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Growth Trends in Soil Fertility Status and Agricultural Extension Services: A Secondary Data-based Analysis

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ABSTRACT

Sustained agricultural productivity depends critically on the maintenance of soil fertility, yet decades of intensive, often nutrient-imbalanced cultivation have altered the macro-, secondary- and micronutrient status of Indian agricultural soils in ways that are not always adequately tracked or addressed through extension outreach. This study employs a secondary data approach to analyse growth trends in (i) the reported fertility status of Indian soils with respect to macronutrients (nitrogen, phosphorus, potassium), secondary nutrients (sulphur) and micronutrients (zinc, boron, iron, copper, manganese), and (ii) the parallel expansion of soil-testing-linked agricultural extension services, principally the Soil Health Card (SHC) scheme and the Krishi Vigyan Kendra (KVK) network, over the period 2015 to 2025. Data were compiled from nationwide soil-testing surveys, official Soil Health Card scheme records, and peer-reviewed secondary-data studies. Results show that secondary and micronutrient deficiencies remain widespread and, for several nutrients, more extensive than historical estimates suggested: nationwide analysis of over 240,000 soil samples across 615 districts found 58.6% of soils deficient in sulphur, 51.2% in zinc, 44.7% in boron, 19.2% in iron, 17.4% in manganese and 11.4% in copper. Macronutrient imbalance also persists, with fertiliser nitrogen-phosphorus-potassium (N:P:K) consumption ratios of 8:4:1 in 2019 and 5:1.8:1 in 2023, both skewed relative to the agronomically recommended 4:2:1 ratio. In parallel, the Soil Health Card scheme has expanded rapidly since its 2015 launch, issuing 107.4 million cards in Cycle I (2015-17), a cumulative total exceeding 227 million by the end of Cycle II (2017-19), and over 250 million cards by mid-2025, supported by a soil-testing infrastructure that has grown from under 4,000 to more than 8,000 laboratories. Despite this substantial institutional expansion, independent assessment attributes only modest, though meaningful, improvements in farmer fertiliser practice - an estimated 8-10% reduction in fertiliser consumption and 5-6% yield gains among adopting farmers - indicating that growth in testing infrastructure and card distribution has outpaced measurable improvement in aggregate soil fertility indicators and balanced nutrient use. The study concludes that closing this gap will require extension strategies that move beyond card distribution toward sustained, crop- and nutrient-specific farmer advisory support, particularly for the secondary and micronutrient deficiencies that remain most severe and least addressed.

INTRODUCTION

Soil fertility the capacity of soil to supply essential nutrients to crops in adequate amount and balance - is a foundational determinant of agricultural productivity, yet it is also one of the natural resource attributes most vulnerable to gradual, often unnoticed degradation under intensive cultivation. Decades of green-revolution-era agriculture in India, characterised by heavy reliance on subsidised nitrogenous fertiliser, particularly urea, alongside comparatively limited attention to phosphorus, potassium, secondary nutrients and micronutrients, have progressively altered the nutrient balance of cultivated soils across much of the country.

Recognising this challenge, the Government of India launched the Soil Health Card (SHC) scheme in February 2015 as a flagship instrument for soil-test-based, balanced nutrient management, complementing the pre-existing Krishi Vigyan Kendra (KVK) network and broader agricultural extension apparatus. Understanding whether, and how rapidly, this expanded testing and advisory infrastructure has translated into measurable improvement in the underlying fertility status of Indian soils is an important, and only partially answered, empirical question.

This study applies a secondary data approach to (i) document the current and historically reported status of macronutrient, secondary nutrient and micronutrient deficiency in Indian agricultural soils; (ii) quantify the growth of the Soil Health Card scheme and associated soil-testing infrastructure since 2015; (iii) situate this institutional growth alongside trends in fertiliser use balance and reported scheme impact; and (iv) draw policy-relevant conclusions on the alignment between extension-service expansion and actual soil fertility outcomes.

