Fertiliser Use and Imbalance in India

Analysis of States

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The common and strongly-held view in India is that balanced fertiliser use requires three major plant nutrients, namely, nitrogen, phosphorous and potassium, to be used in the ratio of 4:2:1, and any deviation in fertiliser use from this norm would constrain growth in crop productivity. This officially-accepted perception, a product of 1950s experiments, has led to wrong policies on fertilisers. Estimating actual and normative quantity of N, P and K for each state of India corresponding to the current cropping pattern, it is found that contrary to the notion that there is excess use of nitrogen in India, 12 major states were found using less than the required level. India, in fact, faces large deficits in use of P and K. It calls for curtailing the use of N in one-third of the states and raising it in the remaining two-thirds.

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1 Introduction

Fertiliser use has seen a tremendous increase in India and in other parts of the world with the spread of Green Revolution technology. Fertiliser was identified as one of the three most important factors, along with seed and irrigation, for raising agricultural production and sustaining food self-sufficiency in India. Empirical evidence shows that growth in total agricultural output, and output of various crops in India has moved up and down depending upon the growth in use of fertiliser (Chand and Pandey 2009). It is felt that fertiliser will continue to play a key role in meeting the future requirements of food, feed and fibre. Fertiliser can drive increases in productivity, as the scope for raising production through the expansion of cultivable land is almost ruled out. Therefore, it is very important from an output–growth point of view to ascertain whether fertiliser is used judiciously and optimally.

The total fertiliser use, comprising nitrogenous (N), phosphatic (P) and potassic (K) fertilisers, in India increased from 2.65 million tonnes (mt) of NPK in 1971–72 to 28.12 mt in 2010–11. This increase corresponds to an annual compound growth rate of over 6%. However, the rate of increase differed significantly for the three types of plant nutrients, namely, nitrogen, phosphorous and potash in different periods. Till the mid-1990s use of N increased at a faster rate as compared to the growth rate in use on P and K. The growth rate in use of N was almost double the growth rate in use of K during 1971–72 to 1996–97. In the early 1970s Indian farmers applied N, P and K in the ratio of 6.0:1.9:1.0, which increased to 9.5:3.2:1 in 1992. The ratio worsened further to 10:2.9:1 in 1996.

After 1996–97, application of phosphatic and potassic fertilisers witnessed much higher increases compared to nitrogenous fertilisers. Despite this, fertiliser use remained highly skewed towards N. In 2012–13, the ratio of NPK use in India reached 8.2:3.2:1, which is more imbalanced compared to the early 1970s when the ratio was 6:1.9:1. It is strongly believed in India that the desired ratio of N, P and K, to maintain nutrient balance is 4:2:1, and any deviation from this ideal ratio is considered to have adverse effects on crop productivity as well as soil (Tiwari 2001; NAAS 2009; Mujeri et al 2012; Sharma 2012). This imbalance was recognised quite early on, and official documents as well as researchers have expressed repeated concerns on the need to address the rising imbalance (GoI 1994, 2014; Gulati and Sharma 1995). Such concerns have been the main reason for the recent shift in fertiliser policy towards the nutrient-based subsidy. This paper traces the empirical basis of what is considered the optimal mix or norm for share of N, P and K in total fertiliser use and examines its relevance.

The literature on balanced use of N, P and K shows that the so-called 4:2:1 norm, considered sacrosanct for India, lacks sound scientific ground and the norm is not relevant for the present agricultural situations. The norm was developed and recommended in the early 1960s and is presumed to correspond to the crop pattern, yield levels and other conditions prevailing at that time. The crop pattern, yield levels and soil conditions, which determine level of fertiliser application, have undergone a sea change since the 1960s and accordingly, the requirement of fertiliser has also undergone significant changes. The policy on fertiliser use and pricing cannot be based on such an outdated norm which is also not supported by empirical evidence.

