

ADOPTION OF SOIL HEALTH CARD-ALIGNED FERTILIZATION AND ECONOMIC RETURNS OF GROUNDNUT SYSTEMS

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ABSTRACT

This study focused on the adoption of Soil Health Card (SHC)-aligned fertilization in groundnut cultivation across India, highlighting its economic and agronomic implications from 2015/16 to 2022/23. Through detailed analysis of national and state-level data, including a snapshot from *kharif* 2022, the research explored area, production, and yield trends alongside rainfall variability using India Meteorological Department (IMD) data. Findings showed a steady cultivation area coupled with yield improvements attributed in part to SHC-guided nutrient management, although yields remained sensitive to climatic and input fluctuations. Economic assessments, based on Minimum Support Price (MSP), indicated that SHC fertilization potentially raised gross returns by 56%, underscoring the financial benefits of balanced, site-specific nutrient application. The study highlighted that embedding SHC in climate-aware management frameworks, ensuring timely last-mile input delivery, and strengthening extension services were critical for translating recommendations into stable on-farm outcomes. In conclusion, results suggested that SHC adoption holds potential as a viable pathway for yield-led, MSP-anchored income growth in India's groundnut systems, but its success hinges on synchronising nutrient advice with rainfall outlooks, market access, and input logistics. The findings reinforce that sustainable gains in productivity and farm incomes will depend on aligning policy, extension, and climate-resilient agronomy, making SHC not only a soil fertility tool but also a model for linking sustainable agriculture with rural economic resilience.

(Key words: Soil Health Card, groundnut, fertilisation, MSP, rainfall variability)

INTRODUCTION

Groundnut cultivation represented a critical node in India's oilseed economy, linking rainfed farming systems with household income security and regional market dynamics across semi-arid and sub-humid zones (Heba *et al.*, 2021). At the same time, soil fertility management emerged as a central constraint and opportunity, given the crop's sensitivity to nutrient balance and moisture variability that shaped outcomes more than intended management alone. Policy attention to oilseeds, including periodic recalibration of support prices, aimed to stabilize incentives, but the realized benefits appeared to depend on how well nutrient advice was translated into field practice under variable weather and input access conditions (Mohanty *et al.*, 2022). Adopting balanced organic nutrient strategies along with moisture-conserving practices can improve soil health, enhance productivity and ensure sustainable groundnut cultivation (Karunakaran *et al.*, 2024).

The Soil Health Card (SHC) scheme, initiated in 2015, sought to correct long-standing nutrient imbalances by giving field-specific fertilizer and micronutrient

recommendations based on soil tests (Anonymous, 2015-16), which, in principle, reduced waste and improved returns. Independent evaluations reported reductions in chemical fertilizer use of roughly 81% and yield improvements on the order of 56% when recommendations were followed (Anonymous, 2024a; Bana *et al.*, 2024), though adoption bottlenecks and input availability issues tempered the aggregate effect in some places (Chinnadurai *et al.*, 2014; Ravikumar *et al.*, 2019). Subsequent official syntheses echoed these findings, suggesting that efficiency gains were plausible where recommendations, inputs, and extension support aligned in time and place (Anonymous, 2024a).

National statistics indicated that groundnut remained a major field crop tracked consistently in India's official agricultural compendia, enabling analysis of area production/yield trends as well as state-wise dispersion relevant to rainfed contexts (Anonymous, 2023a). These datasets supported a structured look at how yields moved relative to cultivation area and how production shifts might have reflected management changes interacting with seasonal rainfall (Anonymous, 2022b). In parallel, *kharif*-

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focused snapshots and state tables facilitated cross-sectional comparisons that were necessary to understand adoption environments beyond national averages.

Given the crop's tradability and price risk exposure, the Minimum Support Price (MSP) provided a useful valuation baseline for assessing gross returns under observed and counterfactual yield scenarios aligned to SHC guidance. Over the 2013-14 to 2022-23 period, official releases recorded substantial MSP increases for major oilseeds, including groundnut (Anonymous, 2018-24; Anonymous, 2023-24b), which likely improved the payoff to even modest yield gains from better-balanced fertilisation in years when procurement and market conditions allowed pass-through to farm-gate prices. Still, pricing signals alone did not guarantee realized income gains where weather shocks or input bottlenecks limited response to recommendations, making agronomy and timing as consequential as nominal price floors (Anonymous, 2018-24).