REVIEW OF LITERATURE

A substantial and growing body of nationwide soil-testing research has documented the extent of nutrient deficiency in Indian agricultural soils. Shukla et al. (2021), analysing 2,42,827 surface soil samples collected from 615 districts across 28 states under the ICAR All India Coordinated Research Project on Micro- and Secondary-Nutrients, reported widespread deficiencies of sulphur and several micronutrients, with deficiency levels for zinc and sulphur in particular found to be more extensive than many earlier, smaller-scale estimates had suggested. A companion analysis by the same research group (Shukla et al., 2021, Sustainability) further examined multi-nutrient co-deficiency patterns, finding that a meaningful share of districts suffer simultaneous deficiency in two or more secondary and micronutrients, complicating single-nutrient correction strategies.

Earlier reviews, drawing on smaller and less systematically representative surveys conducted from the 1980s through the 2000s, had already flagged an increasing trend in micronutrient deficiency in Indian soils since the 1950s, attributing this trajectory to intensified cropping, removal of nutrients in harvested produce without adequate replenishment, and declining application of organic manures relative to synthetic fertiliser. Regional on-farm studies, such as those conducted in the semi-arid tropics of Andhra Pradesh, reported even higher localised deficiency rates - up to 73-95% of fields deficient in sulphur, 70-100% in boron and 62-94% in zinc - illustrating that national averages can mask considerably more acute deficiency in specific agro-ecological contexts.

On the extension side, official evaluation of the Soil Health Card scheme by the National Institute of Agricultural Extension Management (MANAGE) documented strong achievement against sample-collection and card-distribution targets in the scheme's first cycle, while noting persistent gaps between the number of samples collected, the number analysed, and the number of cards ultimately distributed to farmers, alongside challenges in the sampling density needed to achieve genuinely farm-specific rather than village- or grid-level fertility assessment. Broader institutional reviews of India's agricultural extension system (Gulati et al., 2018; Ponnusamy & Padaria, 2021) similarly note that infrastructure expansion, including in extension services tied to soil testing, has generally outpaced growth in measurable behavioural change among farmers, underscoring the value of the joint infrastructure-outcome trend analysis undertaken in this study.

MATERIALS AND METHODS

This study relies entirely on secondary data compiled from official Government of India sources, including the Soil Health Card scheme dashboard and associated Press Information Bureau (PIB) factsheets, the National Institute of Agricultural Extension Management (MANAGE), the Indian Council of Agricultural Research (ICAR), and peer-reviewed nationwide soil-testing studies, principally the All India Coordinated Research Project on Micro- and Secondary-Nutrients dataset reported by Shukla et al. (2021).

Growth in Soil Health Card issuance and soil-testing infrastructure was quantified through direct comparison of reported cumulative totals across successive scheme cycles (Cycle I: 2015-17; Cycle II: 2017-19; subsequent cumulative totals to 2024-25), consistent with the milestone-based reporting structure of the underlying administrative data. Nutrient deficiency status was compiled from the most recent, methodologically robust nationwide survey identified in the literature (Shukla et al., 2021) and, where relevant, compared against earlier published estimates to characterise the direction of change over time, while explicitly noting differences in sampling methodology, depth, and geographic coverage across studies that preclude strict like-for-like comparison. Fertiliser nutrient-use balance was assessed through the reported nitrogen-phosphorus-potassium (N:P:K) consumption ratio at two recent time points, benchmarked against the agronomically recommended ratio of approximately 4:2:1.

RESULTS AND DISCUSSION

This section presents compiled secondary-data trends in Indian soil fertility status, followed by the parallel growth trends in soil-testing-linked extension infrastructure and outreach.

