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THE FERTILIZER PARADOX: Why Indian Farmers Use More Fertilizer but Earn Less

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ABSTRACT

For decades, the operational philosophy of Indian agriculture was shaped by the belief that higher fertilizer application would inevitably translate into higher crop yields. This approach, firmly established during the Green Revolution of the 1960s, relied on high-yielding varieties supported by intensive use of chemical fertilizers and irrigation, and it played a decisive role in overcoming food shortages and achieving national food security. Over time, however, the continued dependence on this input-intensive model has revealed serious economic and ecological limitations. In recent years, fertilizer consumption in Indian farming systems has reached historically high levels, yet farmer profitability has remained stagnant or has even declined in many regions. Long-term field experiments and on-farm studies in the rice–wheat systems of the Indo-Gangetic Plains have shown that repeated application of nitrogenous fertilizers beyond recommended levels often fails to generate proportional yield gains. Instead, excessive nitrogen use leads to nutrient imbalance, accelerated depletion of soil organic carbon, and suppression of beneficial soil microbial activity that governs nutrient availability and uptake. As soil structure and biological health deteriorate, crops respond less efficiently to applied nutrients, making the law of diminishing returns increasingly evident. Farmers are consequently compelled to apply larger quantities of fertilizers simply to sustain earlier yield levels, which substantially raises the cost of cultivation. This cycle deepens dependence on external inputs while offering little improvement in net income, thereby exposing a paradox in which rising fertilizer use no longer guarantees economic benefit. What once functioned as a pathway to productivity and food security has gradually evolved into an input-driven trap, emphasizing the urgent need to reassess fertilizer management strategies and realign them with principles of soil health, nutrient efficiency, and long-term agricultural sustainability.

Keywords*: *Indian farmers, fertilizer use, farm income, soil health, Green Revolution, input costs

Introduction

Agriculture has long formed the backbone of India's economy, employing nearly **45 per cent of the workforce** and remaining central to national food security. Since the mid-twentieth century, Indian farmers have increasingly depended on chemical fertilizers to enhance crop productivity, guided by the widely held belief that higher fertilizer application inevitably leads to higher yields. This approach delivered impressive results during the Green Revolution, particularly in wheat and rice, where national foodgrain production increased from **around 82 million tonnes in 1960–61 to over 130 million tonnes by the early 1980s**. However, the long-term consequences of this input-intensive model have become increasingly evident. In many regions, excessive and imbalanced fertilizer use has led to rising costs of cultivation, declining soil fertility, and yield responses that no longer match input investments. Studies from long-term fertilizer experiments in the Indo-Gangetic Plains have shown that continued application of nitrogen alone, without adequate organic matter or balanced nutrients, reduces soil organic carbon and microbial activity, ultimately limiting nutrient use efficiency. As a result, many farmers now apply higher doses of fertilizers merely to maintain earlier yield levels, trapping them in a cycle of high input costs and stagnant or declining farm income. The widespread adoption of fertilizers was initially driven by post-Independence food shortages and a rapidly growing population, which made traditional nutrient sources such as farmyard manure insufficient at scale. The introduction of high-yielding varieties of wheat and rice during the 1960s further reinforced fertilizer dependence, as these varieties required timely and adequate supplies of nitrogen, phosphorus, and potassium (NPK) to express their yield potential. Government support through fertilizer subsidies, domestic manufacturing, and extensive distribution networks made chemical fertilizers both affordable and easily accessible, accelerating their large-scale adoption. While these interventions ensured food security, they also inadvertently encouraged indiscriminate fertilizer use, highlighting the need to reassess nutrient management strategies in the context of soil health, economic sustainability, and farmer livelihoods.