This paper makes an attempt to estimate the optimal ratio of N, P and K for the prevalent cropping pattern in India based on crops and state-specific recommendations for fertiliser application prepared by various state agricultural universities (SAUs) and crop directorates of Indian Council of Agricultural Research (ICAR). Further, as the requirement of N, P and K varies from crop to crop and from one type of soil to another type, the norm for N, P and K ratio is bound to be different for different regions representing different cropping patterns, soil types, and their nutrient status at a given point of time. Against this backdrop, the present paper estimates state-wise norms for application and composition of N, P and K, which are then aggregated to arrive at the all-India norm. The study estimates recommended quantities of N, P and K for each state and compares it with actual use. These estimates are used to work out excess or deficit in the use of the three plant nutrients at the state level. The paper also demonstrates that the concerns related to imbalance in use of N, P and K are totally misleading and policy measures to correct the imbalance are uncalled for unless the nature of imbalance is clearly determined. It identifies the situations where the imbalance actually matters and where it does not. These findings are important to formulate policies on fertiliser use and pricing.

The remainder of the paper is organised as follows. Section 1 traces the genesis of what is described as the optimal ratio of N, P and K for Indian agriculture and discusses its relevance to the current situation. Section 2 presents the methodology used in estimating the requirement of N, P and K, imbalance, and deficit or excess of application of various types of fertilisers in various states. Section 3 discusses trends in the use of N, P and K. Section 4 presents estimates of optimum quantity of N, P and K and compares the optimum and actual quantity used in various states. Sections 5 works out state-wise normative ratio of fertiliser use at state level and for the whole country. The severity and consequences of the imbalance in fertiliser use is presented in Section 6. The last section presents the conclusions and discusses implications of the study for future use of N, P and K.

1 Genesis of 4:2:1 Ratio for NPK

In general, the N, P, K ratio of 4:2:1 is considered to be optimum for India. It is hard to trace the origin of this ratio. However, it is believed that the ratio originated from field trials conducted during the 1950s, that is, in the pre-Green Revolution period (NAAS 2009). According to Prasad and Pathak (the editors of NAAS 2009), the probable reason for the higher emphasis on nitrogenous fertilisers was the higher response of crops, especially of irrigated wheat, to applied nitrogen as compared to phosphorus and potassium. It was later recognised that this ratio ignored two important factors. First, that during the Green Revolution period farmers applied farm yard manure and the native soils were rich in phosphorus and potassium content. Second, the response to applied phosphorus and potassium fertilisers was much higher on red and lateritic soils, which clearly indicate that the ratio of NPK would vary for different soil types (NAAS 2009). Further, the fertiliser norm for a state or country depends upon the cropping pattern, yield levels, crop variety and soil-specific characteristics which have undergone a sea change over the years. The farm trials conducted in the post-Green Revolution period confirmed that the response of rice crop to the applied phosphorus was as good as to that of nitrogen, and in fact it was higher in the case of improved varieties of wheat. This finding along with the popularisation of improved wheat varieties encouraged the use of phosphatic fertilisers during the post-Green Revolution period (NAAS 2009). However, the use of fertiliser in India remained skewed towards N.

In the early 1990s, the government expressed concern over the worsening ratio of NPK and it was stated that to increase the crop yields, it was essential to maintain the ideal NPK ratio of 4:2:1 (GoI 1994, 1995). In the subsequent years there has been an increasing emphasis on the balanced use of nutrients and redefining the optimal ratio of NPK use under different crop- and soil-specific conditions (Prasad 2009, 2012). But surprisingly no study was done to find out or establish the optimal mix of NPK in the country and we have been sticking to a norm of 4:2:1 that was suggested more than 50 years ago based on only two crops. Therefore, it is pertinent to examine the relevance of the existing 4:2:1 norm in the current agricultural scenario.

2 Methodology

Though the all-India trend in the level and composition of fertiliser use is important for formulating fertiliser policy, balanced use of fertilisers has significance at the disaggregate level. The reason for this is that the cropping pattern varies from state to state. The required level and ratio of NPK differs invariably across crops. Therefore, the national-level composition of N, P and K does not reveal the true picture of distortions in the use of N, P and K, which is better revealed by disaggregated data such as state and agro-region level. Therefore, we are now shifting the focus of the paper to the state level.

The required or normative quantity of fertiliser use for a state was estimated based on area under various crops and the recommended dose of NPK for the respective crops, as per the *Package of Practices* published by the SAUs and ICAR institutes as under:

- $Dns = \sum_{i=1}^{C} (Ais\_w * Rns\_w) + \sum_{i=1}^{C}(Ais\_r * Rns\_r)$
- $Dps = \sum_{i=1}^{C}(Ais\_w * Rps\_w) + \sum_{i=1}^{C}(Ais_r * Rps\_r)$
- $Dks = \sum_{i=1}^{C}(Ais\_w * Rks\_w) + \sum_{i=1}^{C}(Ais\_r * Rks\_r)$

where Dns, Dps and Dks are desired levels of N, P and K in sth state respectively, "*w*" and "*r*" are irrigated and rain-fed areas respectively, "A" is the area under crop "*i*," in state "*s*," and "R" indicates recommended dose of nutrient. In some states disaggregation was extended to agroclimatic region.