Trend in Macronutrient (N, P, K) Status of Indian Soils

Broad-based estimates compiled from soil-testing and biofertiliser status reporting indicate that a substantial majority of Indian agricultural soils remain deficient or low in primary macronutrients. Various secondary-data compilations report that approximately 89%, 80% and 50% of arable soils have historically been characterised as deficient in nitrogen, phosphorus and potassium respectively, while more recent Soil Health Card-based reporting finds that 64% of tested samples were low in nitrogen and 48.5% low in soil organic carbon, with related reporting indicating roughly 83% and 71% of samples deficient in phosphorus and potassium respectively in some assessment cycles. While these figures derive from differing survey designs, testing depths and time periods and are therefore not strictly comparable on a year-by-year basis, they consistently point to persistent, widespread macronutrient and organic carbon deficiency across a large majority of Indian cropland despite decades of fertiliser application, underscoring the imbalance between the type and quantity of nutrients applied and those genuinely limiting in the soil.

Table 1: *Reported deficiency/low status of macronutrients and organic carbon in Indian agricultural soils across different surveys (figures not strictly comparable across periods owing to differing sampling methodologies; compiled from Down To Earth, 2020; SHC scheme reporting).*

Parameter	Reported Deficient / Low Share of Soils (%)	Approx. Source Period
Nitrogen (N)	~89 (historical); 64-97 (SHC-based reporting)	Multi-decade to 2023-24
Phosphorus (P)	~80 (historical); ~83 (recent reporting)	Multi-decade to recent
Potassium (K)	~50 (historical); ~71 (recent reporting)	Multi-decade to recent
Soil Organic Carbon (SOC)	~48.5-85 (varies by survey)	Recent SHC-based reporting

Trend in Secondary and Micronutrient Deficiency

The most methodologically robust and geographically comprehensive recent assessment of secondary and micronutrient status in Indian soils is provided by Shukla et al. (2021), based on analysis of 2,42,827 surface soil samples from 615 districts across 28 states under the ICAR All India Coordinated Research Project. This study found that 58.6% of soils were deficient in sulphur, 51.2% in zinc, 44.7% in boron, 19.2% in iron, 17.4% in manganese, and 11.4% in copper, confirming sulphur, zinc and boron as the three most extensively deficient secondary/micronutrients nationally.

Trend in Fertiliser Use Balance: The N:P:K Ratio

The balance of macronutrient application, commonly summarised through the nitrogen-phosphorus-potassium (N:P:K) consumption ratio, provides a further indicator of the direction of change in Indian soil fertility management. India's N:P:K consumption ratio stood at approximately 8:4:1 in 2019 and had shifted to approximately 5:1.8:1 by 2023, moving closer to, though still skewed relative to, the agronomically recommended ratio of roughly 4:2:1. This shift reflects, in part, growing policy attention to correcting historical over-application of urea-based nitrogen relative to phosphorus and potassium, a distortion widely attributed to the long-standing, comparatively low and static administered price of urea relative to phosphatic and potassic fertilisers.

Table 2: *Growth in Soil Health Card issuance and supporting soil-testing infrastructure, 2015-2025 (compiled from PIB, 2018; Grokipedia summary of official scheme data, cross-checked against MANAGE Impact Study figures).*

Scheme Phase	Samples Collected (Million)	Cards Issued (Million, cumulative)	Soil Testing Labs
Cycle I (2015-17)	~25.3	107.4	~3,900 (approx., mid-cycle)
Cycle II (2017-19)	~25.5 (additional)	~227.2 (cumulative)	Expanding
Cumulative (Sept 2024)	-	~240	Expanding
Cumulative (Mid 2025)	-	~250	>8,000

Growth of the Soil Health Card Scheme and Testing Infrastructure

The Soil Health Card scheme, launched in February 2015, has expanded rapidly in both coverage and supporting infrastructure. In Cycle I (2015-17), 107.4 million Soil Health Cards were issued to farmers following collection and analysis of approximately 25.3 million soil samples; Cycle II (2017-19) added a further 119.8 million cards based on approximately 25.5 million additional samples, bringing the cumulative total to over 227 million cards by 2019. Growth has continued in subsequent years on a rolling, roughly biennial re-testing cycle, with cumulative card issuance reported at approximately 240 million by September 2024 and exceeding 250 million (25 crore) by mid-2025. This expansion has been accompanied by substantial growth in the underlying soil-testing infrastructure, from fewer than 4,000 soil testing laboratories in the scheme's earlier years to a reported network exceeding 8,000 static labs, mobile vans, mini-labs and village-level testing units by 2025.

