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Available 'K' Reserve of Two Major Crop Growing Regions (Alluvial and Shrink-Swell Soils) in India

The crop removal of K often equals or exceeds that of N. Under intensive cropping with high yielding varieties and imparity in nutrient use, K from soils getting depleted is evident from number of field experiments conducted across the country under the All India Coordinated Research Projects (AICRP) of the Indian Council of Agricultural Research (ICAR). The K is thus recognised as deficient element after N and P in Indian soils. The K fertilisers in India are mostly imported and since the gap between removal of K and its application to crop is widening, it is all the more important that the country makes the best use of them. To make such initiative successful, knowledge of K reserve in soils and periodic monitoring of changes in K status should form an essential part of such programme.

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THE GEOGRAPHICAL DISTRIBUTION of the status of K in Indian soils was initiated in late 1960s from point data. Oommen (18) prepared two maps, one on total K and the other on available K of different soil sites from India. The total K was reported high (3722 kg K_2O/ha) and available K_2O was low to medium (< 112 kg K_2O/ha; and in few cases 112-280 kg K_2O/ha). Later, Ramamoorthy and Bajaj (24) generated a map on available K from the results of soil testing services from nearly 200 districts of the country. They reported that the soils in 36 districts are low, 110 districts are medium and 50 districts show high status of K. It has been reported that the K availabilities are controlled by the parent materials of soils. The Indo-Gangetic Plains (IGP) and the soils bordering the Vindhyan system are low in K availability. The soils of the crystalline gneiss or the Gondwana system have high K availability (23). This information, however, was not geo-referenced and thus it is difficult to reach those spots for any monitoring exercise. With the advent of the Geographical Information System (GIS) and also the Global Positioning System (GPS), geo-referencing of soil information has become useful for better utilisation of soil data-sets for national planning.

Potassium is considered as one of the most essential nutrients, especially the available form, and has been found to be very crucial for plant growth. The present study was, therefore, planned to estimate the available K reserves (NH_4OAc-K) of two major soil types (namely the Indo-Gangetic Plains, IGP and Black Soil Region, BSR) of the country through geo-referencing of the identified benchmark (BM) spots. An attempt has also been made to generate thematic maps on available K reserves in the IGP and BSR.

MATERIALS AND METHODS

TO ACCOMPLISH THIS JOB 141 IDENTIFIED BM soils of the IGP and 241 BM soils of the BSR were chosen from the soil data base of the NBSS&LUP, Nagpur (ICAR), obtained through Soil Resource Mapping programme that started in the year 1986, and also from other published literatures (4, 7, 6, 8, 3, 5; 13; 15; 28; 29; 27; 17; 1; 25; 31; 33; 30; 26; 9; 16). The soils which show shrink-swell properties as evidenced by cracks and/or slickensides and pressure faces have been included in the BSR data-sets. These soils belong to either vertisols or vertic intergrades (32). The details of the BM spots of 2 soil types are given in **Tables 1** and **2** and their locations in **Figures 1** and 2.

METHOD

Calculating Available K Reserves

The size of the available K reserve is calculated following 2 steps.

Step 1 : Extractable K was determined by neutral N NH_4OAc (11). The bulk density (BD) of the soils were obtained for a few soils from the published literatures. For the rest of the samples, BD was determined using core samples (diameter 50 mm) of known volume (100 ml) (14, 12). Extractable K was then multiplied with BD and thickness of horizon for individual BM soil for 0-30, 0-50, 0-100 and 0-150 cm depth intervals.

Step 2: Available K content determined by step 1 was multiplied by the area of each BM soil distributed in the IGP and BSR.

The available K reserve was thus calculated in terms of Tg (Teragram, $1Tg=10^{12}g$) using this formula:

$$\text{Available K reserve in soil (Tg)} = \frac{NH_4OAc \text{ extr K } (g g^{-1}) \times BD\ (Mg\ m^{-3}) \times \text{Area (Mha)} \times \text{depth (m)}}{10^4}$$

The K reserve values were also expressed as K in kg/ha.

Generating Thematic Maps

Based on the combination of a number of climatic elements such as rainfall, temperature, potential evapotranspiration