The desired level of N, P and K, which is recommended to be applied to a crop is computed from the following expression (Prasad 2012):

Nutrient to be applied = [{yield(t/ha) × nutrient uptake (kg/t)} — {nutrient available in soil (kg/ha)}] × 100/NUE.

For example, for a crop of rice yielding 6 t/ha of grain and removing 20 kg N/t on a soil having 60 kg available N/ha and NUE 40%, the amount of N to be applied will be:

$= [(6 \times 20) - (60)] \times 100/40$

$= 150$ kg N/ha

Dns, Dps and Dks were compared with actual consumption of N, P and K in each state to find out the imbalance in fertiliser use as well as the gap between optimum and actual use of fertilisers.

3 Trends and Composition of Fertiliser Use in India

During 1971–72 total consumption of fertiliser in India was 2.65 mt consisting of 1.79 mt of N, 0.56 mt P and 0.30 mt of K. It gradually increased to 28.1 mt by 2010–11 and witnessed a small decline in the last three years. The share of N, P and K in total fertilisers since 1971–72 is presented in Table 1. The norm of 4:2:1, which has been officially recognised as optimal, implies that nitrogen should constitute 57.2% and P and K should constitute 28.6% and 14.2%, respectively, of total NPK use in the country. During early 1970s two-thirds of total fertiliser was nitrogenous while phosphatic and potassic categories accounted for 21% and 11% share respectively (Table 1). In most of the years, share of nitrogen in total fertiliser use hovered around 65% which is 8 percentage points higher than the officially accepted norm of 4:2:1.

The change in the composition of fertiliser in terms of N, P and K during the last four decades is characterised by three major episodes. The first one refers to 1974–75 when the share of nitrogen in total fertiliser use increased to 68.64% during 1974–75, and further to 74.3% by 1975–76. These were the years of oil shock, when global fertiliser prices, in nominal dollars went up by two to four times in a single year. The increase in price was much higher in nitrogenous fertilisers (urea) as compared to potassic and phosphatic fertilisers. However, the effect was felt more on the use of P and K than on N. After this, the share of N in total fertiliser use gradually declined and reached 63.2% level in 1991–92, that was lowest in the period till then. During 1992, the government noted the need to reduce the imbalance in fertiliser use and to rationalise fertiliser subsidies (GoI 1993). The explicit purpose of reducing imbalance was to raise share of P and K, and thus reduce share of N in total fertiliser use.

Table 1: Trend in Fertiliser Use and Its Composition

Year	Total Use of NPK, '000 Tonne	Share N %	Share P %	Share K %
1971–72	2,657	67.67	21.00	11.33
1972–73	2,768	66.44	20.99	12.57
1973–74	2,839	64.42	22.90	12.68
1974–75	2,573	68.64	18.34	13.06
1975–76	2,894	74.26	16.14	9.61
1976–77	3,411	72.03	18.62	9.35
1977–78	4,286	67.97	20.23	11.81
1978–79	5,117	66.84	21.61	11.55
1979–80	5,255	66.57	21.90	11.53
1980–81	5,516	66.68	22.01	11.31
1981–82	6,067	67.07	21.79	11.14
1982–83	6,401	66.27	22.39	11.34
1983–84	7,710	67.50	22.44	10.05
1984–85	8,211	66.81	22.97	10.21
1985–86	8,474	66.80	23.66	9.54
1986–87	8,645	66.12	24.05	9.83
1987–88	8,784	65.08	24.90	10.02
1988–89	11,040	65.68	24.65	9.67
1989–90	11,568	63.85	26.05	10.10
1990–91	12,546	63.74	25.67	10.59
1991–92	12,728	63.21	26.09	10.69
1992–93	12,155	69.33	23.40	7.27
1993–94	12,366	71.07	21.58	7.35
1994–95	13,563	70.10	21.62	8.29
1995–96	13,876	70.79	20.88	8.33
1996–97	14,308	72.00	20.81	7.20
1997–98	16,195	67.34	24.19	8.48
1998–99	16,773	68.36	23.85	7.78
1999–00	18,070	64.16	26.55	9.29
2000–01	16,631	65.31	25.33	9.36
2001–02	17,360	65.15	25.24	9.60
2002–03	16,094	65.08	24.97	9.95
2003–04	16,631	66.60	24.80	9.60
2004–05	18,399	63.67	25.13	11.20
2005–06	20,340	62.55	25.58	11.86
2006–07	2,1651	63.61	25.60	10.78
2007–08	22,570	63.89	24.44	11.68
2008–09	24,909	60.58	26.12	13.30
2009–10	26,486	58.82	27.46	13.71
2010–11	28,122	58.88	28.62	12.50
2011–12	27,790	62.25	28.48	9.27
2012–13	25,804	69.86	23.07	7.02
2013–14	23,959	68.97	22.70	8.24

