of grain (**Table 2**).

Based on the project's first-year results with regard to sugar beet and grain corn, one can conclude that the substantial yield increases at all levels of potash fertiliser application in comparison to the background treatment show that there can be significant yield losses when potash fertiliser is not applied, even on soils with increased and high content of plant available K.

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Potassium Budgets: Mapping Potassium Balances Across Different States of India

S. Dutta, K. Majumdar, G. Sulewski, T. Satyanarayana, A. Johnston

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 potassium 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 have been intensified significantly after independence, with better irrigation facilities, introduction of high-yielding (HYV) and hybrid crop varieties with far higher yield potentials than local varieties, and of course, a concomitant increase in fertilizer nutrient use in crops. Food grain production increased five-fold, from 51 million tonnes (Mt) in 1950-51 to over 250 Mt at present, while fertilizer nutrient (N + P_2O_5 + K_2O) consumption increased by nearly 400 times during the same period. However, such increase in nutrient consumption was not in balanced proportion among N, P_2O_5, and K_2O leading to nutrient input – output imbalance. This is especially true for K_2O because historically K application to crops in India has remained inadequate although the K requirements of many crops are equal to or more than their N requirements.

Several studies have highlighted the disparity between nutrient input-output balances in Indian soils and widespread deficit of plant nutrients in soils. It was also reported that out of the net negative NPK balance or annual depletion of 9.7 Mt, N and P depletions were 19 and 12 %, respectively, while 69% of the depletion was attributed to K. Therefore, K application in Indian soils is much less than K uptake 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 presently practiced in the country. A soil well supplied with K for a yield level of 1–2 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. The present study utilized standard data sources and methodologies to assess the changes in K balance across different states of India over a four-year interval (i.e., from 2007 to 2011).

Common abbreviations and notes: K = potassium, N = nitrogen; P = phosphorus; t = tonnes.

Determination of Potassium Balances

The study analyzed the amount of potash fertilizer received by agricultural soils through inorganic and organic sources and the removal of K by different agricultural crops. 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*), and from the Fertiliser Association of India. 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 certain factor, based on average K content in recoverable manure, to estimate K_2O contribution from organic sources.

The total K_2O removal by crops was calculated by multiplying the total production with K_2O removal

Crop	K_2O Removal (kg/ton)*
Wheat	24.00
Rice	19.08
Maize	20.88
Barley (grain)	7.30
Chick pea	25.81
Pigeon pea	62.50
Lentil (Vigna radiata)	25.81
Lentil (Lens culinaris)	18.35
Moth bean (Vigna aconitifolia)	25.81
Groundnut (in shell)	8.51
Sesame	2.54
Mustard	9.21
Linseed	11.62
Cotton	14.80
Sugarcane	1.44

