Event: 7th IPI-FAI Round Table in collaboration with IPNI
Date and venue: 20/3/2012; NAAS Committee Room No.1, NASC Complex, New Delhi
Theme: Refinement of K recommendations in Vertisols

EFFECT OF MINERALOGICAL CHARACTERISTICS ON POTASSIUM AVAILABILITY IN VERTISOLS OF INDIA AND IMPLICATIONS ON CRITICAL K LIMITS

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BACKGROUND

The crop removal of potassium often equals or exceeds the uptake of N from soils

↓

With the increase in pressure in land use for higher crop production the gap between removal of K and its application to crop is <u>widening</u>

↓

It is in view of this the use of K fertilizers should be <u>judicious</u> and to be based on <u>sound database on K reserve in soils</u> and their <u>spatial distribution</u> indicating the <u>dominant minerals</u> in various soil size fractions .

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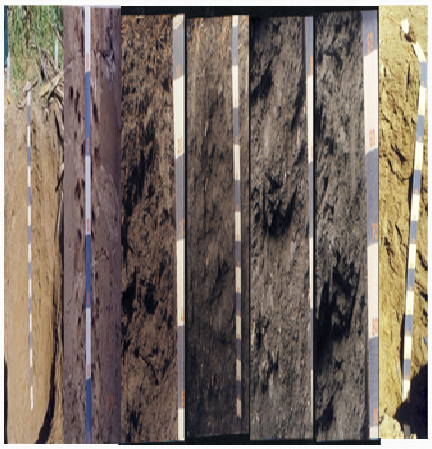
BLACK SOILS – EXTENT AND DISTRIBUTION IN INDIA

- The shrink-swell soils commonly known as black soils (Vertisols and their intergrades) represent a wide area named as black soil region (BSR) of India
- These soils are potentially huge crop production zones in the country
- These are extensively spread in the states of Uttar Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka
- Reports of Vertisols and their intergrades occur in many other states and their total acreage is 116 mha
- Are developed in the alluvium of weathering Deccan basalt.



(Bhattacharyya et al., 1993,2007; Pal and Deshpande, 1987)

Micas are more important than K-feldspars in supplying K to plants.

↓

As the Deccan basalt does not contain micas, the Shrink-Swell soils derived from its alluvium are not expected to be micaceous like the soils of the Indo-Gangetic Plains.

(Rich, 1972; Pal and Deshpande, 1987; Pal et al., 2000; Pal, 2003)

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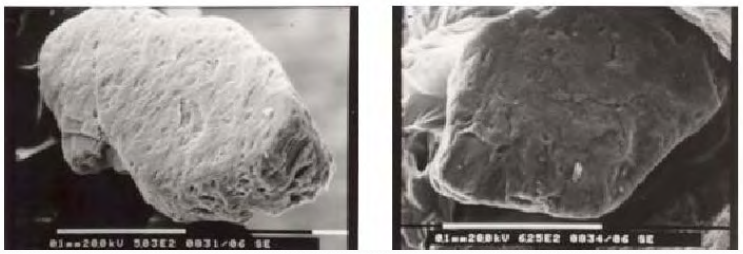
The small amount of mica in these soils are concentrated mainly in their silt and coarse clay fractions.

Their parental legacy is ascribed to erosional and depositional episodes experienced by the Deccan basalt areas during the post Plio-Pleistocene transition period.

(Pal et al., 2001; Pal and Deshpande, 1987)

Petrographic and SEM examination of muscovite and biotite of S-S soils

indicates



little or no alteration

(Pal et al., 2001; Srivastava et al., 2002)

high available K status of Shrink-Swell soils

appears to be

related to the retention of elementary layers of micas

that

Favours the release of K^+ ions even though its content is less

This suggests that the

- ✓ **Nature**
- ✓ **Content**
- ✓ **Weathering stages of micas**

Have a definite role to play in ***K management***

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- ✓ **The observed K adsorption/fixation of Shrink-Swell soils is rarely related to the presence of Vemiculite (Vm) which is known to be the best fixer of added K.**
- ✓ **In routine identification of clay minerals in Shrink-Swell soils, the presence of Vm may often be overlooked.**
- ✓ **Smectites do not have K selectivity as their layer charge is low.**