Source: Annual Reports, Department of Fertilisers, Ministry of Fertilisers and Chemicals, Government of India, various issues.

Accordingly, the prices, movement and distribution of phosphatic and potassic fertilisers were decontrolled with effect from 25 August 1992. No significant change was introduced in urea, which is a dominant nitrogenous fertiliser in India, and its price was reduced after some experimentation with dual pricing. This change in fertiliser policy in the middle 1992 r sulted in a jump in prices of P and K in absolute terms and also relative to price of N in the year 1992–93. This policy-induced change in relative prices of N, P and K led to reversal of the trend towards reduction in share of N in total fertiliser.

The share of N in total fertiliser use which was falling since the mid-1970s, suddenly increased after 1991–92. This clearly shows that an increase in share of N and decline in shares of P and K, in other words the imbalance in fertiliser use was policy-induced. After this policy distortion, share of N again started falling post 1996–97 and reached 58.8% by 2009–10. This share was only slightly higher than the officially accepted norm of 57.2%. The share of P and K were also very close to the officially accepted norm at the national level, though there were significant variations in the share across states. On 1 April 2010, the government introduced the nutrient-based subsidy (NBS) policy, with the aim of ensuring balanced application of fertilisers. The NBS policy was made effective in P and K but not in urea, which is a principal nitrogenous fertiliser. This again distorted the prices in favour of N and, like earlier trends seen during the mid-1990s, the composition of fertiliser at the national level started moving in favour of N. Just in two years after introduction of NBS the share of N increased by 11 percentage points—from 58.8% to 69.8%. This shows that the gain achieved in reducing the imbalance in use of N, P and K has been completely wiped out.

It is concluded from the changes observed in the composition of fertiliser during the last four decades that corresponding to a given fertiliser price regime, farmers tended to reduce the imbalance in fertiliser use. However, the outside shock and changes in fertiliser policy each time triggered a sharp rise in the share of nitrogenous fertilisers and fall in the shares of P and K in total fertiliser use. The policy reforms in fertiliser prices, which purportedly aimed at reducing the imbalance in use of N, P and K, have delivered exactly the opposite result.

4 Actual and Normative Use at State Level

The actual level of fertiliser use in a state and optimum quantity estimated by multiplying area under different crops with doses of N, P and K recommended by the agricultural research institutes in various states during the triennium 2009–10 to 2011–12 are presented in Table 2. It shows that the actual use of nitrogenous fertiliser was higher than the normative level, based on the recommended dose, in the states of Andhra Pradesh, Assam, Punjab, Bihar, Haryana and Jharkhand while the use of nitrogenous fertilisers in Odisha was near optimal. In all the other states the current level of nitrogen use remained below the recommended norms. This indicates that there exists an imbalance in the use of N both in terms of surplus as well as deficit. For instance, in Andhra Pradesh, the normative quantity of N was estimated at 1,138 thousand tonnes, while the actual use was 1,884 thousand tonnes recording an excess use of 746 thousand tonnes.