Table 1 – Soil series of the IGP

AESR No.	Zones	Bio-climate	Soil series
2.1	Northern	Arid	Masitawali, Nihalkhera
2.3			Jodhpur-Ramana, Jassi-Pauwali, Hisar, Lukhi
4.1		Semi-arid, dry	Phaguwala, Ghabdan, Zarifa-Viran, Fatehpur, Balewal, Isri, Jatwan, Kaheru, Langrian, Nabha, Khoh
9.1		Sub-humid, dry	Jagjitpur, Dhadde, Bhanra, Berpura, Khiranwali, Laungowal, Patiala, Sadhu, Suniarheri, Tulewal
4.3	Central	Semi-arid, moist	Sakit, Hirapur, Bijapur
9.2		Sub-humid, dry	Simri (Haiyatpur), Basiaram, Itwa, Akbarpur, Bikramganj, Dullahpur, Barew, Budhauli, Dadar, Darra, Dadraul, Korap, Kathrain, Warkhas, Jogiya, Chatkari, Maher, Nowadih, Chorpaniyan, Merh
13.1		Sub-humid, moist	Belsar, Ekchari, Gaupur, Sarthua, Nanpur, Bahraich, Sivapande, Gobardhana, Matiaria, Dumri, Mathiya, Baswariya, Terhagachh, Naurangia, Alolola, Bakhada, Bananiya, Belsand, Phawanipur, Ghoga, Manikpur, Patar, Qutubpur, Raghunathpur, Sagauli, Sangrampur, Walipur, Bahera, Belgachhi, Bir
13.2		Sub-humid, moist	Haldi
15.1	Eastern	Humid	Amarpur, Hanargram, Sasanga, Madhpur,Konarpara,Chinsurah, Mohanpur, Salmara, Naoda, Samaspur, Sahazadpur, Ruisanda, Jagannathpur, Gopalpur, Bijir, Sadaipur, Balrampur, Chakprayag, Bansghata, Panchpota, Harinathpur, Jatikrishnapur, Uddharanpur, Teltaka, Jambani, Chaknon, Sitalpur
15.3		Sub-humid, moist	Seoraguri, Binnagura, Chunabhati, Rajpur, Barak
16.1		Humid	Singhvita
16.2		Humid	Mechpara
17.2		Humid	Khowai, Nayanpur
18.5		Sub-humid, dry	Sagar, Akshyanagar, Patibunia

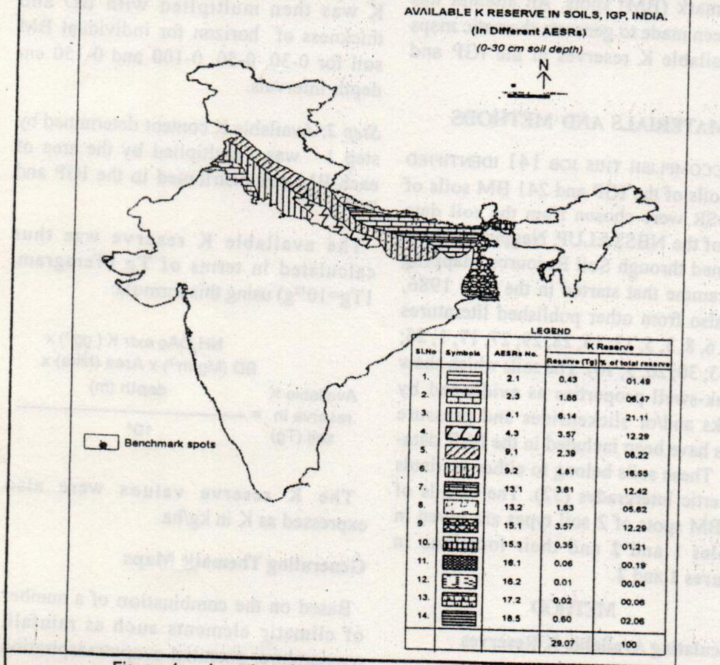


Figure 1 – Location of BM spots and the available K reserve in the IGP

(PET), coupled with the attitude, aspect and vegetation types a bio-climatic map of the country was earlier prepared (2). Out of 11 bio-climatic classes, 6 are in the IGP and BSR. These six bio-climatic classes are mainly differentiated on the basis of mean annual rainfall **(Table 3)**. Later, using the information on physiography, soils, bio-climate and length of growing period, the country was delineated into 60 agro-ecological sub-regions (AESRs) (34). The black soil regions cover 39 AESRs and 14 AESRs are encountered in the IGP (6).

The AESR and bio-climatic maps were digitised and used as base maps to link with the available K reserve of 382 BM soils (141 soils for IGP and 241 for BSR). The data sets of K reserves from the bio-climatic base map were used to find the relation between K and climate (MAR). The K reserve data-sets from the AESR base map were used to find distribution of K reserve in different parts or zones of IGP and BSR. The thematic maps were generated on available K reserves for various soil depth intervals viz. 0-30, 0-50,

