked based on descending Garrett Mean Scores, with higher scores indicating greater severity. This technique offers superior analytical rigor compared to simple frequency distributions as it accounts for complete ranking patterns and provides interval-level measurement enabling meaningful score

comparisons.

Results and Discussion

Profile characteristics of respondents

The socio-economic and psychological profile of respondents (Table 1) reveals important demographic patterns. Age distribution showed predominance of middle-aged farmers (51.67%), followed by elderly (25.00%) and young farmers (23.33%). This pattern reflects typical farming demographics in Telangana where agriculture remains primarily a middle-aged occupation, with limited youth engagement a concerning trend for long-term sustainability (Ankhila *et al.* 2023) [1]. The lower representation of young farmers (less than one-fourth) indicates potential labor migration and limited intergenerational succession in agriculture.

Educational attainment showed encouraging distribution with only 1.67% illiteracy, while majority possessed high school (35.00%) and intermediate (26.67%) education. This relatively favorable literacy profile suggests potential for understanding technical information when presented appropriately. However, post-graduation representation remained marginal (3.33%), indicating limited penetration of advanced agricultural education. Similar educational patterns among SHC beneficiaries were documented by Madhuri *et al.* (2024) [6] in Andhra Pradesh.

Landholding distribution reflected typical agrarian structure with small farmers (36.67%) and semi-medium farmers (26.67%) constituting majority, while marginal farmers represented 20.00%. This predominance of smaller operational holdings has critical implications for SHC adoption, as resource constraints often limit implementation capacity despite awareness. Large farmers with holdings exceeding 10 hectares comprised only 1.66%, indicating minimal presence of commercial farming enterprises in the study area.

Farming experience displayed normal distribution with 46.66% having medium experience, 30.00% high experience, and 23.34% low experience. Extension contact and training exposure both showed medium levels for approximately half the sample (52.50% and 48.34% respectively), suggesting moderate but improvable engagement with agricultural knowledge systems. Psychological variables—scientific orientation, economic motivation, achievement motivation, and innovativeness—predominantly exhibited medium categories (43.33% to 48.33%), indicating that while farmers possess baseline receptivity to scientific practices, intensified capacity building could elevate these attributes to support enhanced adoption.

Technical constraints in SHC adoption

Technical constraints represent systemic deficiencies in scheme design and implementation processes that impede effective utilization of SHC recommendations. Garrett ranking analysis (Table 2) identified critical technical barriers that farmers encounter.

Table 1: Distribution of respondents based on their personal, socio-economic and psychological attributes of the farmers under the study

n = 120				
S. No.	Variable	Category	Respondents	
			Frequency	Percentage (%)
1	Age			
		Young age (up to 35 years)	28	23.33
		Middle age (35 to 50 years)	62	51.67
		Old age (above 55 years)	30	25.00
2	Education			
		Illiterate	02	01.67
		Primary school	24	20.00
		High school	42	35.00
		Intermediate	32	26.67
		Under graduation	16	13.33
		Post graduation and above	04	03.33
3	Farm size			
		Marginal (0.1-1.0 ha)	24	20.00
		Small (1.1-2.0 ha)	44	36.67
		Semi-medium (2.1-4.0 ha)	32	26.67
		Medium (4.1-10.00 ha)	18	15.00
		Large (above 10.00 ha)	02	01.66
4.	Farming Experience			
		Low farming experience	28	23.34
		Medium farming experience	56	46.66
		High farming experience	36	30.00
5.	Training undergone			
		Low	33	27.50
		Medium	58	48.34
		High	29	24.16
6.	Extension Contact			
		Low	25	20.83
		Medium	63	52.50
		High	32	26.67
7.	Scientific Orientation			
		Low	38	31.67
		Medium	54	45.00
		High	28	23.33
8.	Economic Motivation			
		Low	32	26.67
		Medium	52	43.33
		High	36	30.00
9.	Achievement Motivation			
		Low	30	25.00
		Medium	53	44.17
		High	37	30.83
10.	Innovativeness			
		Low	34	28.33
		Medium	58	48.33
		High	28	23.34