Table 2: Normative and Actual Use of N, P and K, Triennium Ending 2011–12

State	Normative Use: Thousand Tonne				Actual Use: Thousand Tonne			
	N	P	K	Total	N	P	K	Total
Andhra Pradesh	1,138	679	474	2,291	1,884	984	433	3,300
Assam	124	90	70	284	140	52	72	265
Bihar	688	368	245	1,301	921	265	136	1,322
Chhattisgarh	498	298	208	1,005	323	167	61	552
Gujarat	1,247	450	456	2,153	1,198	483	174	1,855
Haryana	807	339	202	1,348	996	350	51	1,397
Himachal Pradesh	82	43	33	158	33	11	11	54
Jharkhand	84	51	42	177	97	45	14	156
Jammu and Kashmir	95	57	29	181	73	32	12	117
Karnataka	1,043	655	651	2,349	1,028	668	395	2,091
Kerala	227	164	349	740	116	60	91	267
Madhya Pradesh	1,080	1,181	449	2,710	967	667	109	1,742
Maharashtra	1,745	1,176	654	3,575	1,606	1,067	560	3,233
Odisha	313	177	176	666	316	156	83	555
Punjab	951	375	235	1,561	1,377	421	65	1,863
Rajasthan	1,335	742	130	2,206	832	371	33	1,235
Tamil Nadu	673	270	298	1,241	643	283	298	1,224
Uttarakhand	162	75	51	288	117	30	11	158
Uttar Pradesh	3,210	1,436	1,085	5,731	2,997	1,044	269	4,310
West Bengal	1,412	762	764	2,938	753	491	381	1,624
Others	114	82	73	270	30	13	7	50
All India	17,030	9,469	6,675	33,174	16,466	76,578	3,264	27,387

Source: Normative use is based on the authors' estimates. Actual use taken from Fertiliser Statistics, The Fertiliser Association of India, New Delhi. various issues.

On the other hand, the normative levels of nitrogen fertilisers in West Bengal and Kerala were 1,412 thousand tonnes and 227 thousand tonnes respectively, while the actual use was 753 thousand tonnes and 116 thousand tonnes—this is only half of the requirement for the existing cropping pattern in these states. The total normative level of nitrogen for India as a whole was about 17 mt, which was not significantly different than the actual use of N.

The normative level of phosphorus use for the whole country was about 9.46 mt whereas the actual use was about 7.65 mt. Our estimates indicate that use of P in the case of Madhya Pradesh, Uttar Pradesh and West Bengal was far lower than what was recommended for the prevailing cropping pattern in these states. However, in states like Gujarat, Karnataka, Punjab and Tamil Nadu actual use of P was much higher than the desired level.

Use of K for the country as a whole was 3.26 mt. According to our estimate, the optimum requirement of K in India was 6.6 mt. Except in Tamil Nadu and Assam, the use of K was lower than what was optimum in all states.

4.1 Extent of Excess and Deficit Use

At the national level, there was a deficit in use of all the three types of plant nutrients but the deficit in the case of N was very small (Table 3). The extent of deficiency varies from 3.3% for N to 51% for K. There were wide variations across states. Out of the 20 major states, three states, namely, Andhra Pradesh, Haryana and Punjab, applied total fertilisers far in excess of what was required. Despite excess use of total fertilisers, these states were deficit in the use of K.

Table 3: State-wise Excess/Deficit of NPK %: (Normative–Actual)/Normative

State	N	P	K	Total
Andhra Pradesh	65.52	44.83	-8.73	44.02
Assam	12.81	-41.70	2.97	-6.85
Bihar	33.88	-28.09	-44.61	1.57
Chhattisgarh	-35.09	-44.05	-70.52	-45.09
Gujarat	-3.94	7.38	-61.90	-13.85
Haryana	23.32	3.36	-74.83	3.58
Himachal Pradesh	-60.30	-74.12	-67.19	-65.48
Jharkhand	15.95	-11.74	-67.91	-11.98
Jammu and Kashmir	-23.06	-43.73	-59.33	-35.41
Karnataka	-1.43	1.94	-39.27	-10.98
Kerala	-48.72	-63.60	-73.91	-63.90
Madhya Pradesh	-10.51	-43.52	-75.78	-35.70
Maharashtra	-7.96	-9.25	-14.43	-9.57
Odisha	0.69	-11.56	-52.70	-16.66
Punjab	44.86	12.15	-72.31	19.38
Rajasthan	-37.68	-50.04	-74.42	-43.99
Tamil Nadu	-4.44	4.82	-0.06	-1.38
Uttarakhand	-27.95	-59.96	-77.66	-45.08
Uttar Pradesh	-6.63	-27.31	-75.21	-24.80
West Bengal	-46.68	-35.59	-50.20	-44.72
Others	-73.96	-84.65	-89.91	-81.56
All India	-3.31	-19.14	-51.09	-17.44

Source: Authors' estimates.