IMD's subdivision-wise rainfall statistics for 2022 underscored how spatially uneven monsoon performance could be, with several sub-divisions falling into deficient categories and others recording excess or normal conditions (Anonymous, 2022b). These conditions typically mediated the response of nutrient applications in rainfed groundnut. In such settings, the same fertilizer plan could pay off in one district and underperform in another purely due to rainfall distribution and timing, which hinted that SHC advice worked best when paired with climate-aware scheduling and moisture management. This sensitivity suggested that adoption metrics needed to be read together with rainfall and input access to avoid over- or under-attributing performance to fertilizer alone (Anonymous, 2022b).

Evidence of yield and cost efficiencies associated with SHC was encouraging, but adoption frictions ranging from interpretation of recommendations to the timely availability of sulphur, zinc, and other inputs appeared to limit full realisation of benefits in various pockets. Input cost dynamics, reflected in broader agricultural price indices, also influenced whether farmers stayed the course with balanced fertilisation, especially when liquidity was tight or advisory support was intermittent (Anonymous, 2024b). Against this backdrop, groundnut offered a revealing case to examine how soil-test-based advice translated into economic returns in a rainfed oilseed where rainfall and market context could tilt final outcomes either way (Palai *et al.*, 2024).

This study aimed to document national area production yield movements for groundnut from 2015-16 to 2022-23 using official statistics; examine state-wise dispersion in *kharif*, 2022 with explicit reference to rainfall categories; and assess gross returns under MSP by simulating SHC-aligned yield increments consistent with evaluation evidence on input savings and yield response. In doing so, the analysis intended to connect agronomic recommendations to price-linked farm economics while

foregrounding rainfall variability and adoption constraints that formed realized benefits on the ground (Anonymous, 2023a; Anonymous, 2022b).

MATERIALS AND METHODS

Study scope

The study covered groundnut cultivation in India from 2015-16 to 2022-23 using national area-production-yield (APY) time-series, and a cross-sectional comparison for *kharif* 2022 across major producing states to align agronomic outcomes with rainfall categories. The scope emphasized rainfed sensitivity, policy framing through Minimum Support Prices (MSP), and SHC-aligned yield scenarios to link agronomy with farm-gate valuation (Anonymous, 2023a; Anonymous, 2023-24a).

Data sources

National APY statistics were drawn from Agricultural Statistics at a Glance 2023 compiled by the Directorate of Economics and Statistics (Anonymous, 2023a), enabling consistent measurement across years and states. Rainfall categories and subdivision-wise distributions for 2022 were taken from IMD's Rainfall Statistics of India (Anonymous, 2022b), which classified regions into deficient, normal, and excess for seasonal interpretation. MSP values for groundnut (marketing season 2022-23) were taken from official Cabinet Committee on Economic Affairs releases disseminated by PIB to anchor gross return estimates (Anonymous, 2018-24).

Variables and measurement

Core variables included area (hectares), production (tonnes), yield (kg ha^{-1}), and MSP (₹ Quintal^{-1}), with APY harmonized to official reporting formats for comparability. Yield was computed as $Y = P/A$, where P is production and A is area, consistent with standard agricultural measurement practice (Heba *et al.*, 2021). Gross return ha^{-1} was calculated as $\text{GR} = (\text{yield} \times \text{MSP}) / 100$, converting kilograms to quintals to match MSP units for valuation (Anonymous, 2023a).

Rainfall classification

Rainfall exposure for *kharif* 2022 was assigned using IMD's subdivision and state alignments (Anonymous, 2022a), categorizing states into deficient, normal, or excess bands to reflect moisture regimes relevant for rainfed groundnut response. These categories were used to interpret state-wise yield dispersion and to cautiously attribute performance where moisture stress or surplus likely mediated nutrient response. Where subdivisions cut across state boundaries, the prevailing category for major groundnut zones in the state was applied to maintain agronomic relevance (Anonymous, 2022b).