Table 2: Distribution of respondents based on their technical Constraints

n = 120

S. No.	Constraints faced	Garrett Mean Score (GMS)	Rank
I. Technical Constraints:			
1.	Time gap between soil sample taken and issuing card is very long	62.45	II
2.	Improper information about micronutrient status in soil	65.82	I
3.	Lack of regular monitoring and follow-up by extension personnel	59.73	III
4.	Inadequate awareness about importance of micronutrients	55.48	V
5.	Complexity of soil sampling procedures	57.12	IV
6.	Lack of pre-seasonal training programs	53.67	VI
7.	Limited participation in field demonstrations	48.91	
8.	Insufficient information on correction measures for soil pH problems	51.23	VII

Inadequate information on micronutrient deficiency status emerged as the foremost technical constraint (Garrett Mean Score 65.82, Rank I). Despite the scheme's mandate to assess 12 parameters including five micronutrients, farmers reported that SHC reports frequently lacked comprehensive diagnostic information on Zn, Fe, Cu, Mn, and B deficiencies. This lacuna critically undermines the scheme's objective of promoting balanced nutrition, as micronutrient malnutrition represents a pervasive soil health challenge across Indian agroecosystems. The inadequacy may stem from analytical limitations in soil testing laboratories, where infrastructure and reagent availability for micronutrient analysis often lag behind capacity for macro-nutrient testing. This finding corroborates Lade *et al.* (2024) ^[5] who documented similar information deficits regarding micronutrient status in Vidarbha region.

Delayed issuance of Soil Health Cards ranked second (GMS 62.45, Rank II), constituting a major service delivery bottleneck. Farmers reported temporal gaps exceeding 4-6 months between sample collection and card receipt, by which time cropping seasons had advanced beyond optimal fertilizer application windows. This delay negates the scheme's utility for current season planning, forcing farmers to rely on conventional practices rather than scientific recommendations. The constraint reflects infrastructural inadequacies in soil testing laboratories including equipment breakdowns, staff shortages, and overwhelming sample loads during peak collection periods. Patel *et al.* (2023) ^[8] similarly identified delayed reporting as a primary constraint in Bihar, emphasizing the nationwide nature of this implementation gap.

Lack of regular monitoring and follow-up by extension personnel (GMS 59.73, Rank III) emerged as another significant technical barrier. SHC distribution represents only the initial step; effective adoption requires sustained extension support for interpretation, doubt clarification, and implementation guidance. However, farmers reported minimal post-distribution contact, leaving them to independently decipher technical recommendations without professional assistance. This extension vacuum particularly disadvantages less educated farmers and those cultivating diverse cropping systems requiring complex nutrient scheduling.

Other technical constraints included complexity of soil sampling procedures (GMS 57.12, Rank IV), inadequate awareness about importance of micronutrients (GMS 55.48, Rank V), lack of pre-seasonal training programs (GMS 53.67, Rank VI), insufficient information on correction measures for soil pH problems (GMS 51.23, Rank VII), and limited participation in field demonstrations (GMS 48.91, Rank VIII). These constraints collectively reflect systemic weaknesses in capacity building, knowledge dissemination, and extension service quality that must be addressed through institutional strengthening.

Operational constraints limiting implementation

Operational constraints encompass practical barriers related to input availability, affordability, and market access that prevent farmers from implementing SHC recommendations even when technically understood and accepted. Garrett ranking analysis (Table 3) revealed the severity hierarchy of operational impediments.