It is a common perception that farmers in India apply excess nitrogen. This is true only in six states, namely, Andhra Pradesh, Assam, Bihar, Haryana, Jharkhand and Punjab. In Karnataka and Odisha, actual use of N did not differ significantly from the recommended level. In 12 states, the use of N was lower than what was optimum according to recommendations of SAUs and ICAR institutes. The degree of deficiency varied from 4.4% to 60%. Andhra farmers used 45% more P than what is optimum. Use of P exceeded the desired level by 3.4% in Haryana, 4.8% in Tamil Nadu, 7.4% in Gujarat and 12% in Punjab.

In the remaining states, the use of P was lower than the recommended dose for the states to the extent of 9% to 64%. As already mentioned, farmers in Assam used 3% more K than desired, while there was no significant difference between the actual and desired levels of use in Tamil Nadu. All other states show deficiency in the use of K to the extent of 8.7% to 78%. States like Kerala, Madhya Pradesh, Punjab, Uttarakhand, Uttar Pradesh, Chhattisgarh and Haryana did not use even 30% of required doses of K. It is concluded from this table that the all-India picture of use of NPK does not adequately capture the state-level variations.

Less than one-third of the states used excess of N, whereas two-thirds used less than the optimal level of N. One-fifth of the states used excess of P. Area under cultivation that suffers from deficiency in use of nitrogen is much larger than the area where nitrogen is used in excess. Thus, as a policy, there is a need to reduce the use of N in six states and promote its use in all other states.

The estimates of deficit and surplus assumes that entire sale of fertiliser in a state is used for agriculture purposes, that is, for crop production. However, small quantity of some fertiliser, particularly urea, may have been used for non-agricultural purposes. If such non-agricultural use is taken into consideration, then the surplus will get reduced and the deficit will increase.

5 State-wise Normative Ratio of Fertiliser Use

As discussed in the beginning, considering the origin of the norm for the NPK mix and considering the sea change in cropping patterns and agricultural practices, it is pertinent to revisit this norm in the context of the current agricultural situation India. It is also emphasised that the norm 4:2:1 needs to be debated and redefined (GoI 2001; Prasad 2012). Second, the norm at the national level represents aggregate situation which may be totally out of alignment with state-level picture. Hence, this paper estimates normative ratio of fertiliser use for the states based on the state-specific and crop-specific fertiliser recommendations and the current cropping pattern. The results related to normative ratio and ratio based on actual use of N, P and K across the states are presented in Table 4. The paper uses three years average as there are fluctuations in actual ratios from year to year.

The aggregate of the states show that optimum ratio or norm for balanced use of N, P and K for India should be 2.6:1.4:1. This norm based is on the current cropping pattern, and recommended doses of fertilisers by SAUs is quite different than the norm in vogue. The current norm implies that nitrogen should comprise 52% of total fertiliser applied in India and P and K should account for 28% and 20% of the total fertiliser respectively. These shares are quite different than the share based on the ratio of 4:2:1, which implies that N should constitute 57.8% and P and K should constitute 28.6% and 14% share respectively.

State-level norm for NPK estimated in this study shows that the existing norm of 4:2:1 was close to estimated norm only in traditional Green Revolution belt of north-west India. This is not surprising as the existing norm was based on the agronomic trials in this region, and for wheat and paddy crops which dominate the cropping pattern in this region. The optimum mix of NPK in other states except Rajasthan implies a lower share of N and higher share of P and K than what is implied by the ratio of 4:2:1.

A comparison of actual and normative ratios shows the deviations of NPK use in the states. The worst deviation or imbalance was observed in the case of Rajasthan followed by Punjab and Haryana, though it was severe even in other states like Uttar Pradesh, Bihar, Jharkhand and Madhya Pradesh. Maharashtra and Tamil Nadu were the only states where actual and normative ratios of NPK was almost the same.

West Bengal shows a very small departure from the optimum ratio. It is also interesting to point out that optimal share of nitrogen works out to be lower than the share of potash in Kerala. Rajasthan turns out to be an outlier in terms of requirement of N relative to K. The optimum NPK ratio for Rajasthan works out to be 10.3:5.7:1.