(Pal and Durge, 1987, 1989; Brindley, 1966)

Despite the research initiative on the fundamental aspects of K release and adsorption/fixation in relation to layer silicate minerals in recent years,

hurdle

still remains in their proper characterisation and quantification

that are to be

related to release and adsorption/fixation of K

(Pal et al., 2000, 2001)

Appropriate Steps

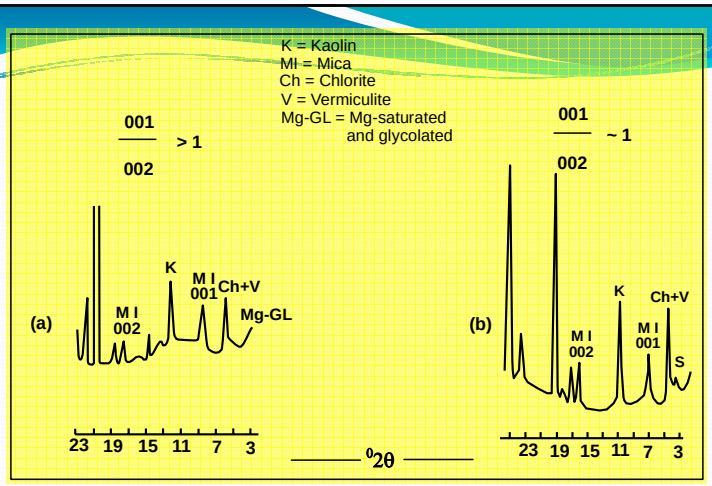
- To characterize and
- To quantify

micas and 2:1 expanding minerals

Characterisation and Quantification of fine grained micas

- **S-S soils contain very small amount of sand, silt and clay size micas.**
- **So far attempts made in highlighting the precise nature of soil mica have been based on the X-ray intensity ratio of peak heights of 001 and 002 basal reflections of mica.**

(Pal et al., 2001)



- **This ratio is in general > 1 in the silt but close to unity in the clay fractions.**
- **The ratio >1 suggests the presence of both muscovite and biotite minerals.**

- **Many workers have used the X-ray intensity of peak heights of (001) and (002) basal reflections of mica for characterizing as well as quantifying micas**
- **This is based on the observation that**
  - ❖ **<u>0.5 nm reflection is stronger in muscovite when compared to biotite micas</u>**
- **Since the (001) and (002)**
  - ❑ **<u>intensities ratio of trioctahedral mica is directly proportional to increased K concentration</u>,**
  - ❑ **many workers tried to quantify biotite mica in soils which can be utilized as an index of <u>*K-reserve in soils*</u>**

(Pal et al., 2001)

Thus, research results of the NBSSLUP pointed out

↓ a need

of a Selective Quantification of Biotite Mica in the common situation in soils containing mixtures of biotite and muscovite

And to determine K stock in soils of BSR .

(Pal et al., 2001; Bhattacharyya et al, 2007)

A. Quantifying Biotite Mica

- The content of biotite in S-S soils and their size fractions through a rigorous and exhaustive Ba-K exchange reactions was estimated.
- The cumulative amount of K released at the end of final extraction by the soils' size fractions, when release of K almost ceased, was considered as released amount mainly from biotite.

Nimkar (2004)

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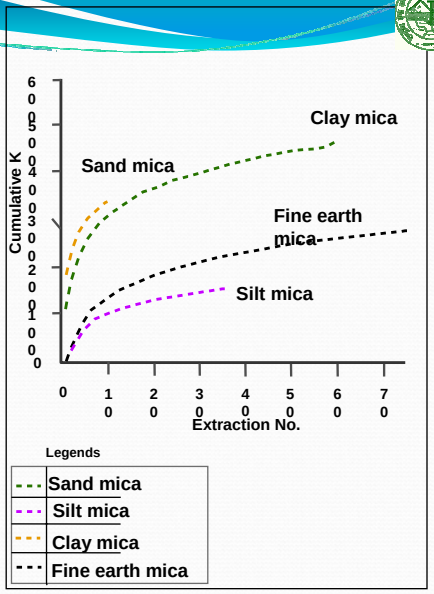
A. Quantifying Biotite Mica

- The contents of biotite in shrink-swell soils in various size fractions through Ba-K batch type exchange was estimated.
- The cumulative amount of K released at the end of final extraction by different size fractions was considered as released amount mainly from biotite .



