Mapping Potassium Budgets Across Different States of India

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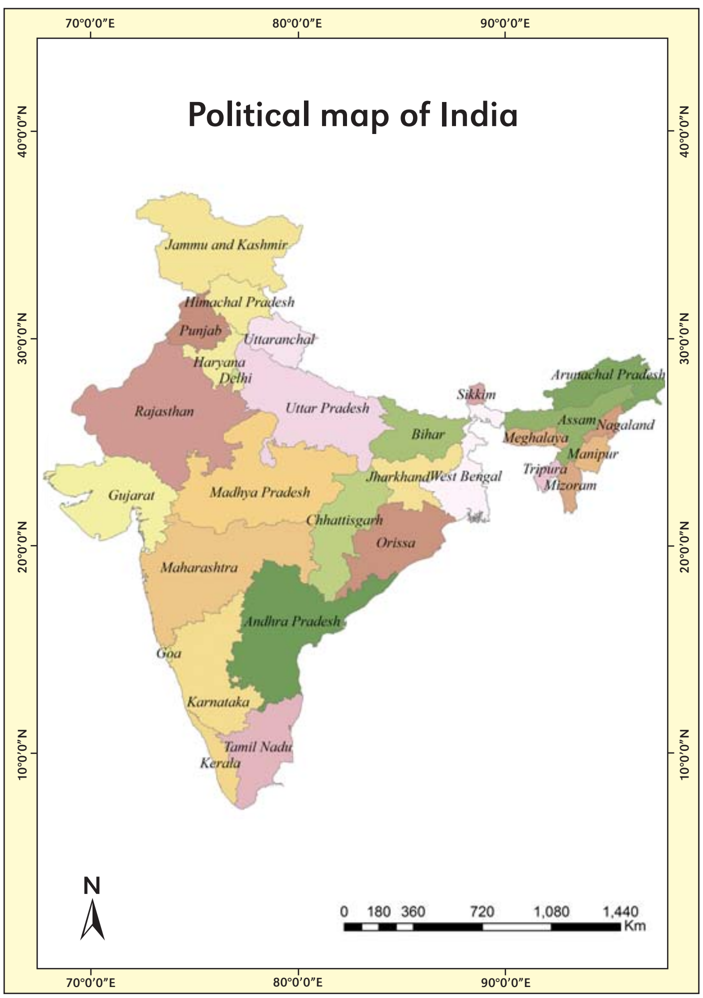
Potassium input-output balances in different states of India were estimated and mapped using the IPNI NuGIS approach. Results showed negative K balances in most of the states suggesting deficit K application as compared to crop K uptake. Deficit application of K contributes to nutrient mining from soil,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

Agricultural systems in India intensified significantly after the country's independence in 1947. Although net cultivated area remained stable at 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 and hybrid crop varieties with far higher yield potentials than the local varieties, and a concomitant increase in fertilizer 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 fertilizer nutrient ($N+P_2O_5+K_2O$) consumption increased by nearly 400 times during the same period. Such rapid growth in crop production and fertilizer consumption can 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 as, historically, K application to crops in India has remained inadequate while K requirements of most crops are equal to or more than their N requirements.



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

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 Fertilizer 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 does not allow an assessment of change in K status with time. The present study utilized standard data sources and methodologies to assess the changes in K balance across

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

Crop	K_2O removal, kg/t
Wheat*	20.00
Rice*	15.90
Maize*	17.40
Barley	6.70
Gram*	25.81
Arhar	62.50
Moong*	25.81
Masoor*	18.35
Moth*	25.81
Groundnut	8.51
Sesame	2.54
Mustard	11.00
Linseed	11.62
Cotton*	14.80
Sugarcane*	1.44

Source: http://nugis-india.paqinteractive.com
*Removal includes crop residue.