Growth in Soil-Testing-Linked Extension Outreach

Soil Health Card delivery does not occur in isolation but is embedded within the broader Krishi Vigyan Kendra and state extension network described in related secondary-data analyses of Indian agricultural extension. KVK farmer outreach - the share of farm households directly reached through KVK interventions, which include soil-test-based nutrient management demonstrations - rose from approximately 1% in 2003-04 to 18.8% by 2024-25, providing an indirect indicator of the growing institutional capacity available to translate Soil Health Card information into on-farm practice change through complementary training, demonstration and advisory activity.

Independent evaluation of the Soil Health Card scheme's on-farm impact reports an estimated 8-10% reduction in fertiliser consumption and 5-6% gains in crop yield among adopting farmers, figures that, while positive, are modest relative to the scale of the underlying nutrient imbalance documented in Sections 4.1 and 4.2. This suggests that the rate of improvement in actual farmer fertiliser practice has grown considerably more slowly than the rate of growth in cards issued and infrastructure established, a pattern consistent with findings from the MANAGE impact assessment noting gaps between sample collection, analysis and effective card-based advisory follow-through.

Relationship Between Extension Outreach and Soil Fertility Status

Placing the infrastructure growth trends of Sections 4.4-4.5 alongside the fertility status trends of Sections 4.1-4.2 reveals a marked asymmetry: Soil Health Card issuance and testing infrastructure have grown at a very rapid pace since 2015, roughly doubling from Cycle I to the cumulative total by 2019 and continuing to expand steadily thereafter, whereas measurable improvement in aggregate soil fertility indicators - most notably the persistence of sulphur, zinc and boron deficiency across roughly half of tested soils as of the most recent comprehensive national survey - has been considerably more modest over the same period. The partial improvement observed in the N:P:K consumption ratio between 2019 and 2023 indicates that behaviour change is occurring, but at a pace that lags substantially behind the pace of institutional and card-distribution growth.

DISCUSSION: BRIDGING THE INFRASTRUCTURE-OUTCOME GAP

The pattern identified in this analysis - rapid growth in soil-testing infrastructure and card distribution alongside comparatively modest improvement in underlying soil fertility indicators - suggests that the Soil Health Card scheme's primary achievement to date has been the establishment of a large-scale data collection and information delivery apparatus, while the harder task of translating that information into sustained, balanced, farm-specific fertiliser practice change remains substantially incomplete. This is consistent with findings across the broader Indian agricultural extension literature, which similarly documents a general pattern of infrastructure expansion outpacing behavioural and outcome change, and points to advisory follow-through, farmer trust in card recommendations, and last-mile input availability (particularly of secondary and micronutrient fertilisers, which are less readily available through the standard urea-DAP-MOP retail channel) as probable binding constraints.

The persistence of widespread sulphur, zinc and boron deficiency, despite these being explicitly reported on Soil Health Cards since the scheme's inception, further suggests that simply providing test-based information is necessary but insufficient; complementary measures - such as ensuring reliable local availability of zinc sulphate, borax and gypsum or other sulphur sources, alongside targeted subsidy or promotional support comparable to that historically extended to nitrogenous fertiliser - may be required to close the gap between diagnosed deficiency and corrective farmer action.

POLICY IMPLICATIONS

- Extension strategies linked to the Soil Health Card scheme should shift emphasis from card distribution volume toward measurable adoption of card-based fertiliser recommendations, particularly for secondary and micronutrients.

