



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(4): 530-535
Received: 19-01-2026
Accepted: 21-02-2026

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Fertilizer consumption in Punjab: Exploitation of urea and soil degradation

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i4Sf.5470>

Abstract

Punjab is a fertilizer exhaustive state that consumes around 3,005,207 metric tons of urea every year (2024-25). This fertilizer use does translate into increased yields, i.e., a kg of fertilizer consumed in Punjab yields 16.24 kg of food grain compared to the national average of 11.05 kg, according to the national green tribunal. Even though fertilizers are essential as a source of nutrients for crop growth, unregulated use of fertilizers like urea can lead to nutrient imbalance, reduce soil organic matter, cause eutrophication, expedite soil acidification, and reduce soil microflora. Heavy subsidies make urea the cheapest nitrogen source available for farmers, leading to overuse. Schemes such as PM-PRANAM are helping the state reduce reliance on chemical fertilizers by promoting alternative sources of nutrition, such as biofertilizers and organic manure. High-efficiency fertilizers like liquid nano-urea and neem-coated urea are also effective alternatives to traditional urea consumption. These, paired with data-driven precision agriculture technology, enable the use of the right amount of fertilizer in required areas with minimum loss of nutrients.

Keywords: Nitrogen use efficiency, Pm-PRANAM, eutrophication, soil health, urea exploitation, nano-urea, precision agriculture

Introduction

Punjab is celebrated as the “Granary of India”, “bread bowl of India”, and many more titles have long been a part of the success story of the country's agricultural sector. The Green Revolution of the 1960s changed the state from a subsistence-based farming economy into one of the most productive agricultural sectors in the world (Prabhu Pingali, 2012; Food and Agriculture Organization, 2021) ^[19, 10]. Though this productivity has come with the cost of environmental damage. Punjab accounts for only 1.53% of India's agricultural area, yet it consumes around 9% of the total fertilizer of the country, with fertilizer consumption of 247.61 kg per hectare during 2023-24-nearly double the national average of 139.81 kg per hectare (Down to Earth, 2024) ^[9]. Among the fertilizers, urea, the principal source of nitrogen for plants, is the most dramatically consumed fertilizer, due to its low cost and immediate impact on the crops (IMPRI, 2023; Karmakar & Saha, 2023 ^[13, 14]. Usage of urea alone increased by 202% since 1980 to 2018, in the states with a majorly following wheat-rice cropping pattern (Down to Earth, 24) ^[9]. The current subsidy structure, where urea gets significantly higher financial support than other potassic and phosphatic fertilizers, has further resulted in over-consumption (NITI Aayog, 2026; Springmann *et al.*, 2025) ^[18, 22]. Consequently, the N: P: K use ratio in India has increased from the recommended 4:2:1 to nearly 10:9: 4.4: 1, while in Punjab these numbers are even more pronounced (IMPRI, 2023; Benbi, 2016) ^[13, 8].

The overuse of Urea has resulted in multiple adverse impacts on soil health and the functioning of the ecosystem. One of the most critical consequences is the fall in Soil organic carbon (SOC), the indicator of sustainability and fertility Singh & Benbi, 2016; ICAR-Indian Institute of Soil Sciences, 2025) ^[21, 12]. Long-term fertilizer studies have shown that continuous use of nitrogen without an appropriate amount of organic content significantly reduces SOC levels and also affects microbial activity (Benbi, 2016; FAO, 2021) ^[8, 10]. In Punjab, the average SOC level has been reported to decrease below 0.5%, which shows the soil is insufficient to bear productive agriculture for long (Singh & Benbi, 2016; ICAR-Indian Institute of Soil Sciences, 2025) ^[21, 12].

The National Green Tribunal has also highlighted the alarming decrease in the quality of soil in the regions characterized by the overuse of fertilizer (National Green Tribunal, 2025) ^[17].

Another major concern linked with urea overconsumption is low Nitrogen use efficiency (NUE). Experiments show that crops typically use only 30-40% of applied nitrogen, while the remaining is lost due to volatilization, leaching, and denitrification processes (NITI Aayog, 2026; Kumar *et al.*, 2022) ^[18, 15]. These losses not only reduce input efficiency but also lead to degradation of the environment, including greenhouse gas emission and contamination of underground water (Sharma *et al.*, 2020; Springmann *et al.*, 2025) ^[20, 22]. Nitrous oxide (N₂O), a by-product of nitrogen fertilizer, has a global warming of causing potential approximately 200 times more than carbon dioxide, making agriculture an evident contributor to climate change (FAO, 2021; NITI Aayog, 2026) ^[10, 18].