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

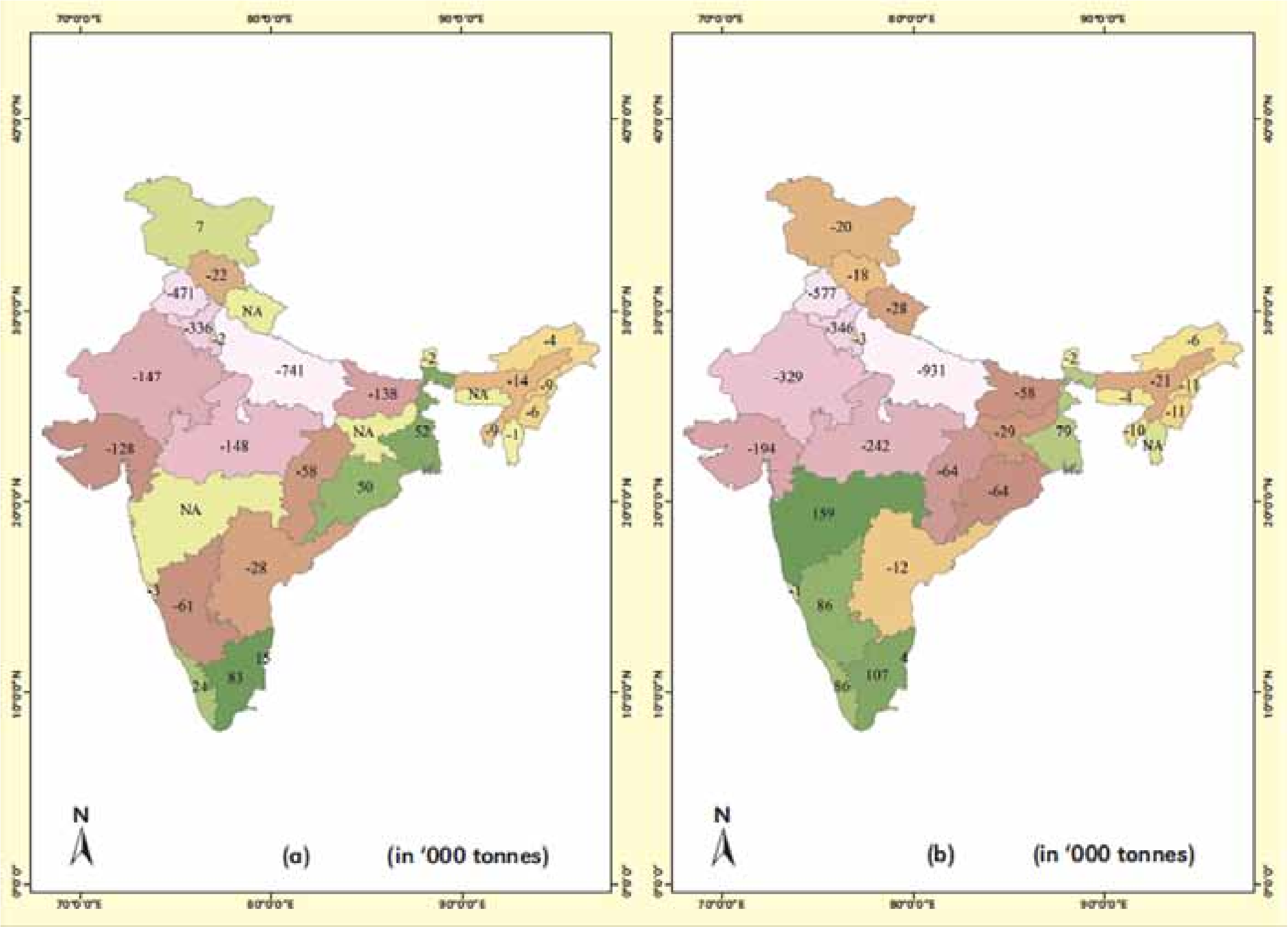

Figure 1. The K_2O Balance (Applied Fertiliser – Crop removal) for (a) 2007 and (b) 2011 across different states of India. NA stands for data not available.

per unit of economic produce. For example, if the rice production for a state in 2007 was 10 t and in 2011 was 12 t, then K_2O removals in 2007 were calculated as 190 kg and in 2011 as 228 kg, considering that K_2O removal for production of 1 t of rice grain as 19.08 kg, as per existing literature. **Table 1** gives values for K_2O removal per unit of economic produce for different crops. Some 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 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 (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 by using ArcGIS 10.1 tool (ESRI, 2012).

Comparison of Potassium Balances Across Different States

The K_2O balances without manure application across different states of India for 2007 and 2011 are shown in **Figure 1 (a-b)**. Negative balance indicates K mining or depletion from soil, while positive balance means "build up" of potassium in the soil. It is evident from the figure that K_2O depletion was more in 2011 than in 2007 in most of the northern (such as Punjab, Haryana, Uttar Pradesh), eastern (Assam, Orissa, Tripura) and western (such as Gujarat, Rajasthan) states of India. This indicated that soils in these states typically received less than the required amount of K_2O. Interestingly, 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 had decreased from 2007 to 2011. This decrease in negative value indicates that there was increase in the K_2O consumption and/or balanced fertilization practices. A similar trend was also observed in the case of Andhra Pradesh. The states of West Bengal and Tamil Nadu showed positive K_2O balances in both 2007 and 2011. A huge change in K_2O balances was observed in Karnataka and Orissa- with Karnataka showing positive balance, while a large change towards negative balance was observed in Orissa.