Table 2 – Soil series of the BSR

AESR No	Zones	Bio-climate	Soil series
4.1	North	Semi-arid, dry	Datwasa, Barhi, Sakit
4.3		Semi-arid, moist	Bainau, Bainar
9.1		Sub-humid, dry	Dhadde, Jagjitpur, Sadhu, Berpura
9.2			Pokhrahi, Baruna, Barew, Dahiya, Simri
12.1		Sub-humid moist	Umri, Bhugaon, Wanparti, Gantoli dongri, Karloka, Umariguda, Sirgeri, Sanfafsi, Birsinghasahi, Kodabandh
12.2			Balbhadrapur
12.3			Batisuan
14.2			Dal Lake series (Srinagar)
2.2	West	Arid	Bhojarda
2.3			Khedbrahma, Dantral
2.4			Jalsika, Lajai, Timbdi, Sokhda
4.2		Semi-arid, dry	Muhmmadgarh, Kotri, Ladpura, Kapasan, Ankhi, Dholi, Akru, Kumbhara, Tatam, Chabhadia
5.1		Semi-arid, moist	Motimarad, Bhola, Mendarda, Semla, Shivrajgadh, Ramgadh, Jira, Khuntwada, Hemal, Kher, Kalyanpur, Umrala, Meghvadar, Parvala-I, Langala, Parvala-II, Ghanghadi, Jalia
5.2			Ratangarh, Jhalipura, Anta, Jalawara, Atru, Ramganj Mandi, Sunel Chhoti, Dhamniya Diwan, Dhodar, Paroliya, Banswara, Sanjeli,Kumari, Sarol, Umardha, Gopalpur, Jalda, Loni, Tarvada, Jalalpur, Panvadi, Dhanwani, Bijapur Kalan
19.1		Sub-humid, moist	Mulad, Bodeli, Sisodara
5.3		Semi-arid, moist	Una, Lilvan,Vavadi,Mandva, Mithapur
4.4	Central	Semi-arid, moist	Dongerpur, Baihrai, Deori Kalam, Kerua, Bhojpur, Siphon
6.1		Semi-arid, dry	Teligi, Lakmapur, Vajramalli, Nidasanur, Masala, Konheri, Purandarwada
6.2		Semi-arid, moist	Saigon, Bhatumbra, Bamni, Bhimavaram, Narayankher, Amalapuram, Asifabad, Jintur, Gevarai, Anantapur, Nimone, Pather,Vajjapur, Kalwan, Jaipur, Anjana, Nipani
6.3			Pangidi, Kelapur, Asra, Paral
10.1	Eastern	Sub-humid, dry	Negwan, Muskari, Kheri, Nabibagh, Bandoli, Bankrai, Khopa, Gubapura
10.2			Kerpani, Sirpur, Wardha, Kinhala, Boripani, Umrer, Panjri, Takali, Bahadura
10.3			Para, Amraunya, Padariya, Mariyadar, Sakor, Talgaon, Baroda kalam, Umariya, Karkeli, Chapratola, Devardah, Badartola
10.4			Makajhir, Pashposi, Dadarghugri, Chichband, Chikutgondi, Dunova, Katol, Linga, Tighara, Sindewahi, Khatera, Andhali, Kohkabor, Gonditola, Tighara
11.0			Kurkheda, Urhje, Hahalddi, Bhanpuri, Awari, Mitekusa, Nangutola, Khujji, Hirawahi, Bawanpuri, Chandranagar, Bichanpur, Khujji Kalam, Mayapur, Pandrapat
13.1		Sub-humid, moist	Belsar, Ekchari, Karai Pasrai, Datraul, Sarthua
15.1		Humid	Chinsurah, Sasanga, Hanrgram, Amarpur, Madhpur
15.2		Sub-humid, moist	Katani, Sholmari, Sholmarigaon
18.4			Daiapalli
18.5		Sub-humid, dry	Nampo, Sagar
3.0	Southern	Arid	Karenhalli, Penukonda
6.4		Sub-humid, dry	Hulihalli, Chetra, Wadkudi, Bumne, Sahuwadi, Sonawadi, Koregaon, Targaon, Penjalwadi
7.2		Semi-arid, moist	Jajapur, Kaukuntala, Karebadur, Hayatnagar, Patancheru, Kasireddypalli, Sangareddi, Emmiganuru, Jammalamadugu
8.1		Semi-arid, dry	Kovilpatti, Surangudi Colony, Palathurai
8.2		Semi-arid, moist	Karya, Vijaypura, Bejjavalli
8.3			Putteri, Annappanpetti
18.2			Karisalkulam, Kodangipatti
19.2		Sub-humid, moist	Chiplun, Gargoti, Vadavayal
19.3			Virthan, Palghar, Haloli, Thane, Mahad, Ramnagar