The Green Revolution and the Rise of Chemical-Intensive Agriculture in India

To understand the present fertilizer-related challenges in Indian agriculture, it is essential to revisit the decades following Independence, when the country's food security situation was highly fragile. During the 1950s and early 1960s, India faced persistent food shortages and relied heavily on wheat imports under the PL-480 "Food for Peace" programme of the United States, leading to what was commonly described as a "ship-to-mouth" existence. With a rapidly growing population and limited possibilities for expanding cultivable land, achieving a substantial increase in food production within existing land resources became a national priority. This challenge was addressed in the mid-1960s with the introduction of the Green Revolution, which marked a decisive shift from traditional, low-input subsistence farming to modern, input-intensive agriculture based on high-yielding varieties (HYVs) of wheat and rice. Supported by irrigation, chemical fertilizers, and improved agronomic practices, these varieties led to rapid productivity gains, particularly in regions such as Punjab, Haryana, and western Uttar Pradesh. Wheat production alone increased from around 12 million tonnes in 1964–65 to over 20 million tonnes by the early 1970s, enabling India to move towards self-sufficiency in food grains. This period marked the beginning of what can be termed the "chemical age" of Indian agriculture, as the newly introduced semi-dwarf HYVs required large and timely applications of nutrients, especially nitrogen, phosphorus, and potassium, to express their yield potential. Traditional nutrient sources such as farmyard manure and crop residues were inadequate to meet these demands at scale, resulting in the widespread adoption of chemical fertilizers. The strong and immediate yield response observed during the early years reinforced the belief that chemical inputs were indispensable for agricultural growth, a perception that continues to influence fertilizer use patterns in India today.

The Psychology of "More": Risk, Fear, and the Illusion of Safety

The persistent overuse of chemical fertilizers in Indian agriculture is often misunderstood as a failure of knowledge or awareness. In reality, it is largely a psychological response to economic vulnerability and existential insecurity. For marginal and small farmers, agriculture represents a high-stakes livelihood exposed to unpredictable weather, pest outbreaks, and volatile market prices. In such an environment, the fear of crop failure is far more severe than the concern over excess input costs. Fertilizers such as urea, being heavily subsidized and easily accessible, are therefore perceived not as wasteful inputs but as a form of low-cost insurance. Applying an extra bag is seen as a precaution against yield loss rather than an unnecessary expense.

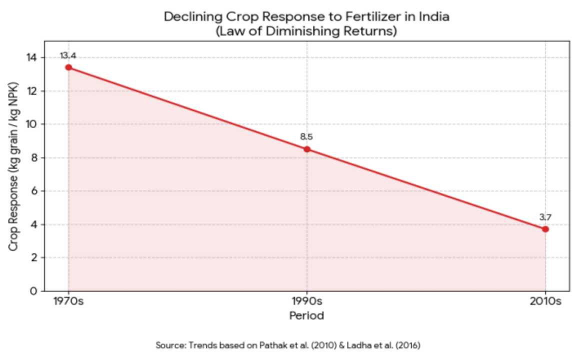
This mindset encourages reliance on experience-based decision-making rather than strict adherence to scientific recommendations. The early years of the Green Revolution reinforced a simple and powerful lesson: higher fertilizer use produced higher yields. These visible successes created a lasting belief system that continues to guide farmer behavior, even though soil conditions and crop responses have changed over time. While contemporary soil science warns against nutrient saturation and imbalance, farmers often fear that reducing fertilizer application may "starve" the crop and invite failure.

The preference for excess fertilizer is further strengthened by the contrast between visible and invisible outcomes. Nitrogen application delivers an immediate and tangible response in the form of lush, dark green crop growth, which farmers associate with health and productivity. In contrast, the benefits of balanced fertilization, improved soil structure, or enhanced microbial activity are slow, intangible, and difficult to observe in the short term. Consequently, farmers tend to trust what they can see in the field more than soil test reports or advisory recommendations.

THE LAW OF DIMINISHNG RETURN IN AGRICULTURE

Period	Avg. Fertilizer Consumption (kg/ha)	Crop Response (kg grain / kg NPK)	Economic Implication
1970s	Low (< 20)	**13.4**	High Profitability (Low Input, High Output)
1990s	Moderate (60-80)	**8.5**	Diminishing Returns begin; costs rise.
2010s	High (> 140)	**3.7**	**Profit Squeeze:** Input costs exceed marginal gain.