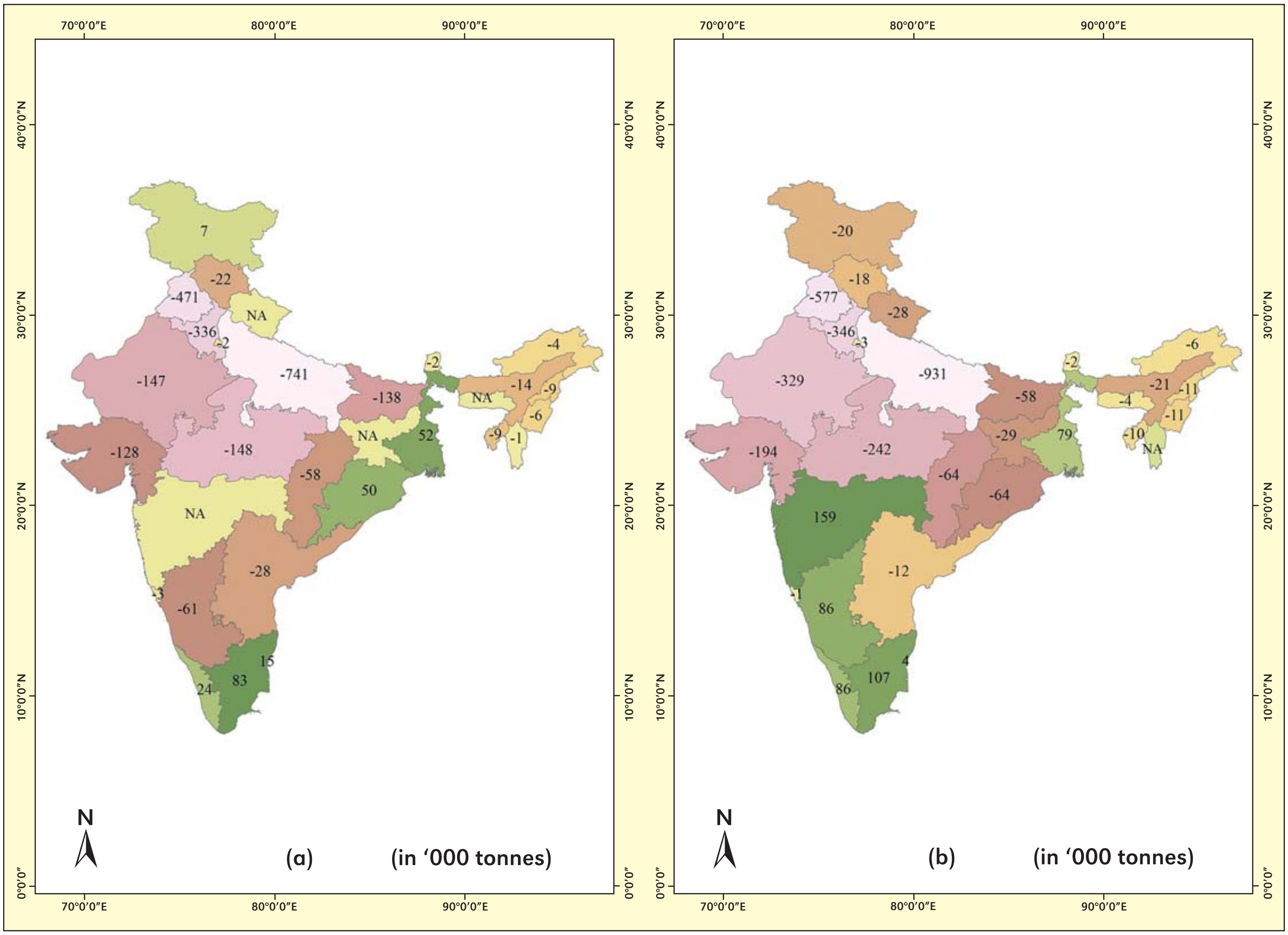


Figure 1. The K_2O balances (applied fertiliser – crop removal) for (a) 2007 and (b) 2011 across different states of India.

different states of India over a four-year interval (i.e., 2007 to 2011).

Determination of K Budgets

The study analyzed the amount of potash fertilizer received by 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 soil. Data on fertilizer 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 the K_2O contribution from organic sources.

The K_2O removal by crops was calculated by multiplying production with K_2O removal per unit of production. **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, Directorate of Economics & Statistics Ministry of Agriculture Govt. of India, (http://apy.dacnet.nic.in/crop_fryr_toyr.aspx) and FAI (2007; 2011). The major crops considered in this study were rice, wheat, maize, barley, gram, arhar (tur), moong, masoor, moth, groundnut, sesame, mustard, 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 states for the years 2007 and 2011 by calculating the difference between the amount of K_2O applied to soil in the form of fertilizer and the crop removal values across different states. These values were then mapped using Arc-GIS 10.1 (ESRI, 2012).