(Nimkar, 2004)

A. Quantifying Biotite Mica

BIOTITE CONTENT MEASURED IN VERTISOLS OF CENTRAL INDIA

- The amount of biotite in
  clay: 1.0 to 1.6 mg/100g
  silt : 0.2 to 0.3 mg/100g
  sand : 0.2 to 0.4 mg/100g

- It constitutes 7 to 19, 2 to 3 and 2 to 5% of the total mica in those size fractions, respectively
- In less than 2 mm fine earth fraction biotite content rarely exceeds 1% which constitute 6-8% of total micas

{Nimkar, 2004)

B. Quantifying Biotites: Other Methods

Biotite content was also measured using *peak height ratio (002/001)* values in selected benchmark soils using the formula:

$$\text{biotite} = \frac{(0.685 - \text{Peak height ratio})}{0.719}$$

(Rajkumar et al., 2006)

B. Quantifying Biotites: Other Methods

Soil horizon	Light minerals (Sp. Gravity < 2.85)	Heavy minerals (Sp. Gravity < 2.85)
Jassi Pauwali (Typic Ustipsamment)		
Ap	0.62	0.50
Cl	0.55	0.52
C4	0.59	0.30
Jodhpur Ramana (Ustochreptic Camborthid)		
Ap	0.55	0.37
Bw2	0.54	0.52
C2	0.60	0.38
Kanjli (Typic Haplustept)		
Ap	0.47	0.43
Bw2	0.50	0.59
C	0.35	0.32
Nabha (Typic Haplustept)		
Ap	0.71	0.53
Bw2	0.74	0.65
C	0.63	0.59
Kandi (Typic Ustipsamment)		
Al	0.45	0.39
Cl	0.40	0.34
C3	0.32	0.22
Kanjli (Typic Haplustept)		
Ap	0.54	0.16
Bw2	0.44	0.40
BC	0.58	0.41

B. Quantifying Biotites: Other Methods

Location	Minerals	Sand (%)	Silt (%)
Sub humid soil (Soil-I pH 7.4)	Muscovite	60.40	100
	Biotite	39.60	0.00
Arid soil (Soil-II pH 8.4)	Muscovite	46.50	72.80
	Biotite	53.50	27.20

C. Quantifying Biotites: Other Methods

ELECTRONIC METHOD: SOFTWARE

- **With the advent of modern software, the X-ray diffractograms offer a greater scope for**
  - **developing a user-friendly model**
  - **to estimate content of biotite in a mixture using various other parameters generated by XPERT-PRO softwares while scanning samples .**

REVISION OF AVAILABLE K ESTIMATION METHOD

In the last Nagpur meeting (Aug 2010)

We discussed about the NH_4OAc method and its drawbacks

To address this issue we shall discuss some research initiatives taken at NBSS&LUP

Objectives

- To evaluate all laboratory methods to determine the available potassium of major benchmark shrink-swell soils.
- To determine the other non-conventional sources which fix as well as release K.

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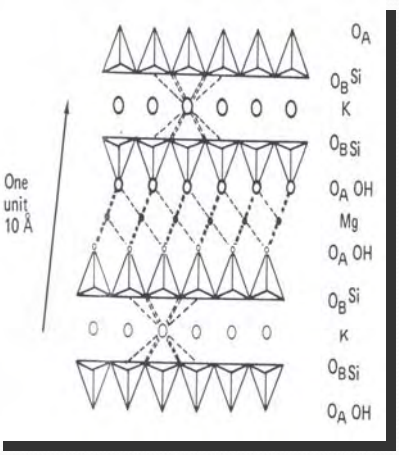
Shrink-swell soil series chosen for study