- Targeted measures to improve local retail availability and affordability of zinc, boron and sulphur-containing fertilisers are needed to complement diagnostic information already being delivered through Soil Health Cards.

- Given the persistent nitrogen-heavy fertiliser use ratio, continued rebalancing of fertiliser subsidy structures to reduce the relative price advantage of urea over phosphatic, potassic and micronutrient fertilisers remains a policy priority.

- Soil-testing infrastructure growth should be matched by proportionate investment in farmer-facing advisory capacity - through KVKs, ATMA and digital advisory channels - to ensure diagnostic capacity translates into practice change.

- Future rounds of nationwide soil-testing surveys, following the Shukla et al. (2021) model, should be repeated at regular intervals to allow rigorous, methodologically consistent tracking of whether soil fertility indicators are genuinely improving over time in response to extension and scheme investment.

Limitations of the Secondary Data Approach

This study's reliance on compiled secondary data from sources with differing sampling designs, testing depths, geographic coverage and reporting periods means that reported deficiency percentages are not always strictly comparable across time, and true longitudinal trends in soil fertility status - as distinct from differences between distinct surveys - cannot be established with full statistical rigour from the available published sources alone. Administrative data on Soil Health Card issuance and testing infrastructure, while drawn from official government reporting, is likewise subject to revision and varying definitions of what constitutes a completed testing-to-card-distribution cycle. Finally, the observed asymmetry between infrastructure growth and fertility outcome improvement is descriptive; establishing a rigorous causal link between Soil Health Card exposure and farm-level fertiliser practice change would require farm-level panel data and econometric analysis beyond the scope of this national-trend secondary-data study.

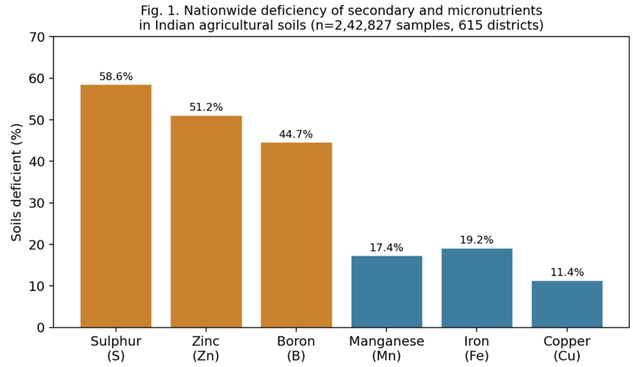

Figure 1: Nationwide deficiency of secondary and micronutrients in Indian agricultural soils, based on 2,42,827 samples from 615 districts (Shukla et al., 2021, Scientific Reports).

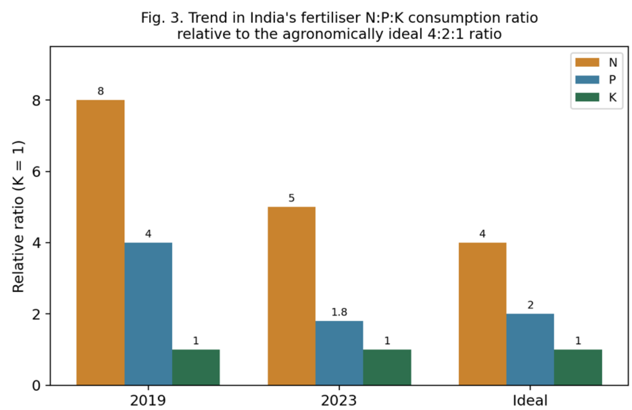

Figure 2: Trend in India's fertiliser N:P:K consumption ratio relative to the agronomically ideal 4:2:1 ratio, 2019 and 2023 (data: Business Standard, 2024, citing Ministry of Agriculture and Farmers Welfare figures).

