Mapping Potassium Budgets Across Different States of India

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Potassium input-output balances in different states of India were estimated and mapped using the IPNI NuGIS approach. Results showed negative K balances in most of the states suggesting deficit K application as compared to crop K uptake. Deficit application of K contributes to nutrient mining from soil, results in the depletion of soil fertility, and may significantly limit future crop yields.

Agricultural systems in India intensified significantly after independence. Although the net cultivated area remained stable around 140 million (M) ha, the area sown more than once increased from about 14 M ha in 1951-52 to 52 M ha in 2009-10 (FAI, 2012). This was largely made possible through the increase in irrigation facilities as the share of gross irrigated to gross sown area increased from 17 to 45% during the same period. This period also witnessed the introduction and large-scale adoption of high-yielding (HYV) and hybrid crop varieties with far higher yield potentials than the local varieties, and a concomitant increase in fertiliser nutrient use in crops. Food grain production increased five-fold, from 51 M t in 1950-51 to over 250 M t at present, while fertiliser nutrient ($N+P_2O_5+K_2O$) consumption increased by nearly 400 times during the same period. Such relatively rapid growth in crop production and fertiliser consumption may cause a mismatch between nutrient application and nutrient off-take from agricultural soils supporting such high crop production growth. This is especially true for K_2O as, historically, K application to crops in India has remained inadequate and the fact that K requirements of most crops are equal to or more than their N requirements.

Several studies have highlighted the disparity between nutrient input-output balances in Indian soils (Biswas, and Sharma, 2008), and widespread deficiency of plant nutrients in soils (Samra and Sharma, 2009). The All India Coordinated Research Project on Long Term Fertiliser Experiments by the Indian Council of Agricultural Research have shown negative K balances even at the optimum NPK application rates across India (Sanyal et al., 2009). Tandon (2004) estimated an annual depletion of 10.2 and 5.97 M t K_2O from Indian soils on a gross and net basis, respectively. He suggested that out of the net negative NPK balance or annual depletion of 9.7 M t, N and P depletion was 19 and 12% respectively, while a 69% depletion was shown for K. Later, Satyanarayana and Tewatia (2009) calculated state-wise nutrient balances in India and showed negative K balances in different states ranging from -0.1 to -1.1 M t.

The above studies highlighted that K application in Indian soils is much less than K off-take by crops, thereby leading to mining of native soil K. The general assumption that most Indian soils are well supplied with K and do not require any K application may not hold true for intensive cropping systems now practiced in the country. A soil well supplied with K for a yield level of 1 to 2 t/ha may turn out to be deficient in K as the yield target moves up due to the availability of better seeds, management options etc. This clearly indicates the necessity of assessing K balance periodically in intensively cropped areas to avoid unwanted decline in soil fertility levels. Earlier studies that assessed the yearly K balances in soils of India, used different methodologies, which do not allow an assessment of change in K status with time. The present study utilised standard data sources and methodologies to assess the changes in K balance across different states of India over a four-year interval (i.e., 2007 to 2011).

Abbreviations and Notes: N = nitrogen, P = phosphorus, K = potassium.

Determination of K Budget

The study analyzed the amount of potash fertiliser received by the agricultural soils through inorganic and organic sources, the removal of K by different agricultural crops, and estimated the K budget that determines the K accumulation or removal from the soil. Data on fertiliser use and the total amount of recoverable manure used in different states were obtained from the Agriculture Census Division, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India website (http://inputsurvey.dacnet.nic.in/districttables.aspx) as well as from the publications of the Fertiliser Association of India (FAI, 2007 and 2011). Information on district-wise K_2O consumption, through inorganic sources and recoverable manure, were accessed from the above two sources. The amount of manure consumed in each district was multiplied by a suitable factor, based on average K content in recoverable manure, to estimate K_2O contribution from organic sources.