The repetitive cropping pattern of rice and wheat in Punjab has further exacerbated the problem. This monoculture system demands high nutrient inputs and rapid nutrient mining from the soils, resulting in deficiency of secondary and micronutrients such as iron, zinc, and sulphur (Karmakar & Saha, 2023; Kumar *et al.*, 2022) ^[14, 15]. Moreover, the imbalance between nutrient consumption and replenishment has resulted in stagnant crop yields despite increasing the fertilizer use, showing the decreasing returns to the chemical inputs (Pingali, 2012; Sharma *et al.*, 2020) ^[19, 20]. The input subsidies and limited awareness of balanced fertilizer use influence farmers' practices, continuing to reinforce this cycle of overconsumption and degradation (IMPRI, 2023; Down to Earth, 2024) ^[13, 9].

The given problems are urgent; we need to critically examine fertilizer consumption patterns in Punjab, especially the exploitation of urea and its impacts on soil health. This study aims to analyse the trends in fertilizer use, the extent of soil degradation due to the same, and explore sustainable nutrient management strategies. Addressing the problem will require integrated measures, such as balanced fertilizer use, the promotion of organic and bio-based inputs, and policy reforms, to ensure long-term sustainability and environmental resilience in agriculture (Springmann *et al.*, 2025; NITI Aayog, 2026) ^[22, 18].

Literature Review

Fertilizer use in Punjab and India

The use of major nutrients like nitrogen, phosphorus, and potassium used per hectare has been documented to have doubled since the 1990s. Sustaining the large agricultural production of grains requires a set amount of nutrients for efficient growth. The national average for the use of fertilizers as agricultural inputs is around 128.02 kg/ha, according to Ramappa *et al.* (2022) compared to average fertilizer use in Punjab, which is exponentially higher, i.e., around 190 kg/ha, according to Aryal *et al.* (2021) ^[7, 6].

The most widely used source of nitrogen in Indian agriculture is Urea. It contributes a total of 82% to the total consumption of nitrogen across India (Ramappa *et al.*, 2022) ^[7]. While the government is incentivising alternatives to urea, such as neem-coated urea, urea remains the most used nitrogenous fertilizer. On the other hand, the use of urea in Punjab is around 320kg/ha, which is much greater than its southern states' counterparts

(Aryal *et al.*, 2021) ^[6]. Additionally, the DAP input in Punjab for wheat is also greater than recommended, i.e., around 125 kg/ha. Even though the overall use of fertilizer has reduced in recent years (2024-25), the overall consumption of these fertilizers remains a concern (Ministry of Chemicals and Fertilizers, 2026) ^[5].

Cropping Pattern and Fertilizer Use

The planting of the same crop in the same place of land in each agricultural season can gradually deplete soil nutrients. Intensive agriculture further results in the exploitation of nutrients. If the same crop gradually uptakes the nutrients from the soil at the same depth, naturally, the nutrient availability at the root zone will deplete. Farmers are forced to use intensive fertilizer inputs to make essential nutrients available to plants (Thornton, 1997) ^[3]. The application of fertilizer also has a hindering effect on existing soil microbes, further becoming a cause of nutrient depletion in soil.

To begin with, a proper rate of input needs to be determined to balance the effects of an intensive cropping system along with management. The inclusion of leguminous crops has also been proven to be effective in improving soil organic matter and nitrogen fixation (Urmi *et al.*, 2022) ^[4]. Overall, inclusion of soil organic matter, micronutrients, and a balanced rate of fertilizer supply is essential for a sustainable cropping system.

Materials and Methods

The study was conducted to understand the use of fertilizer input in regions of state of Punjab. A total of 40 farmers were interviewed across 10 villages that include Bajheri, Deh Kalan, Mehmoodpur, Mandlan, Karimpur, Kalaundi, Dugri, Kotli, Dholan Majra, and Dumna in the districts of S.A.S Nagar, Roorkie, *etc.* These villages were chosen randomly with proximity to the university premises. A questionnaire for an in-person survey of rural households was prepared for a schematic understanding of the fertilizer input pattern in these areas. The collection and analysis of data was done from all households surveyed. The primary focus of the survey was a door-to-door in-person interview with the farming head of each household. To maintain accurate data throughout the questionnaire. A general group discussion was also part of the survey to get a broad understanding of survey parameters. The parameters that were reviewed are mentioned below for understanding.