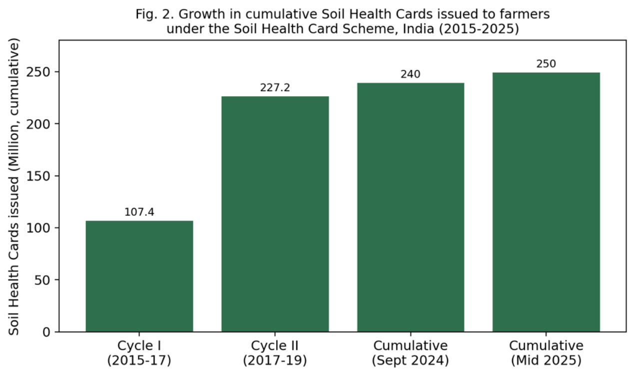

Figure 3: Growth in cumulative Soil Health Cards issued to farmers under the Soil Health Card Scheme, India, 2015-2025 (compiled from PIB, 2018; MANAGE Impact Study; scheme dashboard reporting cited in recent secondary literature).

CONCLUSION

This secondary-data analysis confirms that Indian agricultural soils continue to exhibit widespread deficiency across macronutrients, sulphur and several key micronutrients, with sulphur, zinc and boron remaining deficient in roughly half or more of tested soils nationally as of the most recent comprehensive survey. Over the same period, the Soil Health Card scheme and associated soil-testing infrastructure have expanded very rapidly, issuing more than 250 million cards and establishing over 8,000 testing facilities within a decade of launch. However, the pace of measurable improvement in fertiliser use balance and underlying soil fertility indicators has been considerably more modest than the pace of this institutional expansion, indicating a persistent gap between diagnostic infrastructure growth and realised on-farm outcome improvement. Closing this gap will require agricultural extension strategies that move beyond information delivery toward sustained advisory support, input availability and targeted policy correction, particularly for the secondary and micronutrient deficiencies that remain most severe and least addressed by current fertiliser subsidy and market structures.

REFERENCES

Shukla, A. K., Behera, S. K., Prakash, C., Tripathi, A., Patra, A. K., Dwivedi, B. S., Trivedi, V., Rao, C. S., Chaudhari, S. K., Das, S., & Singh, A. K. (2021). Deficiency of phyto-available sulphur, zinc, boron, iron, copper and manganese in soils of India. *Scientific Reports, 11*, 19760. https://doi.org/10.1038/s41598-021-99040-2

Shukla, A. K., Behera, S. K., Prakash, C., Patra, A. K., Rao, C. S., Chaudhari, S. K., Das, S., Singh, A. K., & Green, A. (2021). Assessing multi-micronutrients deficiency in agricultural soils of India. *Sustainability, 13*(16), 9136. https://doi.org/10.3390/su13169136

National Institute of Agricultural Extension Management (MANAGE). (n.d.). *Impact study of Soil Health Card Scheme.* manage.gov.in.

Press Information Bureau (PIB), Government of India. (n.d.). *Soil Health Card Scheme—Factsheet.* Ministry of Agriculture & Farmers Welfare.

Gulati, A., Sharma, P., Samantara, A., & Terway, P. (2018). *Agriculture extension system in India: Review of current status, trends and the way forward.* Indian Council for Research on International Economic Relations (ICRIER).

Ponnusamy, K., & Padaria, R. N. (2021). Research in agricultural extension: Review of its contribution and challenges. *Indian Journal of Agricultural Sciences, 91*(5), 659–665.

Indian Council of Agricultural Research (ICAR). (2025). *Krishi Vigyan Kendras (KVKs)—Background and significant achievements.* icar.gov.in.

Business Standard. (2024, November 26). *India's soil nutrient ratio improves marginally, but can it hold the line?*

Down To Earth. (2020). *How nutrient-deficient are Indian soils?* Centre for Science and Environment, State of India's Environment reporting.

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