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Technology and Policy Options for Efficient Use of Fertilizers in Indian Agriculture

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Fertilizers along with high-yielding variety seeds and irrigation have played a key role in enhancing agricultural productivity and food supply, thereby ensuring food security and reducing poverty in India. The fertilizer use, since the beginning of the Green Revolution in the mid-1960s, has increased tremendously. However, over the time, their excess and indiscriminate use, probably because of their lower use efficiency, has polluted the natural resources and environment, and resulted in diminishing returns. This policy brief provides a synoptic view of the technology and policy options that can help improve fertilizer-use efficiency, reduce their indiscriminate use and correct nutrient imbalance.

Fertilizer consumption

The high-yielding variety seeds are more input responsive. To realize their potential, these require more of fertilizers and irrigation water. During the past five decades, the demand for fertilizers in nutrient terms (i.e., nitrogen, phosphorus and potash, NPK), has grown exponentially, from 0.78 million tonnes in 1965-66 to 32.53 million tonnes in 2020-21 (Fig. 1) at an annual growth of 5.6%, which is significantly higher than the growth in foodgrain production (2.2%). Their consumption per hectare of gross cropped area (GCA) also increased significantly, from a mere 5.1 kg in 1965-66 to 154 kg in 2020-21.

The consumption of fertilizers in India is characterized by significant disparities in its use, across irrigation environments, crops, and farm size classes. Irrigated agriculture, which occupies about half of the GCA, accounts for about 70% of the total fertilizer consumption. Their per hectare use is 2.4 times more in irrigated agriculture than in rainfed agriculture (Fig. 2).

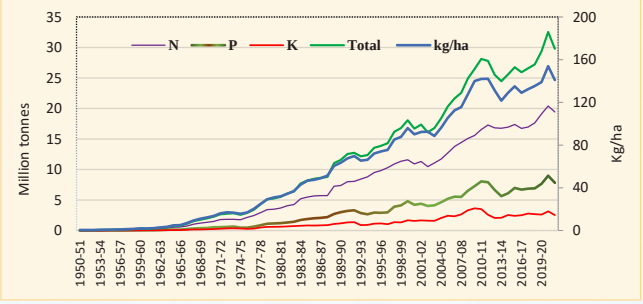

Fig. 1. Trend in fertilizers (NPK) consumption in India, 1950-51 to 2020-21
Source: FAI[1] (various years)

Fertilizer use is inversely related to farm size, in both irrigated and rainfed environments (Fig. 2). On marginal farms (≤1 ha), fertilizer use is 151 kg/ha, which is more than twice of that on large farms (10 ha and above). The marginal farms although share 25.3% of the GCA, these account for 30.1% of the total fertilizer consumption. On the other hand, the share of large farms in the total fertilizer consumption is only half of their share in the GCA (7.8%). The higher fertilizer use on marginal farms is attributed to intensive use of land (i.e., higher cropping intensity), and greater allocation of it to input-intensive crops like vegetables. Notably, the marginal and small farms (<2ha) account for about 55% of the total area under vegetable cultivation in the country[2].

Expectedly, the fertilizer-use intensity (defined in terms of NPK use per hectare of GCA) is higher in commercial crops like sugarcane, cotton, fruits, and vegetables. Together these share 13.3% of the GCA, but account for 22.5% of the total fertilizer consumption (Fig. 3). Rice and wheat, the staple food

[1] FAI (various years). Fertilizer Statistics. *Fertilizer Association of India*, New Delhi.

[2] GoI. (2021). All India Report on Input Survey 2016-17. Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi.

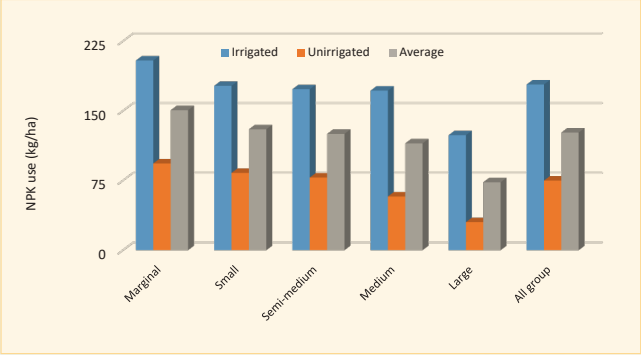

Fig. 2. Fertilizer use in irrigated and rainfed agriculture, 2016-17
Source: GoI (2021)

crops in India, occupy 47% of the GCA and consume 52% of the total fertilizers. Coarse cereals, pulses, and oilseeds, which are mostly grown in rainfed environment, have relatively low share in fertilizer consumption (20%) as against their share of 31% in GCA.