Results and Discussion

1. Cropping Pattern

Table 1: Cropping Pattern in Sample Villages

Village	Cropping Pattern
Bajheri	Rice-Wheat-Mustard
Deh Kalan	Rice-Wheat
Mehmoodpur	Rice-Wheat-Mustard
Madlan	Rice-Wheat-Mustard
Karimpur	Rice-Wheat-Mustard
Kalaundi	Rice-Wheat
Dugri	Rice-Wheat-Mustard
Kotli	Rice-Wheat-Mustard
Dholan Majra	Rice-Wheat
Dumma	Rice-Wheat-Mustard

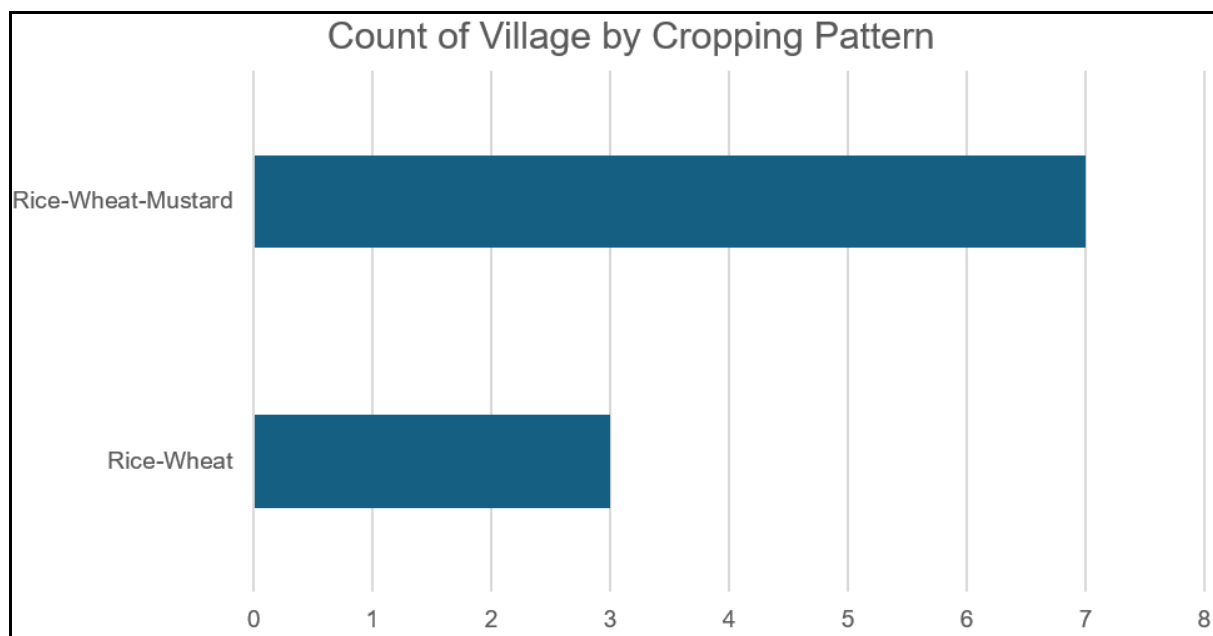


Fig 1: Count of Village by Cropping Pattern

The survey displays that almost all sample villages followed a monocropping system of rice-wheat or rice-wheat-mustard on their farms. The crops of rice and wheat are considered exhaustive in terms of nutrient uptake. Rice specially is the most exhaustive out of 2, requiring the most amount of nutrient uptake to sustain the crop. It effects in further depletion of soil

nutrients (Shahane *et al.*, 2020) ^[1]. The exhaustive nature of these crops gives incentive to farmers to use even more fertilizers.