The current crisis in Indian agriculture is best explained through the economic principle of the Law of Diminishing Returns. In an agricultural context, this law states that while adding an input (like fertilizer) initially increases output (yield), a point is eventually reached where each additional unit of input produces less and less additional output. Finally, a stage of negative returns occurs



where adding more input actually harms the crop and reduces yield.

Historically, during the early Green Revolution, Indian soils were nutrient-hungry, and the "response ratio" was high—every kilogram of NPK applied resulted in a massive jump in grain production. However, decades of intensive cropping have shifted this curve. As noted by Yadav et al. (1998) in their study of rice-wheat systems, the continuous use of inorganic fertilizers without organic amendments has led to yield stagnation. The soil has reached a saturation point where the biological potential of the crop is maxed out, and soil health is degraded.

Data from Pathak et al. (2010) and Dobermann & Cassman (2005) illustrate this stark decline in Nitrogen Use Efficiency (NUE). In the 1970s, applying 1 kg of fertilizer might have produced ~13 kg of grain; today, that same kilogram produces significantly less, forcing farmers to buy more just to maintain the same harvest. This creates a "profit squeeze": the cost of cultivation rises (due to more inputs), but the revenue remains stagnant.

Table 1: Declining Crop Response to Fertilizer in India (Synthesized Data) Based on trends observed by Pathak et al. (2010) and Ladha et al. (2016)

In the present-day scenario, this law dictates the farmer's reality: simply "pouring on" more urea is no longer a path to prosperity but a path to debt, as the biological limit of the soil-crop system has been breached.

Impact of Fertilizer Subsidy Policies on Nutrient Use Efficiency and Soil Health in Indian Agriculture.

Government fertilizer subsidy policies in India, though originally intended to ensure food security and reduce production costs, have unintentionally contributed to declining nutrient use efficiency and widespread soil degradation. A key issue lies in the structural distortion of fertilizer pricing, where urea (nitrogen) remains under strict price control, while phosphatic and potassic (P&K) fertilizers are regulated under the Nutrient Based Subsidy (NBS) scheme and are therefore more exposed to market price fluctuations. As a result, urea is significantly cheaper than P&K fertilizers, creating a strong economic incentive for farmers to over-apply nitrogen while underusing phosphorus and potassium. This imbalance is clearly illustrated in the **rice–wheat cropping system of Punjab and Haryana**, where long-term field studies have shown that farmers often apply more than **250–300 kg N ha^{-1}** annually while applying inadequate amounts of P and K, leading to declining fertilizer

Integrated Nutrient Management: Rebuilding Soil Health and Farm Profitability

With the growing realization that chemical-only fertilization has reached its biological limits, Indian agriculture stands at a critical turning point, as the long-standing strategy of increasing fertilizer inputs to enhance yields has led to soil fatigue, nutrient imbalances, declining crop response, and