Review of available data showed that Uttar Pradesh (UP) produced 41 Mt of foodgrain using 0.17 Mt K_2O in 2007; whereas, in the year of 2011 the total foodgrain production was 51 Mt with total K_2O consumption of 0.27 Mt. Therefore, on an average 4 to 4.5 kg of K_2O was applied for 1 ton of food grain production, which is much less than the required amount. This has led to increasing negative balance of K in Uttar Pradesh

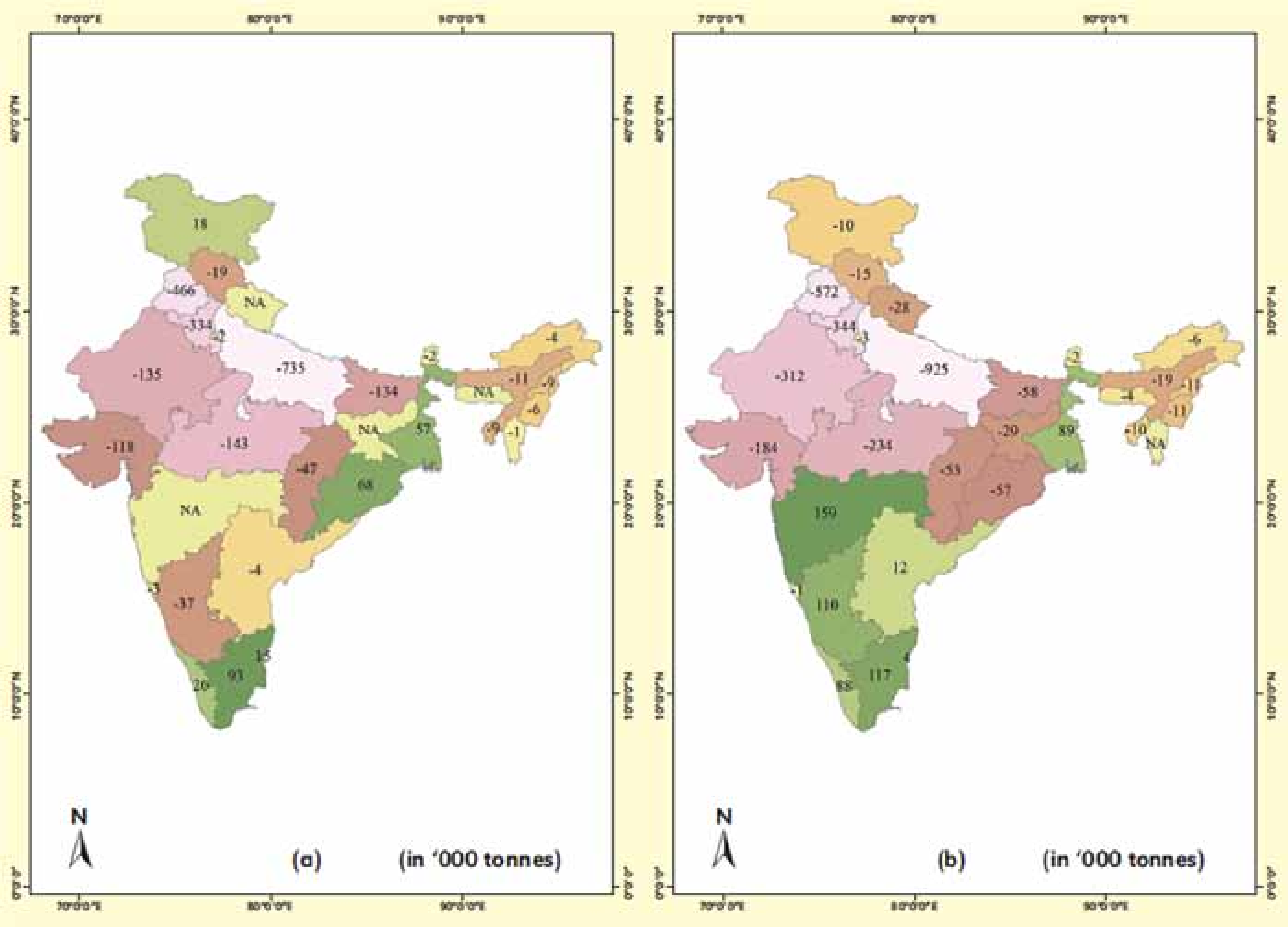

Figure 2. The K_2O Balance (Applied Fertiliser + Manure – Crop Removal) for (a) 2007 and (b) 2011 across different states of India.

from 2007 to 2011. On the other hand, Andhra Pradesh produced 19.3 Mt of foodgrain in 2007 using 0.34 Mt K_2O ; whereas, in the year of 2011 the total foodgrain production was 20.1 Mt with the total K_2O consumption of 0.35 Mt. Therefore, on an average 17 kg K_2O was applied for 1 ton of food grain production. This might be the reason of a lesser negative K balance in 2011 as compared to 2007 for Andhra Pradesh.