2. Fertilizer input in Rice

Table 2: Urea and DAP input in Rice

Village	Urea (kg/acre)	DAP (kg/acre)
Bajheri	128	84
Deh Kalan	104	67
Mehmoodpur	136	89
Madlan	111	74
Karimpur	139	96
Kalaundi	108	71
Dugri	132	85
Kotli	126	79
Dholan Majra	101	63
Dumma	144	92

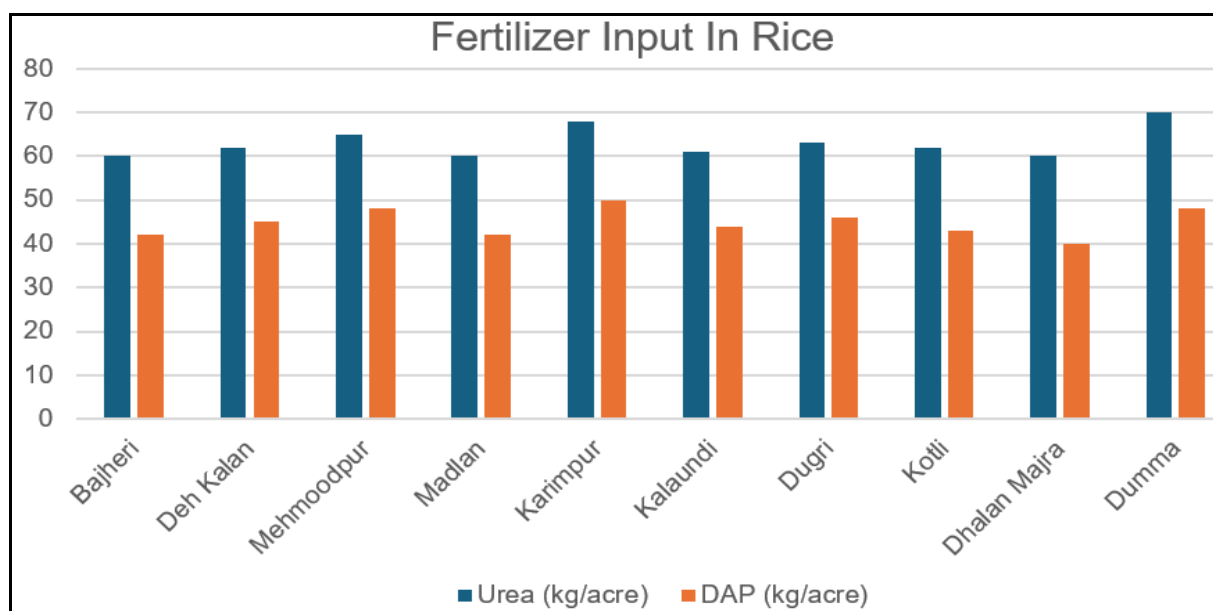


Fig 2: Fertilizer Input in Rice

More nitrogen fertilizer is applied to rice in all villages plotted, showing a high-input system used all along, with farmers consistently depending on it. The consistency of the application indicates similar agronomic practices and growing conditions across the area. Phosphorus use is a little more variable,

suggesting different levels of access to inputs or differing farmer preferences, but still mostly in the moderate to the required range.

3. Fertilizer input in wheat

Table 3: Urea and DAP input in Wheat

Village	Urea (kg/acre)	DAP (kg/acre)
Bajheri	122	68
Deh Kalan	105	60
Mehmoodpur	130	75
Madlan	110	65
Karimpur	135	80
Kalaundi	108	62
Dugri	128	72
Kotli	120	70
Dholan Majra	102	58
Dumma	138	78