rising production response and increasing soil nutrient deficiencies. Consequently, national N:P:K consumption ratios have deteriorated from the recommended 4:2:1 to levels exceeding **10.9:4.4:1** in recent years. Soil test–based surveys and long-term fertilizer experiments in these regions have reported reductions in soil organic carbon and emerging deficiencies of potassium, sulphur, and zinc, despite continued increases in nitrogen use. The problem is further reinforced by subsidy allocation patterns, as nearly **70–75 per cent of the total fertilizer subsidy budget** continues to be directed towards urea, limiting incentives for balanced fertilization and integrated nutrient management. Policy reforms have remained limited, with insufficient emphasis on organic amendments, biofertilizers, micronutrients, and soil health restoration, despite mounting evidence of soil degradation. As a result, the current subsidy framework sustains short-term yield gains while progressively undermining long-term soil productivity, farm profitability, and ecological sustainability. costs, even as yield gains have stagnated. This situation underscores the urgent need to shift from input-intensive practices toward a more efficient and ecologically sound approach centered on nutrient-use efficiency, for which Integrated Nutrient Management (INM) offers a scientifically robust solution. Integrated Nutrient Management involves the judicious integration of chemical fertilizers with organic manures, crop residues, and biofertilizers to meet crop nutrient requirements while simultaneously restoring and sustaining soil health. The core objective of INM is to synchronize nutrient supply with crop demand and improve the physical, chemical, and biological properties of soil. A central component of this approach is the rebuilding of soil organic carbon, which has been severely depleted under continuous chemical fertilization. While chemical fertilizers primarily supply readily available nutrients to crops, organic inputs such as farmyard manure, compost, vermicompost, and green manures nourish the soil by improving structure, enhancing water-holding capacity, and stimulating microbial activity essential for nutrient cycling. Within an INM framework, chemical fertilizers function as supplements rather than substitutes, ensuring balanced nutrient application with judicious nitrogen use and appropriate N:P:K ratios tailored to specific crops and agro-ecological conditions. Biofertilizers such as Azotobacter, Rhizobium, and phosphate-solubilizing bacteria further enhance nutrient availability by fixing atmospheric nitrogen and mobilizing native soil phosphorus, thereby reducing reliance on synthetic fertilizers. The effectiveness of INM is further strengthened through soil testing and site-specific nutrient management, which enable farmers to apply nutrients based on actual field deficiencies rather than generalized recommendations. Evidence from long-term fertilizer experiments across India consistently demonstrates that INM-based systems sustain crop yields more effectively than chemical-only approaches while improving fertilizer-use efficiency. Economically, INM reduces cultivation costs and mitigates risks associated with excessive fertilizer use, while environmentally it minimizes nutrient losses, groundwater contamination, and greenhouse gas emissions and contributes to soil carbon sequestration. Despite challenges such as increased labor requirements and limited availability of organic resources, Integrated Nutrient Management represents a necessary transition toward sustainable, resilient, and profitable agricultural systems in India.

Restoring Ecological Balance for Economic Prosperity

The continued reliance on excessive fertilizer use by Indian farmers, despite declining economic returns, reflects not merely a technical shortcoming but deeper ecological, institutional, and behavioral imbalances within the agricultural system. Decades of yield-focused extension messaging, combined with risk aversion under rain-fed and climate-uncertain conditions, have reinforced the perception that higher fertilizer doses act as insurance against crop failure, a belief further strengthened by distorted subsidy structures that make nitrogenous fertilizers artificially inexpensive. Over time, this approach has weakened soil biological activity, reduced nutrient use efficiency, and inflated production costs without delivering proportionate gains in yield or income. Long-term field experiments in the rice–wheat systems of Punjab and Haryana clearly illustrate this transition, where balanced fertilization combined with organic inputs such as farmyard manure or crop residue incorporation has maintained or improved crop yields while reducing chemical fertilizer requirements and improving soil organic carbon levels. Similar outcomes have been observed in farmer participatory trials under natural farming and integrated nutrient management programs in Andhra Pradesh, where reduced fertilizer use, when supported by soil testing and advisory services, did not increase production risk but instead stabilized input costs and improved net returns. Restoring economic prosperity therefore requires a decisive shift from input-driven agriculture to ecology-based decision-making, where soil health is treated as a productive asset rather than a passive medium. Strengthening integrated nutrient management through balanced fertilization, organic amendments, residue recycling, and site-specific nutrient application offers a practical pathway to rebuild soil function while lowering dependence on chemical inputs. Government initiatives such as the Soil Health Card scheme, promotion of nano-fertilizers, natural farming programs, and digital advisory platforms signal an important policy transition, but their success ultimately depends on farmer trust, consistent extension support, and demonstration-based learning at the field level. When farmers begin to recognize that reduced input use does not necessarily translate into higher risk, fertilizer application becomes a strategic choice rather than a habitual response to uncertainty. In the long run, aligning ecological balance with farm economics provides the most reliable pathway to resilient soils, stable yields, and sustained farmer incomes, thereby resolving the fertilizer paradox not through increased inputs, but through informed and ecologically sound management.

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