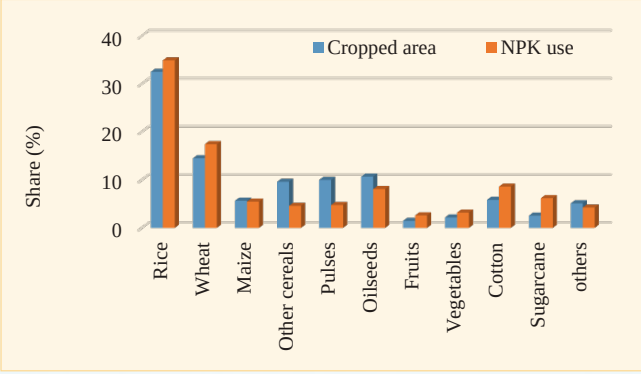

Fig. 3. Percent share of cropped area and NPK use by crop, 2016-17
Source: As in Figure 2

Thus, depending on irrigation coverage, cropping pattern, and cropping intensity, there are significant inter-state disparities in fertilizer-use intensity (Fig. 4). The NPK use is the highest in Telangana (232.8kg/ha) and the lowest in Rajasthan (54.5kg/ha). Fertilizer use intensity is also higher in the Indo-Gangetic plains, comprising the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal (140-170kg/ha).

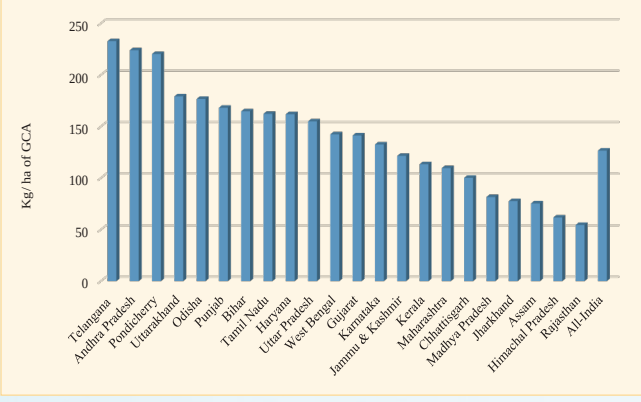

Fig. 4. Average fertilizer use (kg/ha) by state, 2016-17
Source: As in Figure 2.

Fertilizer subsidy

The Government of India has been providing fertilizers to farmers at highly subsidized prices for long. The increasing consumption of fertilizers since the mid-1960s has been accompanied by increased expenditure on subsidy. The total expenditure on fertilizer subsidy (at 2011-12 prices) has increased 25-fold, from Rs 40 billion in 1980-81 to Rs 1,005 billion in 2021-22 (Fig. 5). On per hectare of GCA, it has increased from Rs 232 to Rs 4,756 during this period. The trend in expenditure on subsidy, however, is uneven. It kept on increasing slowly until 2003-04, but reached a peak of Rs 1880 billion in 2008-09 due to global financial crisis. Thereafter, it declined until 2017-18, but again attained a peak in 2021-22. Currently, about 3% of the agricultural gross domestic product is spent on fertilizer subsidy.

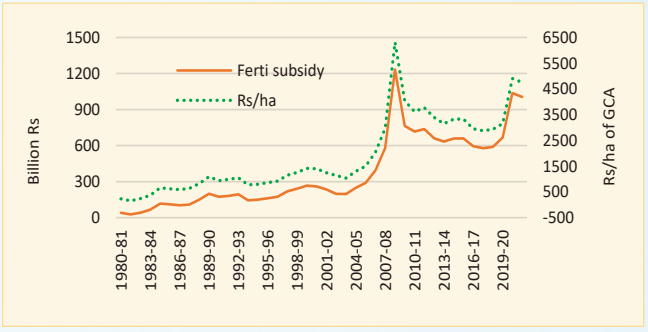

Fig 5. Fertilizer subsidy in India, 1980-2021
Source: As in Figure 1.