Table 3: Distribution of respondents based on their operational Constraints

n = 120

S. No.	Constraints faced	Garrett Mean Score (GMS)	Rank
II. Operational Constraints:			
1.	High cost and unaffordability of fertilizers	64.21	II
2.	Non-availability of recommended micronutrients in local markets	68.34	I
3.	Inadequate credit availability for purchasing recommended inputs	58.45	IV
4.	Insufficient technical guidance on timing and methods of application	52.67	VI
5.	Difficulty in calculating fertilizer doses as per recommendations	61.78	III
6.	Absence of institutional mechanisms for collective procurement at reasonable prices	49.82	VII
7.	Lack of custom hiring services for application equipment	55.23	V

Non-availability of recommended micronutrients in local markets constituted the most severe operational constraint (Garrett Mean Score 68.34, Rank I). While SHC reports specify application of Zinc Sulfate, Ferrous Sulfate, Borax, or other micronutrient fertilizers, procurement remained problematic as local input dealers predominantly stock only NPK fertilizers with limited micronutrient inventory. This supply chain gap forces farmers to either travel considerable distances to district headquarters or abandon micronutrient application altogether. The constraint becomes particularly acute in remote villages with poor connectivity. Similar input availability challenges were documented by Kumar (2025) ^[4] in Madhya Pradesh and Ohlan *et al.* (2025) ^[7] in Haryana, suggesting nationwide supply chain inadequacies. High cost and unaffordability of fertilizers ranked second (GMS 64.21, Rank II), reflecting economic barriers to adoption. The removal of fertilizer subsidies for certain products and price volatility in international markets have substantially increased input costs, constraining purchasing power of small and marginal farmers who constitute the majority. Micronutrient fertilizers particularly carry premium prices compared to conventional NPK products. For resource-constrained farmers operating on tight margins, investing in additional fertilizer categories based on soil test recommendations represents economic risk, especially when immediate yield responses remain uncertain.

Difficulty in calculating fertilizer doses as per recommendations (GMS 61.78, Rank III) posed practical implementation challenges. SHC recommendations typically specify nutrients in elemental form (kg/ha of N, P₂O₅, K₂O), whereas farmers purchase commercial fertilizers with varying nutrient concentrations (e.g., Urea 46% N, DAP 18% N and 46% P₂O₅). Converting elemental recommendations into commercial product quantities requires mathematical calculations that many farmers find daunting, particularly those with limited formal education. This computational barrier leads to either non-adoption or approximation errors in fertilizer application, undermining precision nutrient management objectives.

Additional operational constraints included inadequate credit availability for purchasing recommended inputs (GMS 58.45, Rank IV), lack of custom hiring services for

application equipment (GMS 55.23, Rank V), insufficient technical guidance on timing and methods of application (GMS 52.67, Rank VI), and absence of institutional mechanisms for collective procurement at reasonable prices (GMS 49.82, Rank VII). These findings emphasize need for strengthening both input supply chains through decentralized distribution networks and farmer collectives through Producer Organizations and cooperatives for bulk procurement and shared services.

Socio-personal constraints affecting utilization

Socio-personal constraints reflect individual and social-structural factors influencing farmers' capacity and willingness to engage with SHC recommendations. Garrett ranking (Table 4) identified critical socio-personal barriers.

Table 4: Distribution of respondents based on their Socio-personal Constraints

n = 120

S. No.	Constraints faced	Garrett Mean Score (GMS)	Rank
III. Socio-personal Constraints:			
1.	Lack of awareness about scheme benefits	55.67	IV
2.	Perception of self-interest and corruption among agriculture officers	58.34	III
3.	Difficulty in understanding and interpreting soil test-based recommendations	63.56	I
4.	Limited interest in adopting new practices	52.91	V
5.	Inadequate educational background limiting scientific understanding	61.89	II
6.	Conservative attitudes among elderly farmers resistant to change	49.78	VI
7.	Inadequate family support for implementing recommendations	47.12	VII

Difficulty in understanding and interpreting soil test-based recommendations emerged as the paramount socio-personal constraint (Garrett Mean Score 63.56, Rank I). SHC reports employ technical terminology, numerical data, and scientific concepts that many farmers find incomprehensible without professional interpretation. Terms like 'electrical conductivity,' 'organic carbon percentage,' 'available phosphorus,' and specific numerical thresholds require background knowledge often absent among farming communities. This comprehension gap transforms potentially valuable information into cryptic data, severely limiting actionable utility. The finding aligns with Madhuri *et al.* (2024) ^[6] who reported that only 66% of aware farmers could understand SHC recommendations in Andhra Pradesh.