Analytical framework

Descriptive statistics summarized APY levels and dispersion over time, with trend and growth indicators used to profile movements from 2015-16 to 2022-23 at national

scale (Anonymous, 2023a). Cross-sectional analysis for *kharif* 2022 compared state yields alongside rainfall categories to examine whether observed productivity aligned with moisture conditions in that season (Anonymous, 2022a; and 2022b). Correlation checks between area and production supported interpretation of expansion versus productivity effects, while remaining descriptive rather than causal due to confounding from weather and input access (Anonymous, 2023a).

SHC-aligned scenarios

Impact evaluation evidence on SHC reported yield improvements in the 56% band under adherence to recommendations (Anonymous, 201516; Bana *et al.*, 2024; Paramasivan *et al.*, 2024), which was used to build counterfactual yield scenarios on top of observed 202223 yields. Two scenarios were simulated: $Y^{(5\%)} = 1.05 (Y)$ and $Y^{(6\%)} = 1.06 (Y)$ with corresponding gross returns to approximate the income effect of balanced, soil-test-based fertilization. These were interpreted as indicative, contingent on rainfall adequacy and timely access to recommended macro- and micronutrients (Anonymous, 2024a; Rajendran & Subramanian, 2024).

Economic valuation

Valuation used MSP for groundnut as the pricing baseline for gross returns, reflecting official support prices relevant to farm-gate assessments during the period of interest (Anonymous, 201824). Where context on price movements or market orientation was required, groundnut outlook reports were consulted to ensure alignment with seasonality and procurement frames, while keeping MSP as the primary metric for comparability (Anonymous, 2023 24a).

Data processing

Time-series APY were standardized to consistent units and checked for internal coherence across editions to avoid spurious comparisons (Anonymous, 2023a), with state identifiers harmonized for the *kharif* 2022 cross-section (Anonymous, 2022a). Rainfall categories were merged to state records with season-specific tags (Anonymous, 2022b), and MSP figures were matched to the corresponding marketing season to ensure correct pricing alignment in valuation (Anonymous, 201824; Anonymous, 2024b).

RESULTS AND DISCUSSION

Results indicated that national groundnut output growth over 201516 to 202223 was led mainly by yield gains rather than area expansion, but those gains appeared sensitive to rainfall variability and input access (Anonymous, 2023a; Anonymous, 2022b), with SHC-aligned fertilisation associated with modest 56% yield improvements (Paramasivan *et al.*, 2024; Bana *et al.*, 2024) and proportional MSP-linked income benefits when recommendations were adopted (Anonymous, 2018-2024). State-level outcomes in *kharif* 2022 varied sharply, with higher yields in rain-favoured regions and clear penalties

where moisture was deficient, underscoring the need for climate-aware nutrient management and timely supply of secondary and micronutrients (Bana *et al.*, 2024).

Production dynamics

National data showed that groundnut area remained broadly stable while production rose on the back of higher yields through the late 2010s, before moderating in 202223, a pattern consistent with incremental agronomic improvements and season-to-season weather effects in rainfed belts (Anonymous, 2023a). This trajectory aligned with a management story where balanced fertilisation and better nutrient targeting contributed to productivity, yet final outcomes still hinged on monsoon distribution and timeliness of field operations (Mohanty *et al.*, 2022). Evaluations of the SHC programme reported yield improvements in the 56% range under adherence to recommendations, suggesting a plausible agronomic channel for part of the observed national gains where extension, inputs, and rainfall aligned (Paramasivan *et al.*, 2024).

Rainfall-yield relationships

Rainfall statistics for 2022 highlighted substantial spatial heterogeneity - some meteorological subdivisions fell into deficient categories while others registered normal or excess implying uneven moisture availability across groundnut geographies in *kharif* 2022 (Anonymous, 2022b). Given groundnut's predominantly rainfed cultivation, this spread likely mediated the payoff to fertilizer balancing, with adequate and well-timed rains amplifying response and deficits damping it even when agronomy was sound. Interpreting yield movements against rainfall categories therefore appeared essential to avoid attributing weather-driven variance to fertilizer effects alone (Anonymous, 2022b).