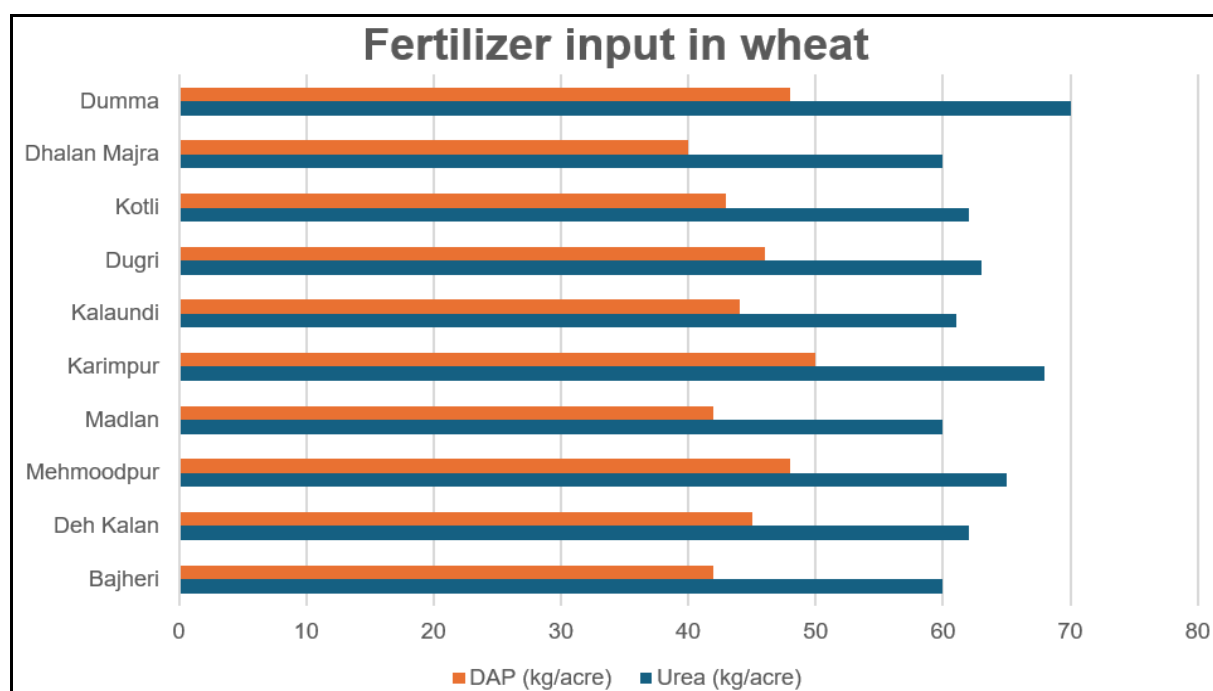


Fig 3: Fertilizer input in wheat

Wheat exhibits a highly stable pattern of fertilizer use, but the input is moderately high compared to rice, while phosphorus application is somewhat lower than for rice. Nitrogen use is still relatively similar, which we attribute largely to cereals' nutrient demand, and because farmers aim for good wheat yields. The

narrow amount of variation means farmers are likely to practice commonalities, supposed to be driven by shared best practices and experience.

4. Fertilizer Input in Mustard

Table 3: Urea and DAP input in Mustard

Village	Urea (kg/acre)	DAP (kg/acre)
Bajheri	60	42
Deh Kalan	62	45
Mehmoodpur	65	48
Madlan	60	42
Karimpur	68	50
Kalaundi	61	44
Dugri	63	46
Kotli	62	43
Dholan Majra	60	40
Dumma	70	48