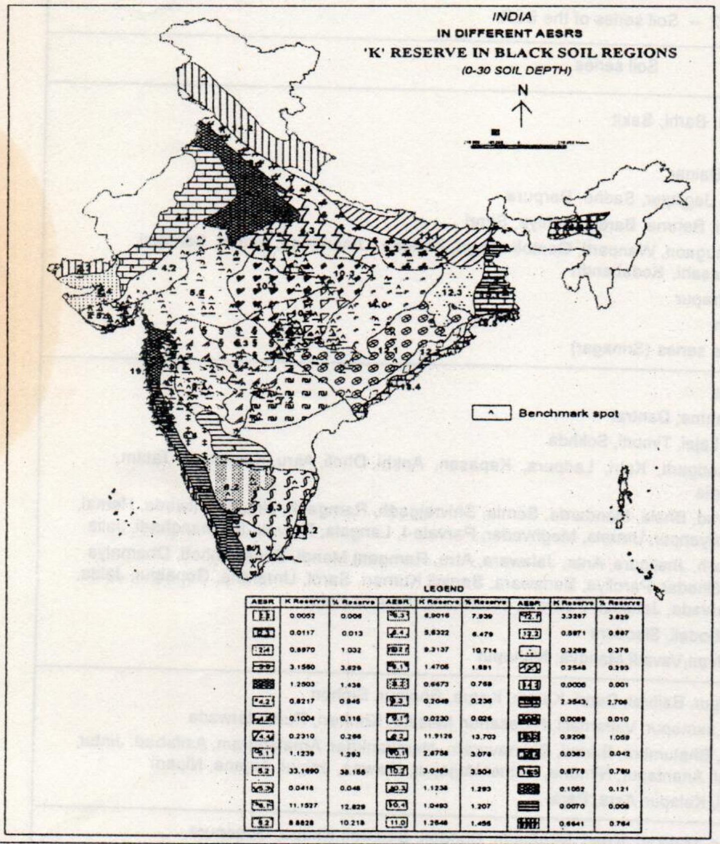


Figure 2 – Location of BM spots and the available K reserve in the BSR

Table 3 – Mean annual rainfall (MAR) and bio-climatic classes in the IGP and BSR

Bio-climatic class	MAR (mm)
Arid	<550
Semi-arid, dry	550-850
Semi-arid, moist	850-1100
Sub-humid, dry	1100-1200
Sub-humid, moist	1200-1500
Humid	>1500

0-100 and 0-150 cm. However, for brevity, the maps for 0-30 are shown in this paper. The following discussion on available K reserve will indicate the reserve in 0-30 cm soil depth unless otherwise mentioned.

RESULTS

Available K Reserve in the IGP

THE RELATIVE SHARE OF DIFFERENT BIO-climatic classes *vis-à-vis* their contribution in available K reserve do not follow any definite trend (**Figures 3a** and **b**). In general, sub-humid, dry (SHd) and moist (SHm) bio-climatic classes covering 23 and 26% area, respectively of the IGP, contribute 46 % of K reserve. A comparison with the mean annual rainfall (MAR), however, shows an increasing trend of K reserve from semi-arid moist (SAm) bio-climatic class (>1000 mm) (**Figure 4**).

The distribution of K reserve in the agro-climatic sub-regions (AESRs) shows that the highest K reserve is in the AESR 4.1 followed by 9.2, 13.1, 15.1, 4.3 and 9.1 (**Figure 5**). The available K reserve in the IGP soils was estimated as 29 Tg which corresponds to 667 kg/ha K.

The IGP may be divided chiefly into three parts, namely northern, central and eastern part (**Table 1**). **Figure 6** shows the areal extent of these 3 parts in the IGP. The relative contribution in terms of available K reserve indicated that the eastern part of the IGP has a better reserve of K than the northern part and