There are significant inter-state disparities in fertilizer use and therefore in fertilizer subsidy. Expectedly, the fertilizer subsidy is estimated the lowest for Rajasthan (Rs 1,827/ha) and the highest for Punjab (Rs 7,320/ha) for the triennium ending (TE) 2021-22[3]. Generally, the fertilizer use and subsidy are higher in the regions better-endowed with irrigation and have a larger proportion of the area under input-intensive crops like paddy, wheat, vegetables and sugarcane.

Fertilizer-use efficiency

Fertilizer-use efficiency is low in Indian agriculture. The use efficiency of nitrogen is reported to be 30-50%, of phosphorus 15-20% and of potash 50-60%[4]. The partial factor productivity of fertilizers in Indian agriculture (measured as ratio of index of crop output to index of fertilizer use at the base 2011-12) declined until 2010-11, and remained almost stable afterwards (Fig. 6), possibly because of government initiatives like introduction of neem coated

[3] At 2011-12 prices (WPI of all commodities).

[4] Sarkar, D., Rakshit A, Ahmad I. Al-Turki, A.I., R. Z. Sayyed, R.Z. and Datta, R. (2021). Connecting bio-priming approach with integrated nutrient management for improved nutrient use efficiency in crop species. *Agriculture* 11(4): 1-18.

urea[5] and Soil Health Card. Rice is the dominant crop in area as well as fertilizer use, and thus the trend in aggregate partial productivity is greatly affected by rice cultivation. For wheat, there is no significant trend in partial factor productivity.

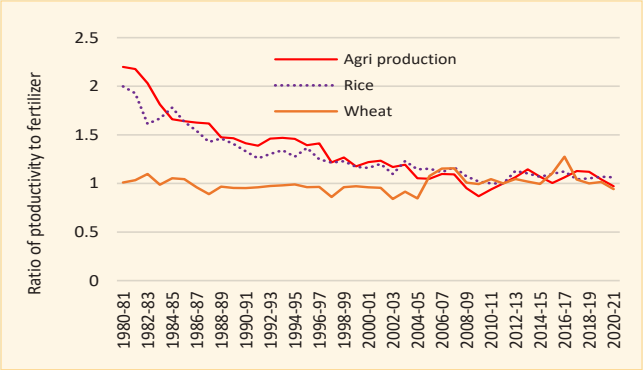

Fig. 6. Trend in partial productivity of fertilizer (NPK),1980-2021
Source: As in Figure 1

Imbalance in fertilizer use

Balanced use of NPK is important to reduce their excessive and indiscriminate use, improve use efficiency, reduce cost of production, and mitigate environmental pollution. In Indian agriculture, NPK ratio of 4:2:1 is considered ideal. Presently, it stands at 6.8: 3.3: 1 (Table 1). From 8.2:3.5:1 in 1991-92 it declined and reached closer to the ideal in 2001-02 but again started rising.

There are significant differences in the application of NPK and their proportions across farm classes. The NPK use is more balanced on marginal farms than on any other farm category. It is the most unbalanced on large farms (>10 ha). This implies that although smallholder farmers apply more fertilizers but in a balanced manner, despite the nitrogenous fertilizers being relatively cheaper than other fertilizers. The unit price of nitrogen in 2015-16 was Rs 12.23/kg, compared to Rs 48.7/kg of phosphorus, and Rs 26.7/kg of potash.

Across states, the imbalance is significantly high in the north-western state of Rajasthan (one of the lowest user of NPK per unit of GCA), and in Punjab and Haryana where the fertilizer use intensity is very high (Fig. 7). In Maharashtra, Assam, West Bengal, Telangana, Karnataka, Tamil Nadu, and Kerala the NPK ratio is closer to the ideal.

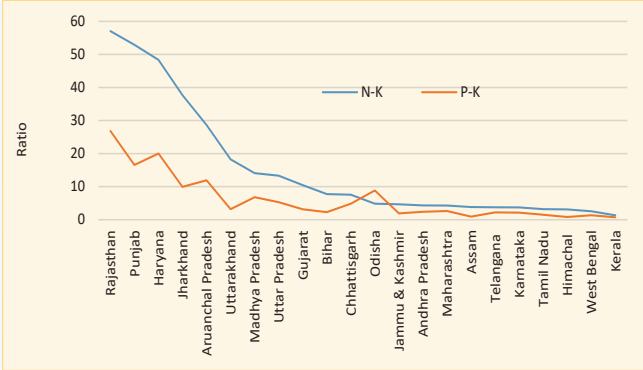

Fig. 7. N: K and P: K ratio across states of India, 2016-17
Source: As in Fig 2.