Potassium Balance Comparison across Different States

The K_2O balances without manure for 2007 and 2011 are shown in **Figure 1** where negative balance indicates K depletion from soil while positive balance indicates build up. It is evident that K depletion was more significant 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. Soils of these states typically receive less than the required amount of K. 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

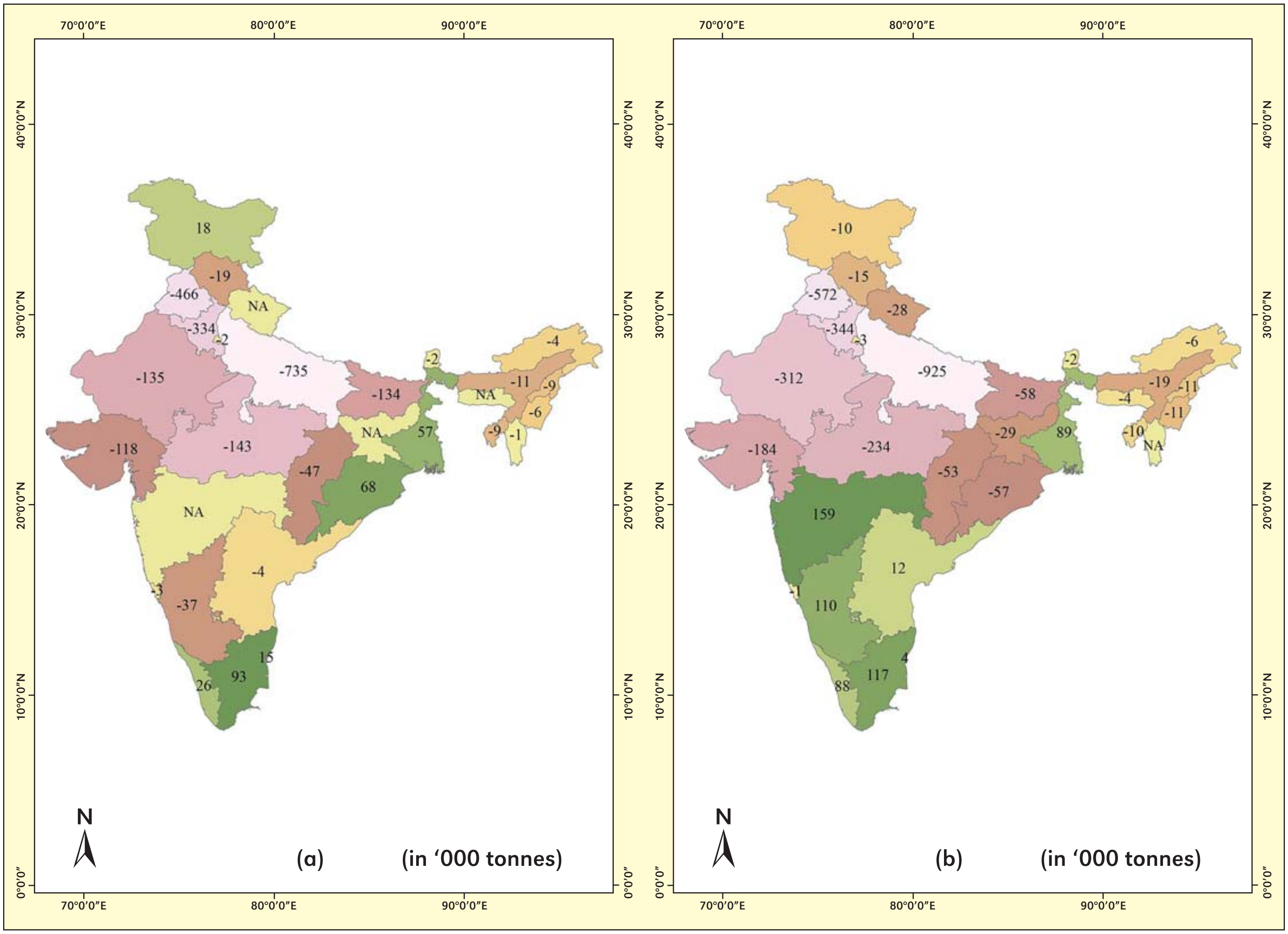


Figure 2. The K_2O balances (applied fertiliser + manure – crop removal) for (a) 2007 and (b) 2011 across different states of India.

2007) in 2011, but the negative K_2O balance has decreased from 2007 to 2011 — an indication that there was increase in the K_2O consumption and/or fertilization practices. A similar trend was also observed in the case of Andhra Pradesh. The states of West Bengal and Tamil Nadu show positive K_2O balance in both 2007 and 2011. 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 kg K_2O was applied per t of food grain production. This might have lead towards more balanced K application for the state and a less 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 results highlight that inclusion of manure input improves the K balance for all states; however, this does not cause much change in the K_2O balance values for most of the states except Andhra Pradesh, where positive K_2O balance was observed in 2011 only after inclusion of manure application. 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 was negative for most of the states across India in the year 2007. These negative values increased in the year 2011 probably due to less fertilizer application and/or higher crop production. 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 future investment 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 compared to 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

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