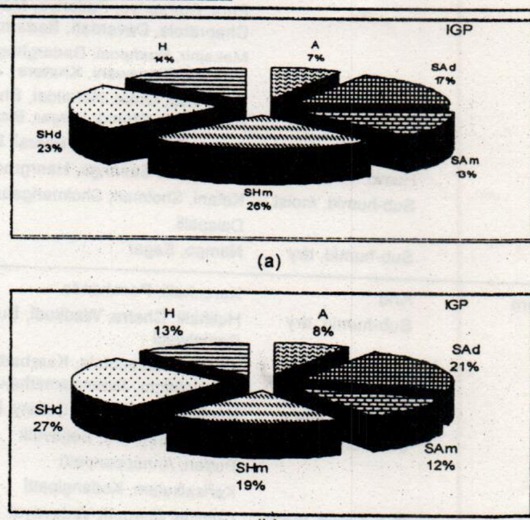


Figure 3 – Share of area of bio-climate (a) and K reserve (b) in IGP

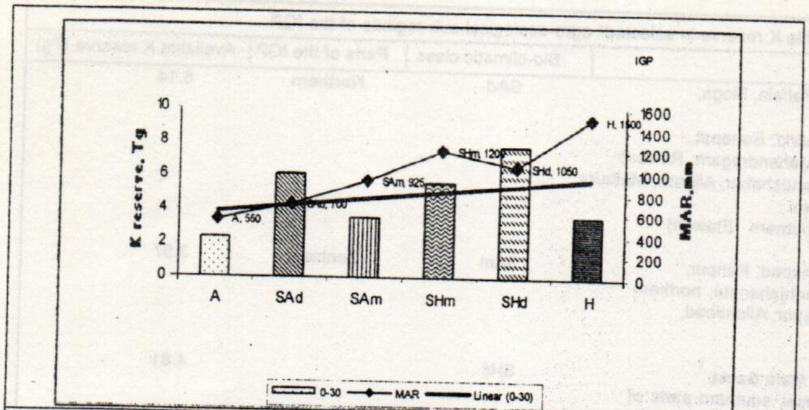


Figure 4 – K reserve vs mean annual rainfall (MAR) (mm) 0-30 cm bio-climate IGP

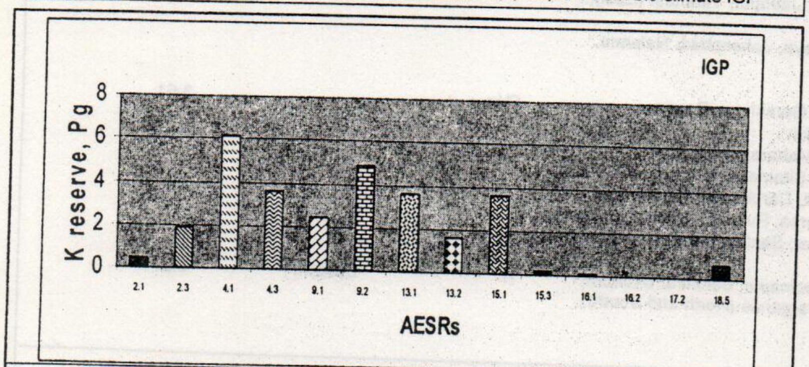


Figure 5 – Available K reserve in soils of the IGP (0-30 cm)

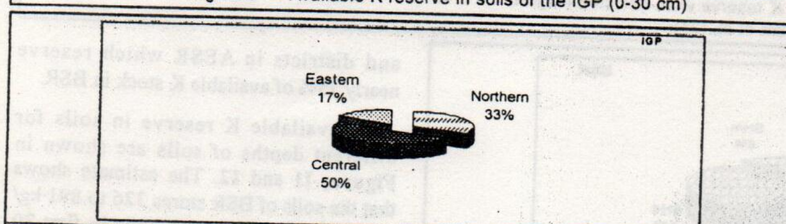


Figure 6 – Areal extent of different parts in the IGP

the central part, which is relatively less harnessed has the maximum available K reserve in the IGP (**Figure 7**). It seems that the surface soil in the northern part is more exhausted than the other parts of the IGP (**Figure 7**).

Geo-referencing the BM soil data in terms of available K reserve for 141 spots in the IGP, a thematic map on available K reserve in the soils of IGP was generated (**Figure 1**). It is interesting to note that out of 14 identified sub-regions only 5 AESRs (4.1, 9.2, 13.1, 4.3 and 15.1) contribute nearly 75% of the total available K reserve (**Figure 1**). **Table 4** shows the states and districts covering the selected AESRs and their respective K reserve.

Available K Reserve in BSR

Six different bio-climatic classes are identified in BSR, these are arid (A), semi-arid, dry (SAd); semi-arid, moist (SAm); sub-humid, dry (SHd); sub-humid, moist (SHm); and humid (H), of which SAm and SHd classes cover more than 70% area of BSR (**Figure 8a**). When K reserve values were arranged in different bio-climatic classes, it is observed that SAm, SHd and SAd store more than 80% of total available K reserve in the BSR (**Figure 8b**). An effort was made to find a relation between rainfall (MAR) and the K reserve per unit area. The study shows that humid bio-climatic class (MAR >1500 mm) stores less K reserve than the arid (MAR <500 mm) bio-climatic class in one million hectare of soils (**Figure 9**).

On the basis of AESRs, BSR was subdivided into 5 zones viz. northern, western, central, eastern and southern (**Table 2**). **Figure 10a** shows that the western zone has larger area than the other 4 zones. The data show that the K reserve is maximum in the western and central zones (36 Tg). However, the central and southern zones reserve more available K per unit area of soils of BSR (**Figure 10b**).

Geo-referencing the BM soil data in terms of available K reserve for 241 spots in the BSR a thematic map was generated (**Figure 2**). **Table 5** indicates the states

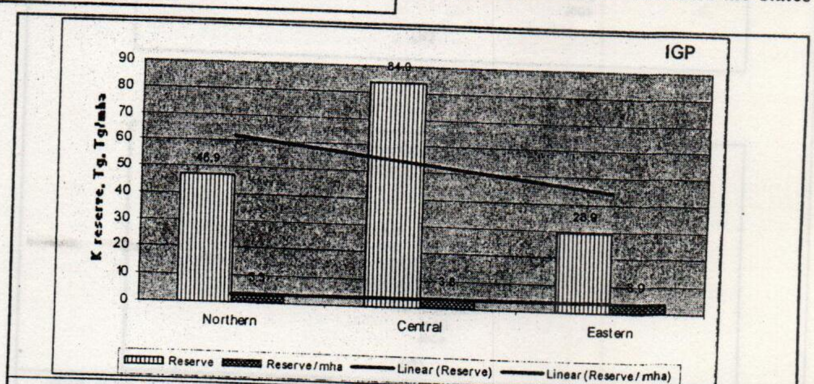
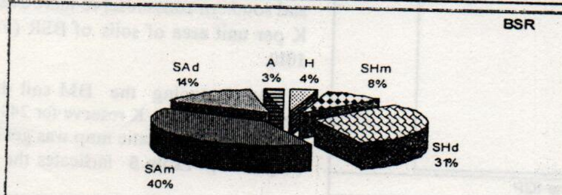