Figure 8 shows the use of fertilizers per hectare vis-à-vis N: K ratio across districts. In about 50% of the districts in the country fertilizer use is less than the national average of 150kg/ha. And, the N: K ratio in about 40% of than is less than or equal to 4, while in the rest 60% it ranges between 4 to 10. In the remaining 50% of the districts where fertilizer use intensity is higher than the national average, the nutrient imbalance also appears high in several of the districts.

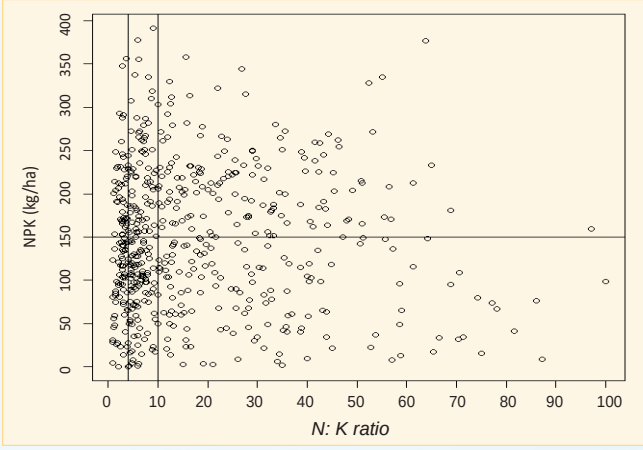

Fig. 8. Distribution of districts by fertilizer use and N: K ratio, 2021-22
Source: As in Fig. 1.

Table 1. NPK ratio by farm size

Farm class	1991-92	1996-97	2001-02	2006-07	2011-12	2016-17
Marginal (<1 ha)	6.7:2.5:1	5.7:2.4:1	3.8:1.7:1	5.1:2.1:1	5.6:2.3:1	5.3:2.5:1
Small (1.0-1.99 ha)	7.2:3.0:1	5.6:2.7:1	4.3:2.1:1	4.8:2.3:1	4.9:2.4:1	6.5:3.2:1
Semi-medium (2.0-3.99 ha)	8.4:3.6:1	7.4:3.5:1	5.0:2.5:1	6.4:2.9:1	5.8:2.9:1	7.1:3.1:1
Medium (4.0-9.99 ha)	9.5:4.3:1	11.3:5.2:1	7.5:3.5:1	8.8:3.8:1	7.5:3.7:1	10.2:5.6:1
Large (10 ha and above)	13.5:5.9:1	21.5:9.7:1	13.4:5.9:1	13.4:5.6:1	10.5:4.4:1	14.6:6.5:1
All class	**8.2:3.5:1**	**7.4:3.4:1**	**4.9:2.3:1**	**6.0:2.6:1**	**5.8:2.7:1**	**6.8:3.3:1**

Source: Estimated using data from the Agricultural Census Division available at https://agcensus.nic.in/

[5] Ramappa K.B., Jadhav V. and Manjunatha A.V. (2022). A benchmark study on economic impact of neem coated urea on Indian agriculture. *Scientific reports*. https://doi.org/10.1038/s41598-022-12708-1

Options for efficient use of fertilizers

There are several pathways to optimize fertilizer use and restore nutrient balance. There is a specific suggestion towards this. India has diverse soil types varying in nutrient contents; hence, the universal NPK ratio of 4:2:1 is not applicable everywhere. There is a strong need to evolve NPK ratio for each district, based on its cropping pattern, soil type and rainfall to target fertilizer management strategies.

Some specific suggestions are as follows:

Parity in nutrient prices: To restore the nutrient balance and optimize fertilizer use, fertilizer price or subsidy policy needs to be reformed considering the relative consumption levels of N, P and K, and their prices. Before the implementation of policy of decontrol of P and K in 1992 the N: K ratio was around 6, but after the decontrol it started rising reaching a peak in 1996-97 (Fig. 9). Nevertheless, it started declining and reached towards the ideal in 2009-10. Further, after the introduction of the Nutrient Based Subsidy (NBS) scheme in 2010 the N: K ratio increased initially but remained almost stable afterwards. Note that price of urea has remained constant since 2011-12 at Rs 11.54/kg.