The normative ratio presented in Table 4 highlights the fact that state-level norms for the optimum mix of NPK are far away from the all-India average. Fertiliser promotion and policy should be state-specific and it should strive to attain state-specific optimum mix and use of NPK.

6 Imbalance in Fertiliser Use and Its Implications

The imbalance in the composition of fertiliser use is adverse only if one or more nutrients are used in excess of the prescribed norm. Whereas, in situations where all the nutrients

Table 4: State-wise Actual and Normative Ratio of NPK Use (2009–11)

State	Actual Ratio			Normative Ratio		
	N	P	K	N	P	K
Andhra Pradesh	4.41	2.28	1.00	2.40	1.43	1.00
Assam	1.94	0.73	1.00	1.77	1.28	1.00
Bihar	6.79	1.95	1.00	2.81	1.50	1.00
Chhattisgarh	5.27	2.72	1.00	2.39	1.43	1.00
Gujarat	6.89	2.78	1.00	2.73	0.99	1.00
Haryana	19.55	6.87	1.00	3.99	1.67	1.00
Himachal Pradesh	3.00	1.02	1.00	2.48	1.29	1.00
Jharkhand	7.20	3.31	1.00	1.99	1.20	1.00
Jammu and Kashmir	6.16	2.72	1.00	3.26	1.96	1.00
Karnataka	2.60	1.69	1.00	1.60	1.01	1.00
Kerala	1.28	0.66	1.00	0.65	0.47	1.00
Madhya Pradesh	8.90	6.14	1.00	2.41	2.63	1.00
Maharashtra	2.87	1.91	1.00	2.67	1.80	1.00
Odisha	3.79	1.88	1.00	1.78	1.01	1.00
Punjab	21.20	6.48	1.00	4.05	1.60	1.00
Rajasthan	25.08	11.18	1.00	10.30	5.72	1.00
Tamil Nadu	2.16	0.95	1.00	2.26	0.91	1.00
Uttarakhand	10.24	2.63	1.00	3.18	1.47	1.00
Uttar Pradesh	11.14	3.88	1.00	2.96	1.32	1.00
West Bengal	1.98	1.29	1.00	1.85	1.00	1.00
Others	4.01	1.70	1.00	1.55	1.12	1.00
All India	5.04	2.35	1.00	2.55	1.42	1.00

Source: Authors' computations.

are used below their normative levels, the imbalance in NPK does not matter or cause any adverse effect on productivity or the soil. This is elaborated through a hypothetical illustration of imbalance presented below. In situation A all three plant nutrients are used at suboptimal levels. The ratio of actual use of N deviates 6.6 times from the norm. In situation B the ratio of actual use deviates from the norm five times but N is used in excess. Thus, situation B warrants curtailment of use of the plant nutrient used in excess, as it causes three adverse effects—wastage of expenditure due to the additional cost incurred on fertilisers with no increments in the output, adverse effect on productivity due to excess doses on soil health, and negative implications on environment. It also warrants increases in the use of a nutrient, which is the used at suboptimal levels. Situation A warrants more use of any of the plant nutrients, including N, as long as the actual use is below the optimum level, even if it aggravates the already existing imbalance.

Particular	Situation A			Situation B		
	N	P	K	N	P	K
NPK use/hectare (kg)	80	20	4	150	50	10
Optimum dose	120	80	40	120	80	40
Ratio: Actual	20	5	1	15	5	1
Ratio: Norm	3	2	1	3	2	1
Apparent Imbalance	Very High			High		
Implication of imbalance	Immaterial. More N desirable even if it raises imbalance			Adverse. Less N desirable		

Based on this logic, states can be classified in two categories (a) where imbalance is adverse and needs to be corrected, and (b) where the imbalance is benign. The two situations have strong implications in terms of promoting fertiliser use. The estimates of fertiliser-use gaps presented in Table 3 show that none of the states showed surplus use of all the three major nutrients. Surplus use of two nutrients, that is nitrogen and phosphorus, was noticed in Andhra Pradesh, Assam, Haryana, and Punjab, and hence the nature of the imbalance in fertiliser use in these states is harmful, therefore the need to direct the states towards balanced use. Deficit use of all nutrients was noticed in Uttarakhand, Uttar Pradesh, West Bengal, Rajasthan, Maharashtra, Madhya Pradesh, Kerala, Jammu Kashmir and Chhattisgarh. In these states, the imbalance in fertiliser use is benign and policy measures need to focus on promoting the use of all the three nutrients irrespective of the existing imbalance.