Figure 7 – K reserve per unit area IGP

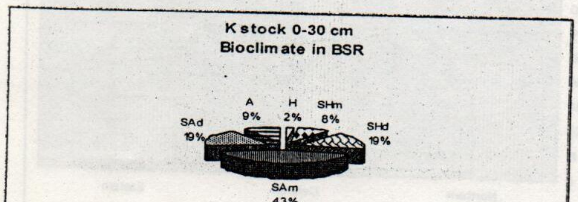
Table 4 – Available K reserve in selected* agro-ecological sub-regions of the IGP

AESRs	States (Districts)**	Bio-climatic class	Parts of the IGP	Available K reserve (Tg)
4.1	Punjab (Amritsar, Kapurthala, Sangrur, Patiala, Moga, Faridkot & Ferozpur) Haryana (Kurukshetra, Kaithal, Karnal, Jind, Sonepat, Panipat, Rohtak, Faridabad, Gurgaon, Mahendragarh, Rewari) Uttar Pradesh (Meerut, Ghaziabad, Bulandshahar, Aligarh, Mathura, Etah, Agra, Mainpuri, Firozabad, western Muzafarnagar, southern Moradabad, southern Etawah)	SAd	Northern	6.14
4.3	Uttar Pradesh (Budaun, Hardoi, Farrukhabad, Kanpur, Unnao, Varanasi, Etawah, southern Shahjahanpur, northern parts of Jalaun, Hamirpur, Banda, Mirzapur, Allahabad, Pratapgarh and Sonbhadra)	SAm	Central	3.57
9.2	Uttar Pradesh (Bareilly, Pilibhit, Sitapur, Bara Banki, Sultanpur, Azamgarh, Ghazipur, Lucknow, southern parts of Nainital, Lakhimpur Kheri, Mau, Faizabad, Balia, Rampur (East), northern parts of Shahjahanpur, Hardoi, Jaunpur, Varanasi (East), Rai Bareli and Fatehpur) Bihar (Bhojpur, Rohtas, Aurangabad, Gaya, Jahanabad, Nalanda, Patna and Nawda)	SHd		4.81
13.1	Uttar Pradesh (Bahraich, Gonda, Basti, Gorakhpur, Deoria, northern Faizabad, Azamgarh, Mau, Balia, southern parts of Siddarthanagar and Maharajgang) Bihar (Paschim and Purba Champaran, Sitamarhi, Gopalganj, Siwan, Saran, Muzaffarpur, Vaishali, Madhulani, Darbhanga, Samastipur, Begusaroi, Khagaria, Madhopura, Saharsa, Purnia, Katihar, Bhagalpur, Munger, Godda, northern Patna, Derghar, Santhal Parganas and Sahibganj)	SHm		3.61
15.1	West Bengal (Kolkata, Haora, Hugli, Medinapur, Bankura, Birbhum, Bardhaman, Murshidabad, Nadia, 24 Parganas (North and South), Maldah, West Dinajpur) Bihar (East Sahibganj)	H	Eastern	3.57

* only the AESRs contributing >10% of available K reserve were selected **(Figure 1)**
** Also see Bhattacharyya et al. (6) and Velayutham et al. (34).



(a)



(b)

Figure 8 – Areal extent of different bio-climatic class (a) and the K reserve (b) in BSR

and districts in AESR which reserve nearly 75% of available K stock in BSR.

The available K reserve in soils for different depths of soils are shown in **Figures 11** and **12**. The estimate shows that the soils of BSR stores 326 to 891 kg/ha K more than the IGP soils in first 30 and 150 cm soil depth, respectively.

AVAILABLE K RESERVE : SOIL AND CROP MANAGEMENT IN THE IGP AND BSR

THE PRIME K-BEARING MINERALS IN IGP and BSR are micas that are concentrated mainly in their silt and clay fractions (10; 19; 21; 22; 23). Of the two types of mica viz. muscovite and biotite, it is the latter which is important in terms of K nutrition to plants (23). The soils of the IGP are dominantly micacous unlike those of BSR where smectitic minerals are dominant. In view of this the present study makes an

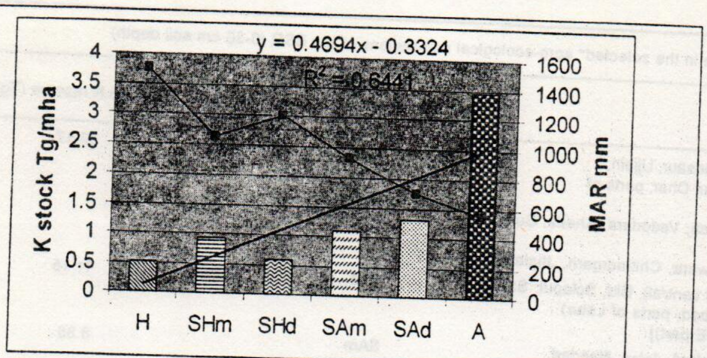


Figure 9 – K reserve vs mean annual rainfall (MAR) in 0-30 cm depth of soils in different bio-climates, BSR