Sl.No	Soil Series	Dist./ State
1	Chunchura	Hooghly, West Bengal
2	Nabibagh	Bhopal, Madhya Pradesh
3	Panjri	Nagpur, Maharashtra
4	Takarkheda	Amravati, Maharashtra
5	Sarol	Indore, Madhya Pradesh
6	Kasireddipalli	Medak, Andhra Pradesh
7	Kovilpatti	Tutikorin, Tamil Nadu
8	Teligi	Bellary, Karnataka
9	Nimone	Ahmednagar, Maharashtra
10	Sokhda	Rajkot, Gujarat

Source of mica in shrink-swell soils :

- It is known that micas are more important than K-feldspars in supplying K to plants
- However, the Black Soil Region (BSR) dominated by Vertisols and their intergrades contain no mica of its own.



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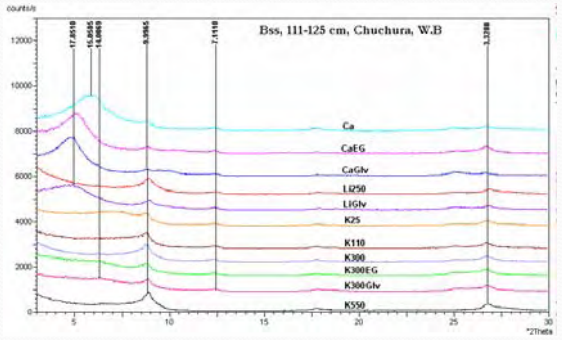
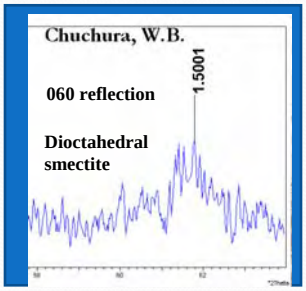
CHUNCHURA, Hooghly, West Bengal

Mica as source of K is well known in Shrink-swell soils





- **Besides mica other 2 : 1 minerals are controlling K dynamics in soils??**
- **How to solve this riddle???**
- **Charge chracteristics of Clay minerals could be a plausible answer.**

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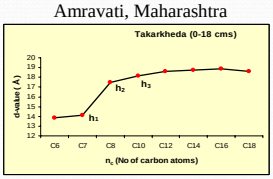
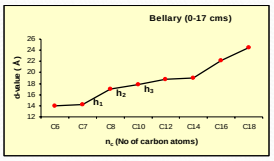
Variation of d-values with no. of C atoms

Amravati, Maharashtra



Bellary, Karnataka



Curves (d-values vs. no of c atoms)

show

Mono- to Bilayer and Bi- to Pseudotrilayer transition

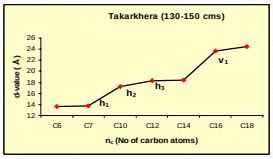
which indicates

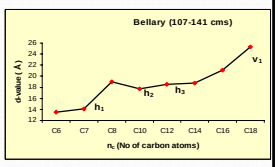
Unsymmetrical charge distribution

and suggests

Heterogeneity in smectites

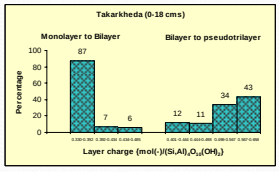
(Lagaly, 1976; Ray et al, 2003b)



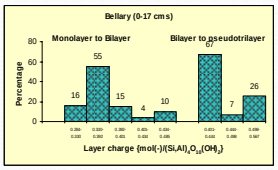


Charge distribution

Amravati, Maharashtra



Bellary, Karnataka



Charge distribution (Peak migration Analysis)

indicated

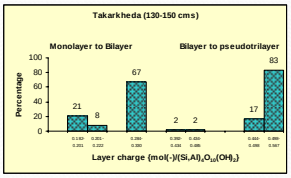
Two types of charge

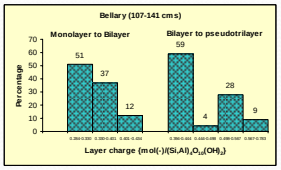
High **Low**

Heterogeneity may be due to

- **Hydroxy-interlayering**
- **Stacking arrangement**
- **<u>High charge indicated higher K adsorbtion</u>**

(Stul and Mortier 1976, Ray et al, 2003b)