Inadequate educational background limiting scientific understanding ranked second (GMS 61.89, Rank II). While overall literacy was relatively high, scientific literacy specific to soil science and agronomy remained low. Understanding nutrient dynamics, soil chemistry, and fertilizer response relationships requires conceptual frameworks that formal schooling without agricultural specialization does not necessarily provide. This educational deficit necessitates supplementary capacity building through extension education, yet as documented earlier, such training remains inadequate.

Perception of self-interest and corruption among agriculture officers (GMS 58.34, Rank III) reflected trust deficits in extension systems. Some farmers expressed skepticism that SHC recommendations might favor particular fertilizer brands or be influenced by commercial interests rather than scientific objectivity. This credibility gap undermines confidence in recommendations and reduces adoption likelihood. Building trust requires transparent operations, conflict-of-interest disclosure, and farmer-centric extension approaches that prioritize beneficiary welfare over bureaucratic convenience.

Other socio-personal constraints included lack of awareness about scheme benefits (GMS 55.67, Rank IV), limited interest in adopting new practices (GMS 52.91, Rank V), conservative attitudes among elderly farmers resistant to change (GMS 49.78, Rank VI), and inadequate family support for implementing recommendations (GMS 47.12, Rank VII). These findings emphasize need for social mobilization, peer learning platforms, and demonstration-based extension to shift normative perceptions and build social capital supporting innovation adoption.

Psychological constraints influencing adoption

Psychological constraints encompass attitudinal, motivational, and perceptual factors operating at individual cognitive level that influence technology acceptance and implementation behavior. Garrett analysis (Table 5) prioritized psychological barriers.

Table 5: Distribution of respondents based on their Psychological Constraints

n = 120			
S. No.	Constraints faced	Garrett Mean Score (GMS)	Rank
IV. Psychological Constraints:			
1.	Lack of motivation to adopt soil health practices	66.78	I
2.	Preference for traditional practices over scientific recommendations	59.87	III
3.	Perception that benefits are too distant or uncertain	53.45	V
4.	Fear of yield reduction or lack of faith in scientific results	63.45	II
5.	Skepticism about accuracy of soil testing	56.23	IV
6.	Fatalistic attitude attributing outcomes to fate rather than management	48.12	VII
7.	Lack of confidence in implementing complex recommendations	50.78	VI

Lack of motivation to adopt soil health practices constituted the foremost psychological constraint (Garrett Mean Score 66.78, Rank I). This motivational deficit reflects farmers' failure to perceive tangible benefits or immediate returns from implementing SHC recommendations. Unlike yield-enhancing technologies with visible, short-term impacts, soil health improvements manifest gradually over multiple cropping cycles, creating perception that benefits are distant or uncertain. Additionally, when micronutrient applications do not produce dramatic yield increases in nutrient-sufficient soils, farmers may conclude recommendations are ineffective, reinforcing apathy. Motivation enhancement requires result demonstrations, success story documentation, and economic impact quantification to make benefits tangible and proximate rather than abstract and distant.

Fear of yield reduction or lack of faith in scientific results ranked second (GMS 63.45, Rank II). Some farmers expressed apprehension that reducing fertilizer doses as recommended for high-nutrient soils might compromise yields, particularly when recommendations deviate substantially from traditional practices. This risk aversion stems from livelihood dependency on agricultural income where yield losses translate directly into economic hardship. Past experiences with failed recommendations from extension agencies compound this skepticism. Building confidence requires participatory on-farm trials where farmers observe results on their own fields with scientific support, reducing perceived risk.