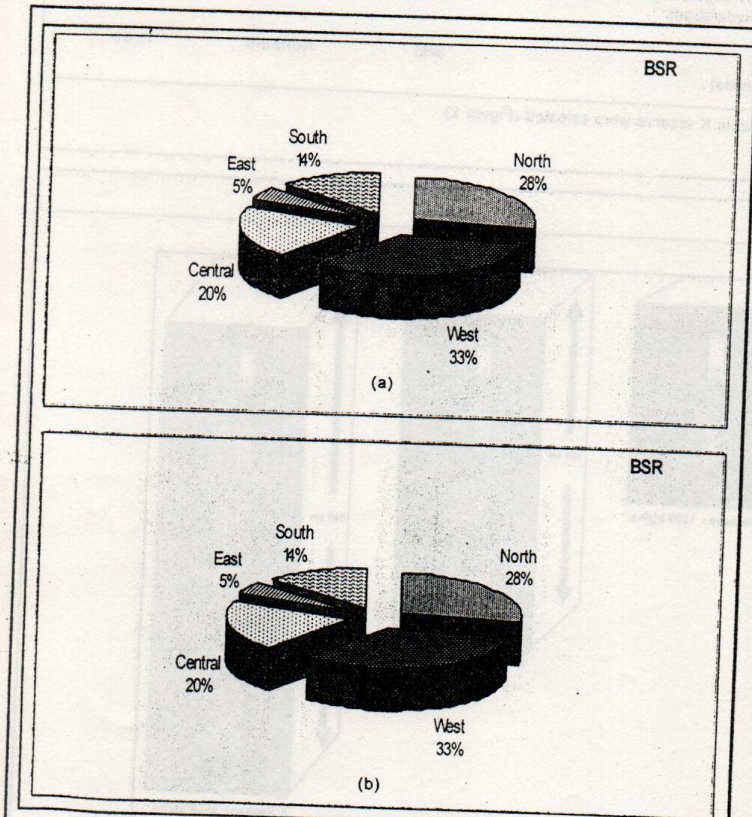


Figure 10 – Areal extent of different zones in BSR (a) and K reserve per unit area in 0-150cm soil depth (b)

interesting observation in terms of available K reserve of the IGP which is lower at all depths than that of the BSR.

The land use histories of both the soils perhaps make these scenario realistic. The lower reserve of the IGP might be related to the exhaustive mining of K through extensive agricultural land uses during the Green Revolution era and also thereafter. Such uses in soils of BSR are generally not observed as these soils are mostly under rainfed conditions supporting single crop in a year. It has been experimentally found that the apparently high available K of soil of BSR is not sustainable when genetically modified deep-rooted crops like hybrid cotton was introduced because these soils contain very low amount of K releasing minerals like biotite. Such crops started responding to K application after 3 years of cropping. In contrast, the crop response to K fertiliser application in soils of IGP is seldom observed even after cropping for the last 30 years. This is due to the high K reserve in soils rich in biotite mica (23).

More K reserve in the subsoils of the IGP may be exploited by introducing deep-rooted crops. An overall more K reserve in soils of BSR might permit introduction of second crop through some possible management interventions in the semi-arid tropics, the area which has not been exploited completely in terms of crop management.

CONCLUSIONS

THE GEO-REFERENCING OF THE AVAILABLE K information of the two major soil types of the country not only provides a state-of-the-art information at this point of time but also provides a robust platform at national level to monitor the changes in available K status due to changes in the land use scenarios. This approach appears to be one of the viable ways to manage the natural resources, specially the soils, for posterity. It can also help in developing an appropriate land use through geo-referenced soil information system for crop planning (SISCroP).

Table 5 – Available K reserve in the selected* agro-ecological sub-regions of the BSR (0-30 cm soil depth)

AESRs	States (Districts)**	Bio-climatic class	Parts of IGP	Available K reserve (Tg)
5.2	Madhya Pradesh (Jhabua, Ratlam, Mandsaur, Ujjain, Indore, Dewas, East Nimar, West Nimar, Dhar, parts of Rajgarh and Shajapur) Gujarat [Godhra (Panchmahal), Bharuch, Vadodara, Kheda, Surat (northern and central part)] Rajasthan [Bundi (south), Kota, Banswara, Chittaurgarh, Jhalawar, Baran]	SAm	Western	33.17
6.1	Maharashtra (Ahmednagar (south and central), Bid, Solapur, Sangli, Satara, Pune (eastern part), Osmanabad, parts of Latur) Karnataka [Bijapur (north), Raichur (NE part)]	SAd	Central	11.15
6.2	Masharashtra [Nashik, Dhule, Aurangabad, Jalna, Nanded, Parbhani, Latur, northern hills of Ahmednagar, Jalgaon (west)] Karnataka (Bidar, Gulbarga) Andhra Pradesh (Nizamabad, Adilabad)	SAm		8.88
7.2	Andhra Pradesh (Karimnagar, Warangal, Rangareddy, Mehboobnagar, Nalgonda, Khammam, Sangareddy and Hyderabad)	SAm	Southern	9.31
9.2	Uttar Pradesh (Bareily, Etah) Bihar (Bhojpur, Aurangabad, Bhagalpur, Buxar, Nalanda, Nawada, Patna and Nawda)	SHd	Northern	11.91