The K_2O removal by the crops was calculated by multiplying the production with the removal per unit production. For example, if the rice production for a state in 2007 was 10 t and in 2011 was 12 t, then the K_2O removal in 2007 was 190 kg and 2011 was 228 kg considering the fact that the K_2O removal for production of 1 t of rice is 19.08 kg (Buresh et al., 2010). **Table 1** describes the K_2O removal per unit production for different crops used for calculation of State-wise K_2O removal in this study. The data source was Special Data Dissemination Standard Division, Director-

Table 1. Crop K_2O removal per unit of crop yield.

Crop	K_2O removal, kg/t
Wheat	24.00
Rice	19.08
Maize	20.88
Barley (grain)	7.30
Gram	25.81
Arhar (Tur)	62.50
Moong	25.81
Masoor	18.35
Moth	25.81
Groundnut (nuts)	8.51
Sesame (seed)	2.54
Rapeseed (seed)	9.21
Linseed (seed)	11.62
Cotton	14.80
Sugarcane	1.44

Sources for the removal values for different crops are listed here: http://nugis-india.paqinteractive.com/About%20NuGIS/

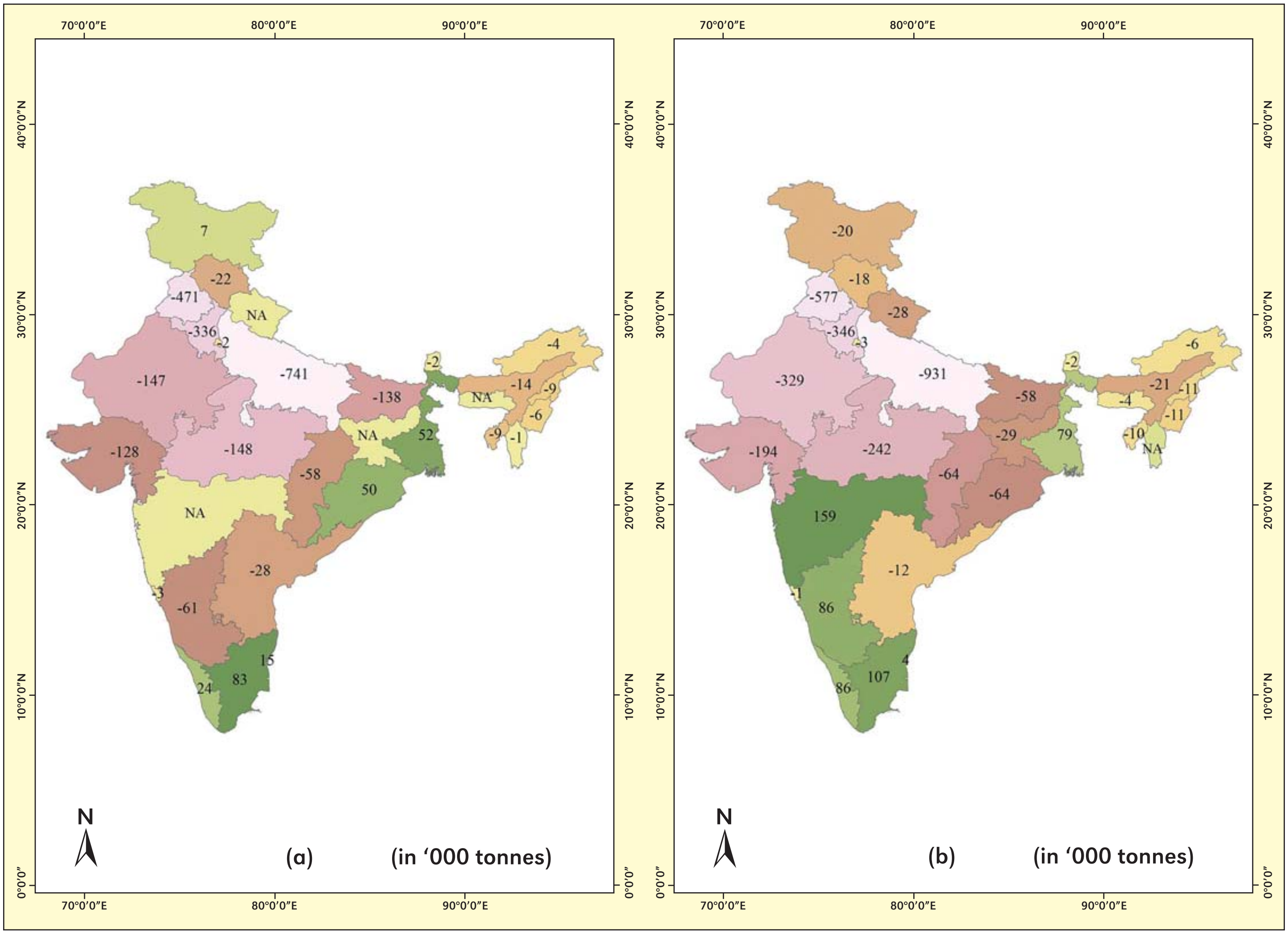

Figure 1. The K_2O balances (applied fertiliser – crop removal) for (a) 2007 and (b) 2011 across different states of India.

ate of Economics & Statistics Ministry of Agriculture Govt. of India, (http://apy.dacnet.nic.in/crop_fryr_toyr.aspx) and the publication of The Fertiliser Association of India (FAI, 2007 and 2011). The major crops considered in this study were rice, wheat, maize, barley, gram, arhar (tur), moong, masoor, moth, groundnut, sesame, rapeseed, linseed, cotton, and sugarcane. Potassium removal by horticultural crops was not considered in the K balance estimations.

The K_2O balances were calculated for different sates for the years 2007 and 2011 by calculating the difference between the amount of K_2O applied to soil in the form of fertiliser (with and without considering the manure application) and the crop removal values across different states. These values were then represented on the map of India using Arc-GIS 10.1 (ESRI, 2012).

Potassium Balance Comparison across Different States