Other psychological barriers included preference for traditional practices over scientific recommendations (GMS 59.87, Rank III), skepticism about accuracy of soil testing (GMS 56.23, Rank IV), perception that benefits are too distant or uncertain (GMS 53.45, Rank V), lack of confidence in implementing complex recommendations (GMS 50.78, Rank VI), and fatalistic attitude attributing outcomes to fate rather than management (GMS 48.12, Rank VII). These findings emphasize need for cognitive-behavioral interventions through experiential learning, social proof via farmer-to-farmer diffusion, and participatory approaches that build self-efficacy and shift locus of control toward internal attribution.

Integrated constraint analysis and theoretical perspectives

The multidimensional constraint analysis reveals that SHC adoption is impeded by complex, interacting barriers operating across technical, operational, socio-personal, and psychological domains. This finding aligns with technology adoption theories that conceptualize adoption as a multi-stage process influenced by innovation attributes, adopter characteristics, social systems, and organizational infrastructure (Rogers 2003) ^[11]. The relatively higher severity of technical and operational constraints compared to socio-personal and psychological barriers suggests that systemic implementation failures constitute more critical impediments than individual farmer limitations—an important insight contradicting deficit models that blame non-adoption on farmer ignorance or backwardness.

The prominence of micronutrient-related constraints—inadequate information, non-availability in markets—reflects a systemic blind spot in Indian agricultural input systems historically focused on NPK fertilizers. Despite accumulating scientific evidence of widespread micronutrient deficiencies affecting crop quality and human nutrition, institutional responses remain inadequate. The SHC scheme's diagnostic capacity for micronutrients must be matched by corresponding supply chain development and farmer awareness campaigns to realize balanced nutrition objectives.

Delayed card issuance represents a critical service delivery failure that undermines scheme credibility and utility. International best practices in soil testing services emphasize turnaround times of 7-14 days to enable timely fertilizer planning. Achieving such standards requires substantial investment in laboratory infrastructure, human resources, and process automation. The recent technological interventions including mobile applications and GIS-integrated portals represent positive steps, but must be complemented by grassroots-level laboratory strengthening.

The comprehension difficulties highlighted in socio-personal constraints indicate need for transformative changes in how SHC information is communicated. Current text-heavy, data-intensive reports must evolve toward farmer-friendly formats incorporating visual aids, vernacular language, simplified advisories, and actionable prescriptions. Successful precedents exist in other countries where soil test reports include color-coded nutrient status indicators, pictorial application guides, and crop-specific management calendars that enhance farmer understanding without requiring scientific literacy.

The motivational and psychological barriers emphasize need for behavioral interventions beyond information dissemination. Creating demonstration plots showing yield impacts of SHC-based management versus conventional practices can provide social proof and build confidence. Farmer Producer Organizations can serve as platforms for peer learning and collective problem-solving. Extension approaches must shift from didactic knowledge transfer to facilitative problem-solving that respects farmer knowledge while introducing scientific innovations.

Policy Implications and Recommendations

The constraint analysis yields several critical policy implications for strengthening SHC scheme implementation and enhancing adoption levels. These recommendations target systemic improvements across institutional, technical, and programmatic dimensions.

- **Laboratory infrastructure strengthening:** Accelerate establishment of Village-Level Soil Testing Laboratories beyond current 665 units to achieve district-level density ensuring accessibility within 15-20 km radius. Equip laboratories with modern analytical instruments for rapid micronutrient testing. Implement quality assurance protocols through inter-laboratory proficiency testing. Deploy mobile soil testing vans for remote areas. Establish turnaround time benchmarks of maximum 14 days from sample collection to card distribution, with digital tracking systems for transparency.
- **Farmer-friendly communication redesign:** Redesign SHC formats to incorporate visual communication elements including color-coded nutrient status indicators (red for deficient, yellow for medium, green for sufficient), pictorial application guides showing recommended practices, simplified explanations avoiding technical jargon, and crop-specific management calendars aligned with local cropping patterns. Develop multi-media content including video advisories in Telugu demonstrating interpretation and implementation. Print recommendations on durable, weather-resistant material to ensure longevity beyond single season.
- **Pre-seasonal capacity building:** Mandate pre-seasonal training programs for all SHC recipients organized by Rythu Vignana Kendras and Agricultural Extension Officers. Training curriculum should cover soil health concepts, interpretation of test reports, calculation of fertilizer doses, micronutrient identification and application, organic amendments, and soil pH correction. Employ participatory methods including hands-on demonstrations, farmer-to-farmer learning, and on-farm trials. Target 100% training coverage of

SHC beneficiaries within three months of card distribution.