* only the AESRs contributing >10% of available K reserve were selected (Figure 2)
** Also see Velayutham et al. (34).

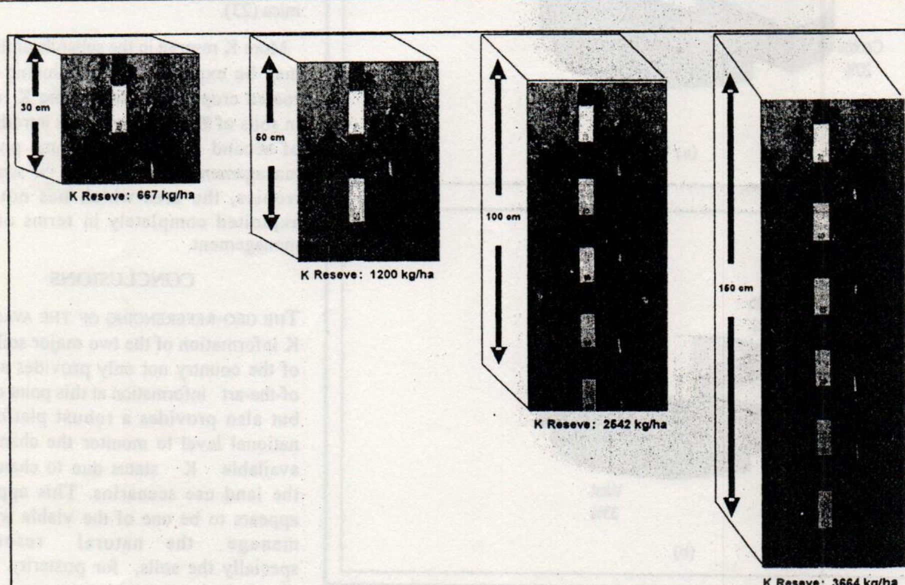


Figure 11 – Available K reserve in the soils of the IGP over different soil depths

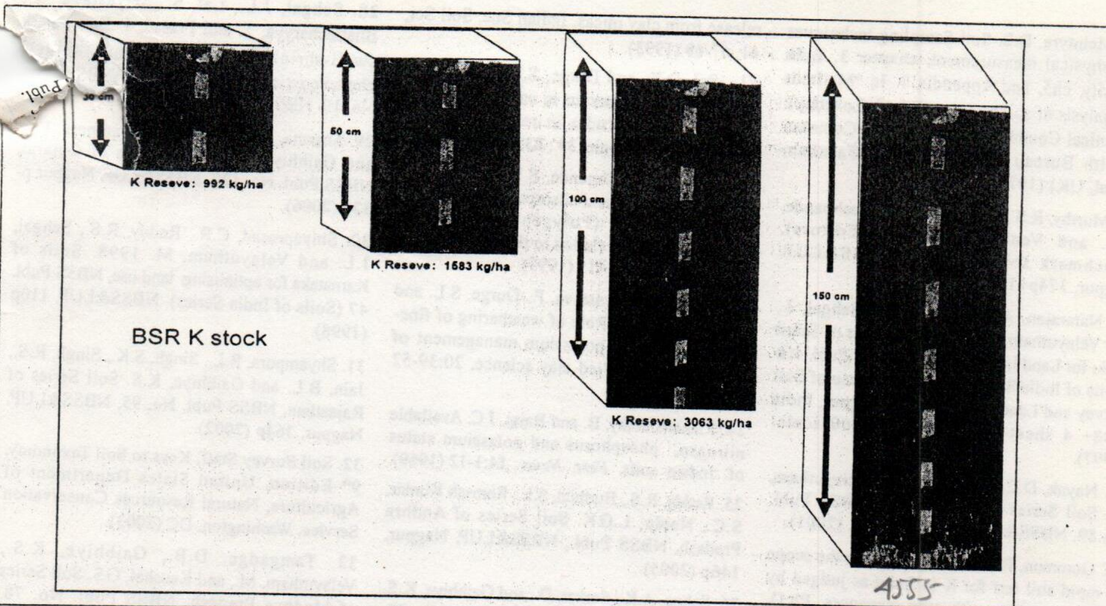


Figure 12 – Available K reserve in the soils of the BSR over different soil depths

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