Layer Charge as well as K

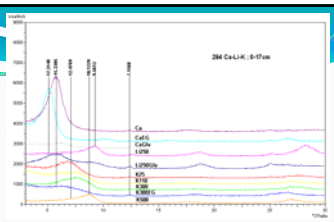
both ***Decreases with depth***

Layer Charge [(mol(-)/(Si,,Al)$_4$O$_{10}$(OH)$_2$)]

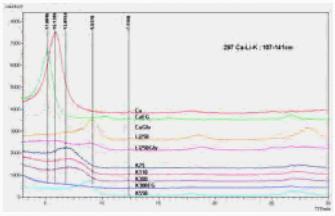
cm	Takarkheda		Bellary
0	0.46	Ap	0.44
	0.43	Bw	0.42
	0.43	Bss	0.42
	0.40	Bss	0.41
150	0.40	Bc	0.40

Decrease

(Ray et al, 2002)



XRD of Bellary fine clays



Hints contribution of K-minerals other than mica

HCS/LCV

D. Quantifying Biotites: An indirect Method through *soil K reserves*

Georeferencing soil K datasets should be the other important step

to estimate the K reserve in the black soils

for periodic monitoring of changes in K status

(Bhattacharyya et al., 2007)

D. METHOD

CALCULATING K STOCKS

The size of potassium stock is calculated following 2 steps.

step 1 : **Determination of extractable K by neutral N NH_4OAC and then multiplying it with BD and thickness of horizon for individual soils Benchmark (BM) for 0-30, 0-50, 0-100 and 0-150 cm.**

Step 2: **Total K content determined by step 1 was multiplied by the area of each BN soil distributed in the IGP and BSR**

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

$$\text{K stock in soil (Tg)} = \frac{\text{NH}_4\text{OAc extr K } (gg^{-1}) \times \text{BD } (Mg\ m^{-3}) \times \text{Area (Mha)} \times \text{depth (m)}}{10^4}$$

The K stock values were also expressed also K (kg/ha)

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METHOD

GENERATING THEMATIC MAPS

-1:4.4 m scale AESR and Bioclimate maps (Base Maps)

-Digitisation of maps of AESRs and Bio-climate (1:4.4 m)

-locating 241 BM spots

-Developing thematic maps for Available K stock for different soil depths in

- **AESR (to find out zonal K reserves within BSR)**
- **Bioclimate (to find K reserves in different climate)**

Geo-SIS

BSR

Main Menu

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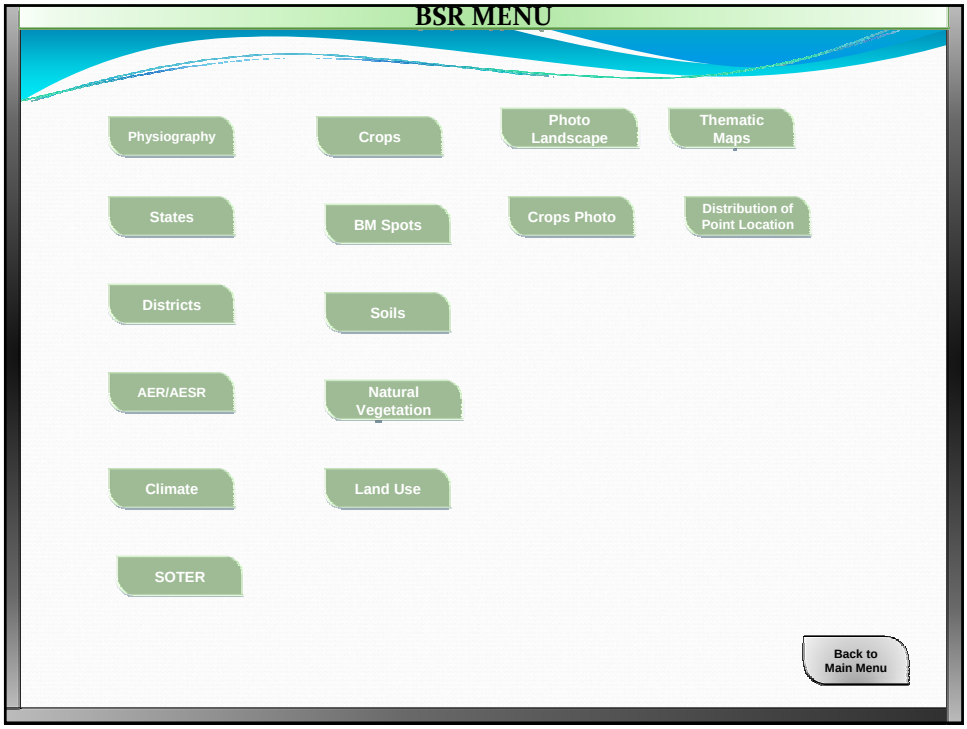