State dispersion in *kharif* 2022

A cross-sectional look at *kharif* 2022 confirmed wide yield dispersion across major producing states, with Rajasthan at approximately 2,179 kg ha⁻¹ and Gujarat near 1,647 kg ha⁻¹, while Uttar Pradesh and Andhra Pradesh registered considerably lower yields around 830 kg ha⁻¹ and 429 kg ha⁻¹ respectively, mirroring rainfall and local constraints reported by the field survey (Anonymous, 2023a). States with normal to excess rainfall tended to show higher realised yields and larger production volumes, while deficient categories lined up with depressed performance, reinforcing moisture as a first-order driver in rainfed response to nutrient management (Anonymous, 2022b; Heba *et al.*, 2021). These contrasts implied that SHC recommendations worked best when paired with state-specific timing, moisture management, and assured access to recommended sulphur, zinc, and other inputs (Ravikumar *et al.*, 2019).

Economic returns under MSP framing

With MSP for groundnut set at ₹ 5,550 quintal⁻¹ for marketing season of 202223 (Anonymous, 202324a), gross return hectare⁻¹ scaled directly with yield, making even modest productivity gained financially meaningful in

procurement-aligned markets. Under SHC-aligned scenarios, an indicative 56% yield uplift translated almost one-for-one into higher gross returns at MSP, conditional on rainfall adequacy and timely availability of the recommended nutrient basket to realize the agronomic response (Bana *et al.*, 2024; Paramasivan *et al.*, 2024). Where monsoon distribution or input access fell short, that pass-through likely weakened, which may explain attenuated returns in some rain-stressed or logistics-constrained pockets during the season (Anonymous, 2022b).

Adoption and constraints

Impact syntheses of SHC pointed to dual realities: measurable improvements in fertilizer balance and modest yield gains where recommendations were followed, alongside adoption frictions such as interpretation gaps, delayed card delivery, and inconsistent availability of secondary and micronutrients (Anonymous, 201516; Anonymous, 2024a). These frictions were consequential in rainfed groundnut, where missing a rainfall window or lacking a key micronutrient often erased the expected response despite correct base-NPK application (Chinnadurai *et al.*, 2014), suggesting that advisory and supply coordination mattered as much as prescription accuracy. Integrating rainfall monitoring with last-mile input logistics and practical extension guidance thus appeared necessary to convert SHC advice into stable on-farm returns across variable seasons (Rajendran and Subramanian, 2024).

Implications

Results collectively suggested that productivity-led growth in groundnut was feasible and had likely occurred where agronomy, inputs, and rainfall aligned, but resilience remained thin in moisture-stressed contexts without complementary scheduling and input support (Anonymous, 2023a). MSP provided a clear pricing baseline that magnified the value of small yield gains, yet stable realisation required procurement access and market conditions that could transmit those gains to farm incomes in-season (Anonymous, 2023-2024a). SHC's promise was most evident when embedded in climate-aware management and reliable input supply chains, particularly for sulphur and zinc, which repeatedly emerged as binding elements in farmer adoption narratives and measured outcomes (Bana *et al.*, 2024).

The study concluded that adopting SHC aligned fertilization in India's groundnut systems was a viable pathway to raise productivity and farm incomes, provided rainfall, input access, and extension support aligned in practice (Anonymous, 2022a). In short, yield-led gains paired with MSP-anchored valuation translated into tangible economic benefits, but the realised outcomes hinged on climate variability and the timely availability of recommended macro- and micronutrients (Paramasivan *et al.*, 2024).

Overall assessment

Across 201516 to 202223, national area remained broadly steady while output growth was driven primarily by yield improvements, indicating that better nutrient management and incremental agronomic advances were

already moving the needle where seasons cooperated (Anonymous, 2023a). Given groundnut's rainfed footprint, the payoff to SHC guidance proved sensitive to rainfall distribution, underscoring why identical prescriptions performed differently across states and seasons in *kharif* 2022 (Anonymous, 2022b). Framed against MSP, even modest SHC-consistent yield uplifts translated nearly one-for-one into higher gross returns in years when procurement and market channels transmitted the price signal (Anonymous, 201824).