The K_2O balances without manure across different states for 2007 and 2011 are shown in **Figure 1** where negative balance indicates K mining or depletion from soil while positive balance means "build up" of K_2O in the soil. It is evident from the figure that the K_2O depletion was more in 2011 compared to 2007 in most of the northern (such as Punjab, Haryana, Uttar Pradesh), eastern (Assam, Odisha, Tripura) and western (such as Gujarat, Rajasthan) states of India. This indicated that the soils of these states typically received less than the required amount of K_2O. Interestingly, the K_2O balances were negative in Bihar in the year 2007 as well as for Bihar + Jharkhand (Jharkhand was part of Bihar in 2007) in 2011, but the negative K_2O balance has decreased from 2007 to 2011. This decrease in negative value indicates that there was increase in the K_2O consumption and/or fertilisation practices. A similar trend was also observed in the case of Andhra Pradesh. The states of West Bengal and Tamil Nadu have shown positive K_2O balance in both 2007 and 2011, suggesting that no K mining has occurred in these two states. Surprisingly, a huge change in K_2O balances was observed in Karnataka and Odisha; while Karnataka showed positive balance, and a large change towards negative balance was observed in the case of Odisha. Review of available data showed that Uttar Pradesh produced 41 M t of foodgrain using 0.17 M t K_2O in 2007; whereas, in the year 2011 the total foodgrain production was 51 M t with total K_2O consumption of 0.27 M t. Therefore, on average, 4 to 4.5 kg of K_2O was applied per t of food grain production, which is much less than the required amount. This might be the reason for the increasingly negative K_2O balance in Uttar Pradesh (**Figure 1 and 2**). On the other hand, Andhra Pradesh produced 19.3 M t of foodgrain in 2007 using 0.34 M t K_2O; whereas, in the year 2011 the total foodgrain production was 20.1 M t with total K_2O consumption of 0.35 M t. Therefore, on average, 17