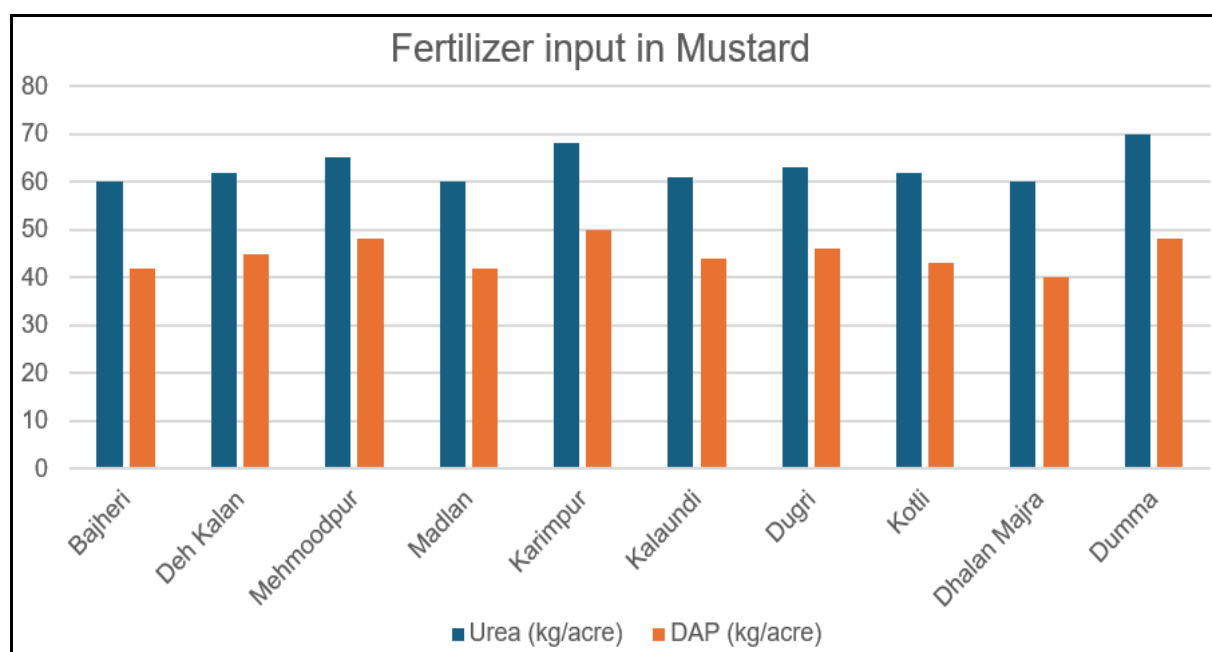


Fig 4: Fertilizer Input in Mustard

Mustard has a low input and less intensive system of cultivation compared to rice and wheat, which is also evident from the pattern of fertilizer use. The applications for nitrogen and phosphorus are low, suggesting that farmers do not invest much into this crop, as it does not have the high yield expectations or inputs like other crops.

Mustard management was more similar across villages, and it is not likely to be a highly managed crop.

5. Overall Fertilizer Consumption

Village	Avg Urea (kg/acre)	Avg DAP (kg/acre)
Bajheri	125	76
Deh Kalan	105	64
Mehmoodpur	133	82
Madlan	110	70
Karimpur	137	88
Kalaundi	108	67
Dugri	130	79
Kotli	123	75
Dholan Majra	102	61
Dumma	141	85

The pattern of fertilizer consumption across the villages reflects a systematic high-input agricultural system driven primarily by rice and wheat cultivation. Nitrogen use is high and stable, which suggests heavy reliance on urea for crop productivity; phosphorus application can be considered medium but not highly variable.

The apparently small difference across villages indicates that farmers are all pursuing similar management practices and input strategies.

Fertilizer inputs: an overview

The study states that most villagers followed a monocropping system of Rice and wheat, with a few including mustard as a third crop. These signify an intensive cultivation of this exhaustive crop. Furthermore, there is no crop rotation to allow soil nutrition to recharge. A very few farmers had a diversified cropping pattern that included sugarcane, maize, and vegetables. The fertilizer input signifies that farmers follow a high-input and high-reward system. The farmers' input of urea is moderately

high in all the villages, followed by DAP. The lack of variation in fertilizer dosage signifies a common system followed by farmers for fertilizer input. This is either through word of mouth or their experience, as confessed by a lot of farmers. This further supports that Punjab's fertilizer input is 223.46 kg/hectare compared to the national average of 90kg/hectare (Khajuria, 2016) [2].

The fertilizers used, i.e., Urea and DAP, are both used to supply micronutrients. The study signifies that almost no farmer was inputting a source of micronutrients in soil, except for including cow dung manure in fields. Micronutrients are generally not considered as important to farmers compared to nitrogen and phosphorus.

Compared to wheat and mustard, the highest fertilizer use was of rice, with more urea and DAP input. While mustard fertilizer use was significantly lower, presumably because it is a minimally managed crop and requires fewer inputs comparatively.

The study shows that these 10 villages followed a high-input grain-based monocropping system. Which is higher than moderate fertilizer input without regard to the official recommended dose or long-term soil impacts and sustainability.

Conclusion

This study shows that urea overuse in the Punjab region has led to a measurable and rapid decline in soil health. With fertilizer consumption at 247.61 kgs per hectare, approximately double the national average and an N: P: K ratio of 31.4:8:1 against the recommended dose, the soil of Punjab is suffering from severe macronutrient stress (Down to Earth, 2024; IMPRI, 2023) [9, 13]. Soil organic carbon (SOC) fell below the average critical point by 0.49%, nitrogen use efficiency reduced to 40%, with the residues resulting in contamination of groundwater or volatilizing as greenhouse gas (Benbi, 2016) [8]. These outcomes are structurally driven by the policies and subsidies, and the price of urea is far lower than that of phosphate and potash, contributing to an imbalance of fertilizer consumption in the agricultural soil of Punjab.

To reduce or reverse this degradation, we need to follow three coordinated reforms: revising the subsidies of fertilizer towards a nutrient-based model, promoting crop diversification beyond the mono-cropping pattern of rice and wheat, along with strengthening the implementation of soil health with the

effective farmer-level guidance (Springmann *et al.*, 2025; Karmakar & Saha, 2023)^[22, 14]. Without the following measures, the soil of Punjab will continue to be exploited to the core, threatening not only state agriculture but the food security of the whole of India.

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