Quantitative synthesis

Official statistics supported a yield led production trajectory through the late 2010s with moderation in 2022-23, consistent with season-to-season monsoon variance affecting rainfed belts and the stability of area under cultivation (Anonymous, 2023a). SHC evaluations reported approximate 56% yield gains under adherence, which when combined with the prevailing MSP for groundnut suggested meaningful income increments at the plot level where rainfall and input logistics aligned (Bana *et al.*, 2024; Paramasivan *et al.*, 2024). The evidence base thus pointed to a credible agronomic channel for gains, while cautioning that realised benefits were contingent on local moisture and input conditions (Anonymous, 2022a).

Adoption and constraints

Documented adoption frictions—interpretation gaps, delayed card delivery, and inconsistent access to sulphur, zinc, and other inputs—limited the translation of prescriptions into stable outcomes, especially in rainfed systems where missing a rainfall window negated response (Chinnadurai *et al.*, 2014; Ravikumar *et al.*, 2019). Rainfall heterogeneity in 2022, with sub-divisions classified as deficient, normal, or excess, further explained cross-state yield dispersion and cautioned against attributing weather-driven variance to fertilizer practice alone (Anonymous, 2022b). Together, these constraints clarified why SHC's average impacts were modestly positive but uneven across space and time (Rajendran and Subramanian, 2024).

Policy and practice implications

MSP provided a clear valuation baseline, magnifying the value of small productivity gains, but farm gate realisation depended on procurement access and in-season market conditions, not just announced prices (Anonymous, 202324b). Embedding SHC in climate-aware scheduling, last-mile micronutrient supply (notably sulphur and zinc), and practical extension increased the likelihood that recommendations converted into stable on-farm returns (Bana *et al.*, 2024). National statistics and rainfall diagnostics together suggested that targeting advisory and inputs to moisture outlooks would improve both agronomic efficiency and income reliability (Anonymous, 2023a).

Future directions

Priority actions included strengthening extension for interpretation and timing, assuring micronutrient supply chains, and integrating rainfall monitoring into fertilizer scheduling for rainfed groundnut geographies (Paramasivan

et al., 2024). On the economic side, aligning MSP operations and market access with seasonal realities would help ensure that productivity gains flow through to gross returns with fewer leakages (Anonymous, 201824; Anonymous, 2023 24b). Continued use of official APY datasets to track

dispersion and trend shifts will be essential for evaluating whether climate aware SHC adoption delivers durable, state specific improvements in productivity and livelihoods over subsequent seasons (Anonymous, 2023a).

Table 1. National APY trend summary (201516 to 202223)

Year	Area (M ha)	Production (MT)	Yield (kg ha ⁻¹)
201516	4.61	67.7	1,469
201617	5.33	78.4	1,471
201718	4.73	73.3	1,548
201819	4.56	74.0	1,622
201920	4.77	94.5	1,981
202021	5.52	102.6	1,858
202122	5.10	103.5	1,909
202223	5.55	97.6	1,758

Source: Anonymous, 2023. Directorate of Economics and Statistics, Government of India

Table 2. Groundnut area, yield, and production by state, *kharif* 2022

State	Area (ha)	Yield (kg ha ⁻¹)	Production (MT)	Rainfall category
Gujarat	1,709,000	1,647	2,814,474	Normal/Excess
Rajasthan	789,860	2,179	1,721,136	Excess
Madhya Pradesh	450,000	1,453	653,986	Normal/Excess
Karnataka	369,810	1,279	473,000	Excess
Maharashtra	161,000	1,079	176,678	Normal/Excess
Uttar Pradesh	125,998	830	104,544	Deficient
Andhra Pradesh	506,554	429	217,449	Normal

Sources: Anonymous, Agricultural and Processed Food Products Export Development Authority (APEDA, 2022) and Rainfall Statistics of India, IMD (2022)

Table 3. MSP-based gross returns and SHC scenarios (202223)

Scenario	Yield (kg ha ⁻¹)	MSP (Rs q ⁻¹)	Gross returns (Rs ha ⁻¹)	Observations
Actual 202223	1,758	5,850	102,843	Baseline using observed yield and MSP
+5% SHC-aligned yield	1,846	5,850	107,985	5% impact consistent with evaluations
+6% SHC-aligned yield	1,863	5,850	109,014	6% upper-bound scenario from studies

Source: Anonymous, 2023, Directorate of Economics and Statistics and Anonymous, 20182024 Press Information Bureau (PIB), Government of India

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