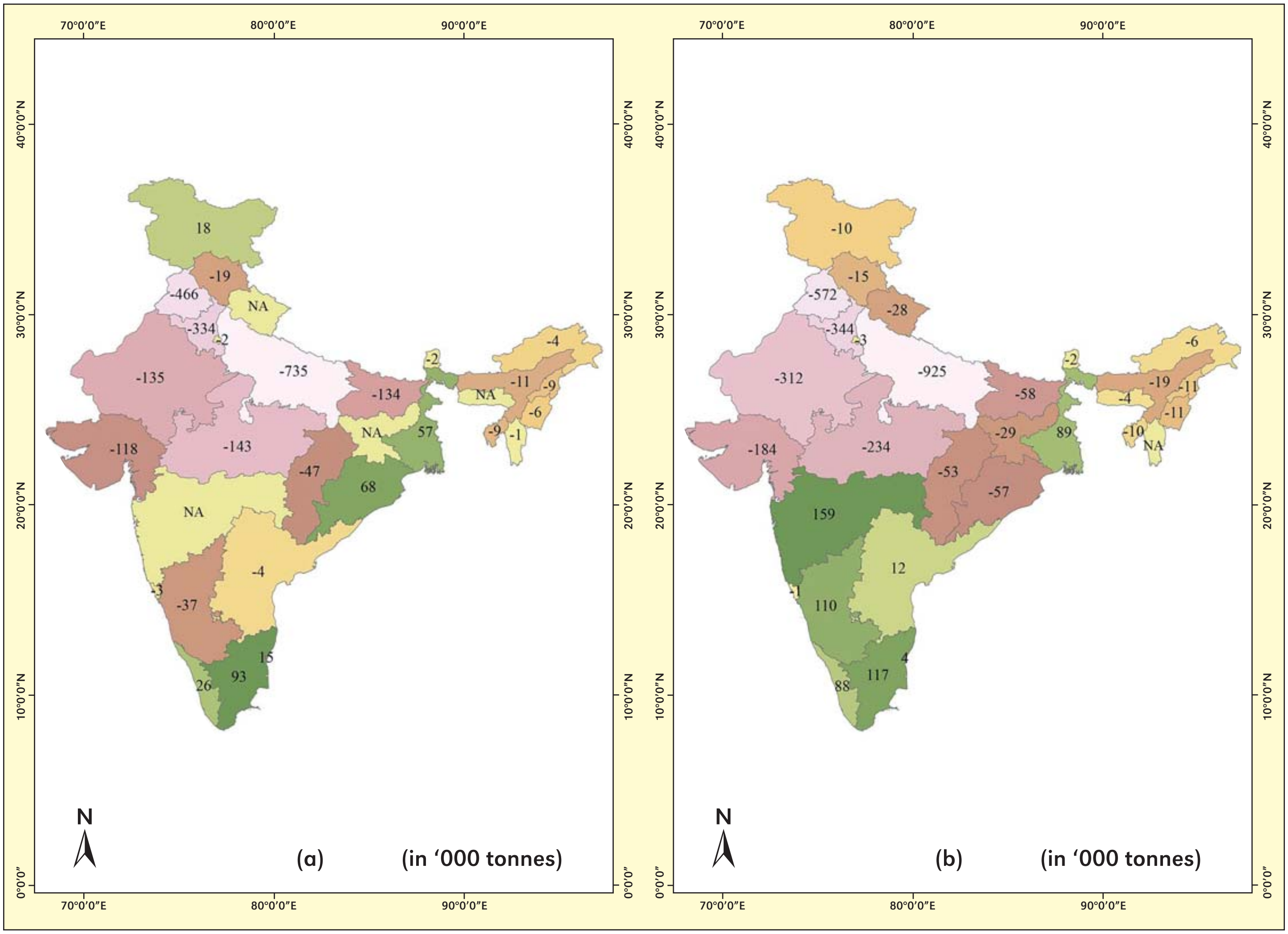

Figure 2. The K_2O balances (applied fertiliser + manure – crop removal) for (a) 2007 and (b) 2011 across different states of India.

kg K_2O was applied per t of food grain production. This might have lead towards more balanced K_2O application for the state and a lesser negative balance in 2011 as compared to 2007.