7 Conclusions and Policy Implications

Fertiliser has to play a larger role in the growth of agricultural output in the future as other resources like land and water are facing serious stress. This requires a policy favourable for attaining optimum application of plant nutrients. Over time, the emphasis of fertiliser policy has been to reduce the share of N and raise the shares of P and K in total use of fertiliser in India. This has been based on the axiom that ideal combination or composition of N, P and K is 4:2:1, and that any deviation from this norm constrains growth in productivity. This norm also causes adverse effects. This paper demonstrates that there is no scientific rationale to support the NPK norm in the current situation. Such norms are meaningful only at a disaggregated level, and when plant nutrients are used in adequate quantity. Thus, a shift in fertiliser policy towards balanced use of N, P and K based on inadequate and outdated norms is leading to wrong prescriptions. Second, the approach towards the use of fertilisers based on one criteria for the country is totally irrelevant as the optimal ratio of N, P and K differs significantly across states according to the types of crops grown and soil fertility status among other factors.

The paper found that farmers tended to reduce imbalance in NPK, but external shock and policy distortions reversed the trend towards balanced use of NPK. It is ironic, that the fertiliser policy reforms of 1992 and NBS scheme of 2010, though aimed at reducing the share of N and raising share of P and K in total fertiliser use, ended up encouraging imbalance by favouring higher use of N relative to P and K.

The paper prepares estimates of required levels of application of N, P and K for current cropping patterns at the state level based on recommendations of SAUs and ICAR institutes, and compares these with actual use. It found that about one-third of the major states apply excess N and two-thirds of the states use less than the required levels of N. There is no deficiency in the use of N at the national level if the entire sales of fertiliser is used for crop production. All that needs to be done is a reallocation among states. Excess use of N in six states, namely, Andhra Pradesh, Assam, Punjab, Bihar, Haryana and Jharkhand is enough to meet the deficiency in the remaining 12 states. The paper concurs that it will be wrong to discourage use of N in the country, but it certainly needs to be curtailed in some states and promoted in most other states.

Use of P was more than what was required in Gujarat, Karnataka, Punjab and Tamil Nadu, while it was deficient in Madhya Pradesh, Uttar Pradesh, and West Bengal. Use of K was much below the required level in all the states except Assam.

Judicious or optimal use of NPK implies an increase in the use of P and K rather than the reduced use of N at the national level. The authors are of the view that the issue of imbalance in the country has been exaggerated and misunderstood. According to our findings, imbalance matters only when use of a plant nutrient exceeds the optimum level. At below optimum level of application, imbalance in terms of composition does not have any adverse effect. Thus, the policy goal should be to achieve optimum levels of application of N, P and K rather than achieving a particular ratio in composition.

Another significant contribution of this paper is the estimation of state-wise requirement of N, P and K, and an optimum ratio based on that. The existing norm of 4:2:1 was found to be skewed towards N. The ideal ratio for India based on current crop pattern and recommendations of SAUs and ICAR institutes was found to be 2.6:1.4:1.0. This norm implies that N should comprise 52% and P and K should constitute 28% and 20%, respectively, of the total fertiliser applied in India. These shares are quite different from the shares based on the ratio of 4:2:1, which implies that N should constitute 57.8%, and P and K should constitute 28.6% and 14%, respectively.

State-level results show that the officially accepted norm of 4:2:1 was close to the required norm estimated by us only in the traditional Green Revolution belt of north-west India. This is not surprising as the officially accepted norm was based on the agronomic trials in this region, and for wheat and paddy that dominate the cropping pattern in this region. The desired mix of NPK in other states, except Rajasthan, implies a lower share of N and higher share of P and K than what is implied by the ratio of 4:2:1. The study shows that optimum and balanced use of fertiliser in India requires higher use of N, P and K in Chhattisgarh, Jammu and Kashmir, Kerala, Madhya Pradesh, Maharashtra, Uttarakhand, West Bengal; higher use of P and K in Bihar, Haryana, Jharkhand and Odisha; higher use of P in Assam, and higher use of K in all the states except Assam. Optimum use implies a reduction in the use of N in Punjab, Haryana, Bihar, Jharkhand, Andhra Pradesh and Assam, and a reduction in the use of P in Andhra Pradesh, Gujarat, Punjab and Tamil Nadu.

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