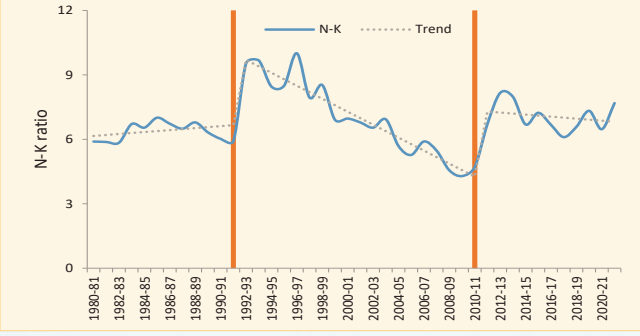

Fig. 9. Policy intervention and nutrient imbalance, 1980-2021
Source: As in Figure 1.

Link subsidy to Soil Health Card (SHC): Fertilizer supply to farmers is linked to their Aadhar Cards. A better way to optimize fertilizer use and restore nutrient balance is to link it to crop-specific recommendations contained in the SHC. The lab testing of soil samples, however, is time-consuming; hence, the automation of soil testing is essential to ensure timely delivery of information on soil properties. Towards this, the state governments should take benefits of PM-PRANAM (Prime Minister's Programme for Restoration, Awareness, Nurturing and Improvement of Fertility of Mother Earth) scheme that offers incentive for achieving optimality in fertilizer use.

Promote new generation fertilizers: New generation fertilizers such as customized and nano-fertilizers, which slowly release nutrients, can significantly enhance fertilizer-use efficiency and without any yield penalty. Evidence shows that application of nano-fertilizers[6] in conjunction with regular fertilizers reduces fertilizer use, improve fertilizer use efficiency and increase crop yield at least by 7%.

Promote bio-fertilizers and organic manures: Biofertilizers are technically and economically feasible alternatives of chemical fertilizers to improve soil health, reduce cost of production, and improve crop yields[7]. However, their poor quality is a matter of concern, which needs to be addressed through enforcement of the regulations. Likewise, there is a considerable scope to convert the huge biomass, that Indian agriculture generates, into biogas and bio-manure. Their production should be promoted at village or block level through collectives or small-scale enterprises. Their conjunctive use with chemical fertilizers will not only reduce chemical fertilizer demand but also improve soil and environmental health and crop yields[8].

Promote legumes: Legumes are a storehouse of nitrogen, sequester carbon, and reduce greenhouse gas emission[9]. India still imports about 15% of its domestic demand for pulses. Incorporation of legumes in the cropping system can reduce dependence on imports of fertilizers as well as pulses and save foreign exchange.

Research for higher nutrient-use efficiency: Agricultural research should endeavour to develop crop varieties that are more responsive to soil nutrients and sequester atmospheric nutrients through leaves or roots. The other option is the genetic modification of crops for desired traits. Given the success of research in crop biofortification, insertion of such traits in crops does not seem impossible.

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6 Kumar Y., Tiwari K.N., Singh T., Sain N.V, Laxmi S., Verma R., Sharma G.C., and Raliya R. (2020). Nanofertilizers for enhancing nutrient use efficiency, crop productivity and economic returns in winter season crops of Rajasthan. *Annals of Plant and Soil Research*, 22(4):324:335.

7 Rao D.L.N. (2018). Promoting biofertilizers in IPNS with improved technology and extension in India. In SAARC Training Manual on Integrated Nutrient Management for Improving Soil Health and Crop Productivity (P. Dey, S. Srivastava, N.K. Lenka, K.C. Shinogi, A.K. Vishwakarma and A. K. Patra, Eds.). *ICAR- Indian Institute of Soil Science, Bhopal*. 2018;71-76.

8 Sharma S, Padbhushan R, Kumar U. (2019). Integrated nutrient management in rice–wheat cropping system: An evidence on sustainability in the Indian subcontinent through meta-analysis. *Agronomy*. doi:10.3390/ 9020071.

9 Stagnari, F., Maggio A, Galieni M, and Pisante M. (2017) Multiple benefits of legumes for agricultural sustainability: An overview. *Chemical and Biological Technologies in Agriculture*:4 (2):1-13. DOI 10.1186/s40538-016-0085-1

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