- **Extension follow-up mechanisms:** Institutionalize systematic post-distribution follow-up through field visits by Agricultural Extension Officers within one month of card issuance for doubt clarification and implementation support. Establish mobile-based helplines connecting farmers with soil scientists for real-time query resolution. Create WhatsApp groups at village level for peer learning and continuous engagement. Develop farm-specific advisories rather than generic recommendations to enhance relevance.
- **Input supply chain enhancement:** Establish Village Nutrient Banks or Soil Health Centers stocking comprehensive range of fertilizers including micronutrients, secondary nutrients, organic amendments, and soil ameliorants. Incentivize private input dealers to maintain micronutrient inventory through minimum stocking requirements in licensing regulations. Facilitate collective procurement through Farmer Producer Organizations to achieve economies of scale and reduce prices. Explore subsidy mechanisms specifically for micronutrient fertilizers to enhance affordability.
- **Result demonstration and impact documentation:** Establish long-term demonstration plots in each village comparing SHC-based management versus conventional practices, monitoring yield, quality, input costs, and net returns over multiple seasons. Document and disseminate success stories of farmers achieving productivity gains and cost savings through SHC adoption. Conduct participatory field days enabling peer observation of results. Commission independent impact assessments quantifying economic, environmental, and soil health benefits to build evidence base.
- **Convergence with complementary schemes:** Integrate SHC scheme with Pradhan Mantri Krishi Sinchai Yojana for precision nutrient management under irrigation, with Mission Organic Value Chain Development for promoting organic alternatives, with Paramparagat Krishi Vikas Yojana for natural farming systems, and with Kisan Credit Card for ensuring credit availability for inputs. Leverage MGNREGS for soil conservation activities recommended in SHCs. Ensure complementarity rather than fragmentation across agricultural programs.

Conclusion

This investigation systematically examined the multidimensional constraints limiting adoption of Soil Health Card recommendations among farming communities in Karimnagar district. The constraint hierarchy identified through Garrett ranking technique reveals that implementation barriers predominantly stem from systemic service delivery failures rather than farmer inadequacies. Technical constraints—particularly inadequate micronutrient information and delayed card issuance—constitute primary impediments. Operational barriers centered on input non-availability and unaffordability further compound adoption challenges. Socio-personal constraints reflect communication gaps necessitating information redesign, while psychological factors emphasize need for experiential learning and motivation enhancement.

The findings underscore that the Soil Health Card scheme, despite its conceptual soundness and policy significance, suffers from critical implementation deficits that prevent realization of intended benefits. Bridging the awareness-adoption gap requires systemic improvements spanning laboratory infrastructure strengthening for timely reporting, farmer-friendly communication redesign for enhanced comprehension, intensive pre-seasonal capacity building for skill development, robust extension follow-up mechanisms for implementation support, input supply chain development ensuring availability and affordability, result demonstrations for motivation enhancement, and programmatic convergence for holistic impact.

Future research should examine differential constraints faced by distinct farmer categories (small versus large, educated versus less educated, progressive versus traditional) to enable targeted interventions. Longitudinal studies tracking constraint evolution across multiple SHC cycles would reveal whether implementation improves with program maturity. Comparative analyses across states with varying implementation models could identify best practices for replication. Impact assessments quantifying agronomic, economic, and environmental outcomes of sustained SHC adoption would strengthen evidence base for continued policy support. Ultimately, transforming the SHC scheme from a card distribution exercise into a genuine soil health improvement program requires addressing these multifaceted constraints through coordinated institutional action and sustained political commitment.

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