Figure 2 (a-b) illustrates K_2O balances by including manure applications across different states of India. As expected, our results highlighted that the inclusion of manure reduced negative K_2O balances and increased positive K_2O balances in all the states. However, inclusion of potassium added through manure in the K balance calculation did not change the K_2O balance values for most of the states except Andhra Pradesh, where a positive K_2O balance was observed in 2011 after inclusion of manure application, while K_2O balance by considering only inorganic fertilizer and crop removal had 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.

Overall, the K_2O balance was negative for most of the states across India in the year 2007; and the difference or the negative values increased in the year 2011, probably be due to lesser fertilizer application and/or higher crop yields. Such depletion may not be immediately apparent through assessment of available K in soils because such depletion may occur from the non-exchangeable pool of soil K that is usually not measured during soil testing. But such unnoticed depletion of K from the soil may seriously deplete the K fertility status of soils 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. Indian soils in general, and the alluvial soils in particular, are rich in micaceous minerals that contribute to high K supplying capacity of 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.

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Soil Potassium in Uruguay: Current Situation and Future Prospects

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Recent field research in Uruguay has revealed K deficiencies in the main field crops of the country. A preliminary survey indicates that almost 5 million ha would be deficient in K. A critical soil test K level (STK) of 0.34 meq/100g (133 ppm), has been estimated from 50 field trials.

Efforts to understand K dynamics in soils of Uruguay have been scarce compared with those for understanding N and P dynamics, which have been studied in different situations and cropping systems. Earlier studies in K response to fertilization were done for crops that have high-K requirements such as sugarcane, sugar beet, potato, onion, and cotton, for which some guidelines for fertilizer recommendations based on soil type were established. In grain crops, the first K studies were made in the 60's, and K responses were observed in wheat grown in soils developed from cretaceous sandstones. Two decades later, a few studies in soybean showed little or no K response in northeastern soils. The lack of K studies [illegible] in high K soils, under conventional tillage and crop rotations that included pastures, resulting in no K fertilizer recommendations. Potassium fertilization was recommended only below 0.30 meq/100g (117 ppm), following the references of US Corn Belt, which reported low K response probability with STK over 0.23-0.33 meq/100g (90-130 ppm) in soybean and maize under conventional tillage.

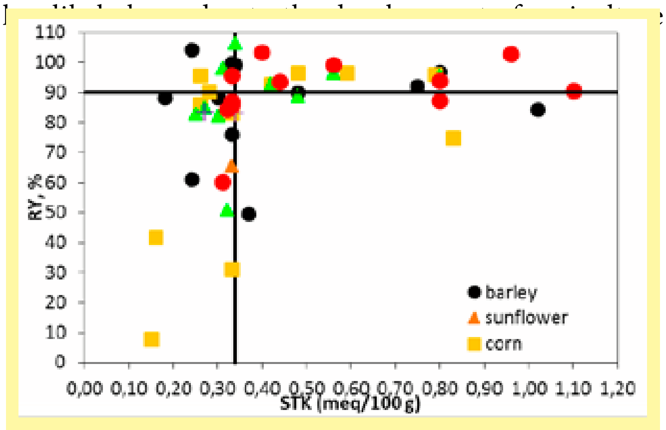

Fig. 1. Relationship between relative crop yield (RY) and soil test K (STK; 0-20 cm) in Uruguay. Based on data of 50 field experiments. RY expressed as the percent ratio between averaged yields of Check and Fertilized plots (100-200 kg/ha of KCl). Source: Barbazán et al. (2010, 2011).

More recently, field research by the faculty of Agronomy (UdelaR), INIA, and other organizations reported some cases of K deficiency symptoms in soils with low STK in maize and Lotus corniculatus L.. Moreover, the increasingly occurrence of visual K deficiency symptoms, lead to more specific studies, which showed K response in several crops. A summary of 50 recent studies (which had the same tillage system, and similar experimental design, rate, and K source), found a critical STK level of 0.34 meq/100g (133 ppm; 0- 20 cm depth) (Barbazán et al., 2010; 2011), representing a breakthrough in K research in Uruguay (**Fig. 1**).

Soil K levels: Distribution and nutrient balances for Uruguay

Soils of Uruguay present a wide range of STK (**Fig. 2**). According to the Soil Survey Guide of Uruguay, soil units covering approximately 5 million ha would have low K availability. In the typical agricultural area of western Uruguay, STK is medium to high.

However, agriculture scenarios of Uruguay have