Figure 2 illustrates the K_2O balance by including the manure application across different states of India. As expected, our result highlights that inclusion of manure input reduces the negative balance and increase the positive balance for all the states; however, this does not cause much change in the K_2O balance values for most of the states except Andhra Pradesh, where the positive K_2O balance was observed in 2011 after inclusion of manure application while K_2O balance by considering only inorganic fertiliser and crop removal has given negative values. This is due to the fact that availability of organic manure for field application is limited in India because of competitive use of organic resources for fodder, fuel and other domestic purposes.

Our study highlighted that the K_2O balance (i.e., difference between K_2O applied through the application of fertiliser and manure and the removal of K_2O by the major crops) was negative for most of the states across India in the year 2007. These negative values increased in the year 2011 probably due to lesser fertiliser application and/or higher crop production. The K_2O balance data highlights negative values that indicate depletion of K_2O from soil and therefore mining of K after harvesting. Such depletion may not be immediately apparent through assessment of available K in soils as such depletion may occur from the non-exchangeable pool of soil K that is usually not measured during soil testing. Indeed, such unnoticed depletion of K from the soil may seriously deplete the K fertility status of the soil that will require much higher investment in future to restore the fertility levels. Studies have shown that excessive depletion of interlayer K may cause irreversible structural collapse of illitic minerals, thereby severely restricting the release of K from such micaceous minerals (Sarkar et al., 2013). Indian soils in general, and the alluvial soils in particular, are rich in micaceous minerals that attribute high K supplying capacity to these soils. However, there is a threshold value of K depletion a soil could support, beyond which any further depletion would cause irreversible loss of K fertility levels, a major soil quality parameter. This may adversely affect the productivity of these soils.

Summary

Our study highlighted negative K_2O balances in many Indian states, which increased in 2011 vis-à-vis 2007. Therefore, adequate and balanced application of K is required to reverse the trend of K depletion in Indian soils. Potassium application needs to be based on assessed indigenous K supplying capacity, that varies spatially and temporally, and the K requirement for achieving specific yield targets of a particular crop. This will ensure sustained crop productivity and maintenance of soil health. BC-SA

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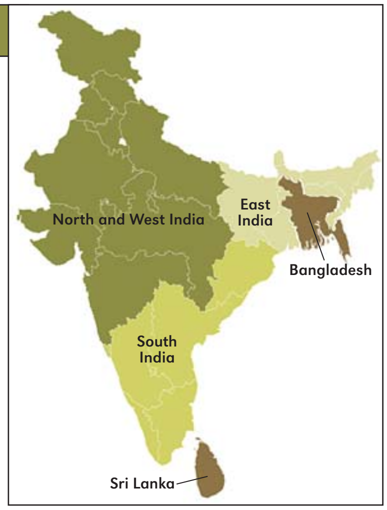

Site-specific nutrient management for rice-wheat system in Punjab

Site-specific nutrient management for rice-wheat system in Haryana

Assessment of soil K supplying capacity from soil nutrient reserves and dissemination of nutrient management technologies through Nutrient Manager

Development of soil fertility map as a decision support tool for fertiliser recommendation in citrus

Fertility mapping and balanced fertilisation for sustaining higher productivity of pearl millet-wheat cropping system in Agra district

Comparative evaluation of nutrient dynamics under conventional and no-till systems of crop establishment in rice-wheat and rice-maize cropping systems

Balanced fertilisation for enhancing the productivity of pearl millet-wheat-green gram crop sequence in Agra region of Uttar Pradesh

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East India and Bangladesh

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Global Maize Project in India: Ranchi, Jharkhand

Site-specific nutrient management for rice-wheat system in Bihar

GIS-based spatial variability mapping of agricultural holdings for precision nutrient management in red and lateritic soil zone

Development and validation of Nutrient Expert for Maize in Bangladesh

South India and Sri Lanka

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