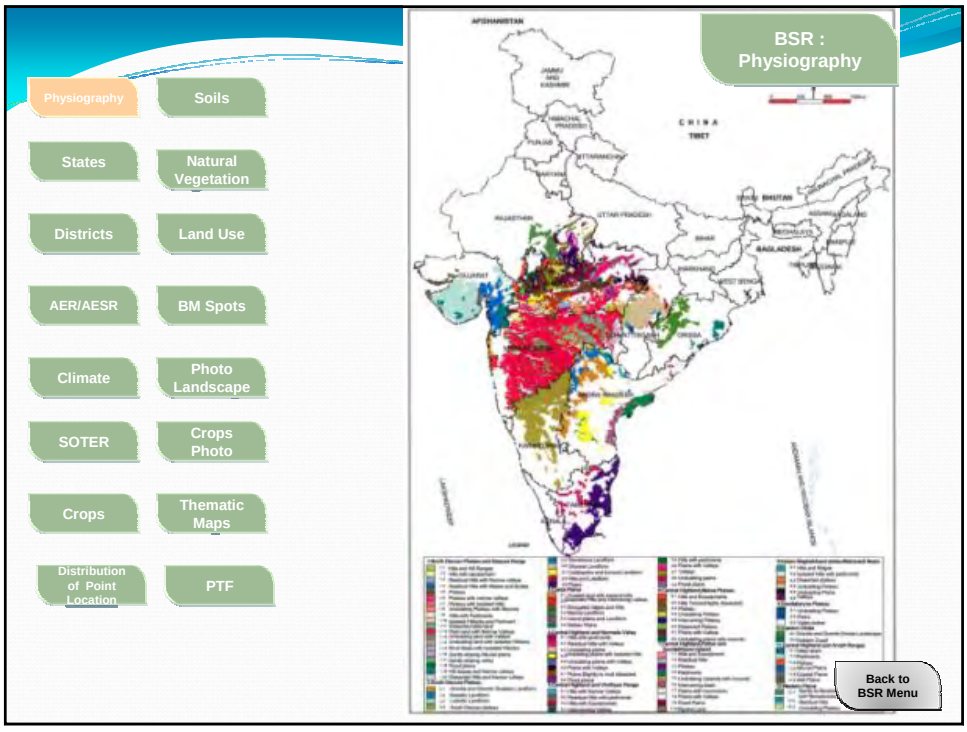

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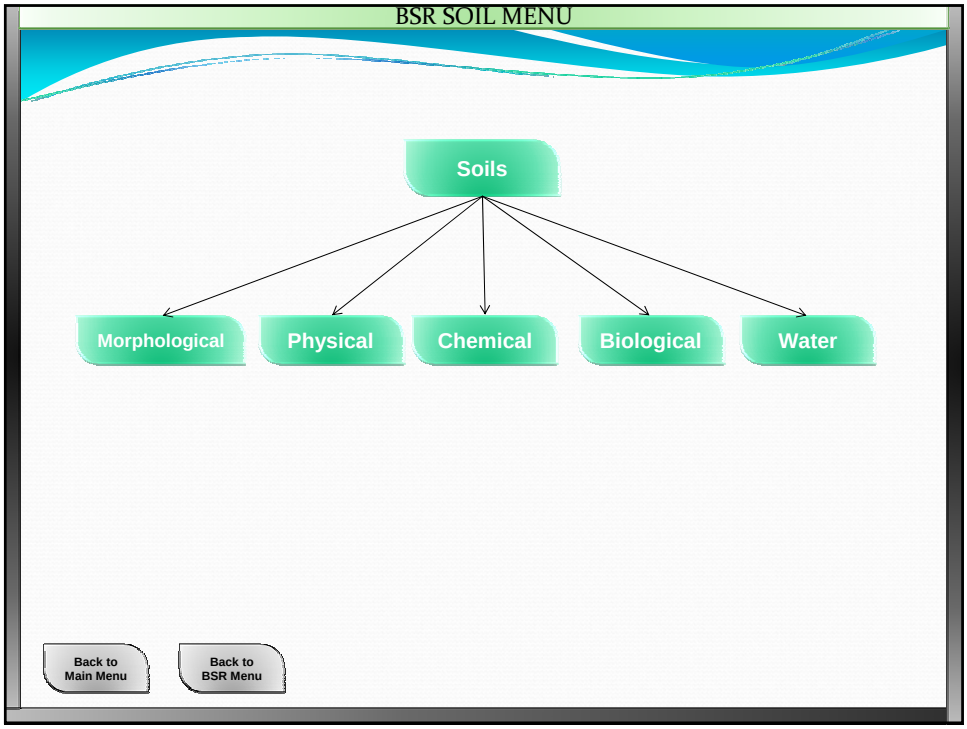

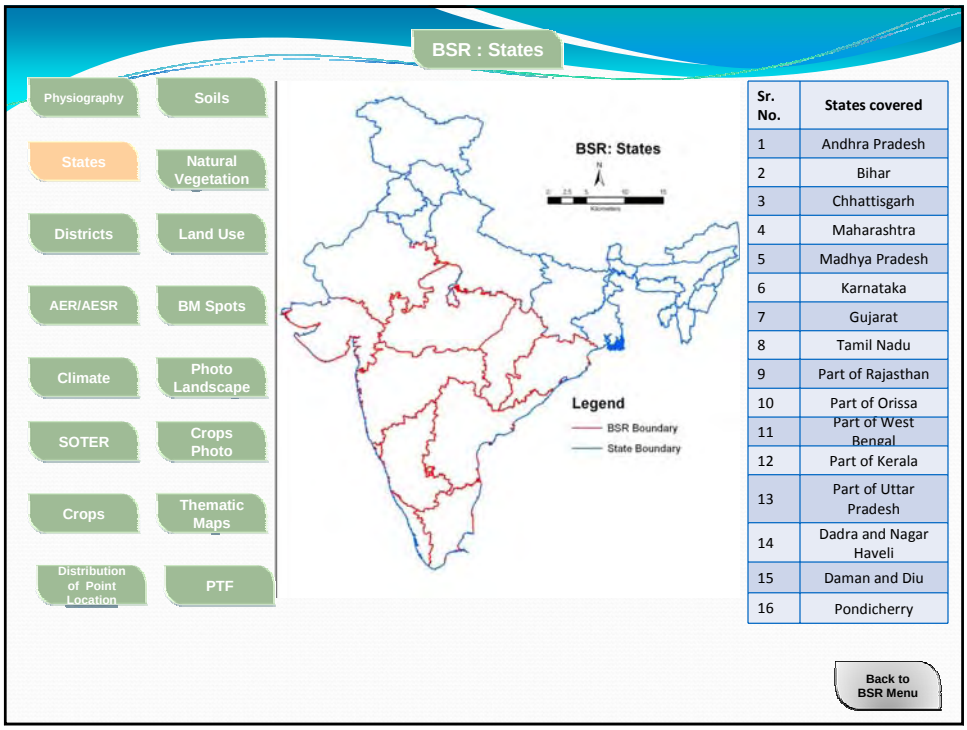

Sr. No.	States covered
1	Andhra Pradesh
2	Bihar
3	Chhattisgarh
4	Maharashtra
5	Madhya Pradesh
6	Karnataka
7	Gujarat
8	Tamil Nadu
9	Part of Rajasthan
10	Part of Orissa
11	Part of West Bengal
12	Part of Kerala
13	Part of Uttar Pradesh
14	Dadra and Nagar Haveli
15	Daman and Diu
16	Pondicherry

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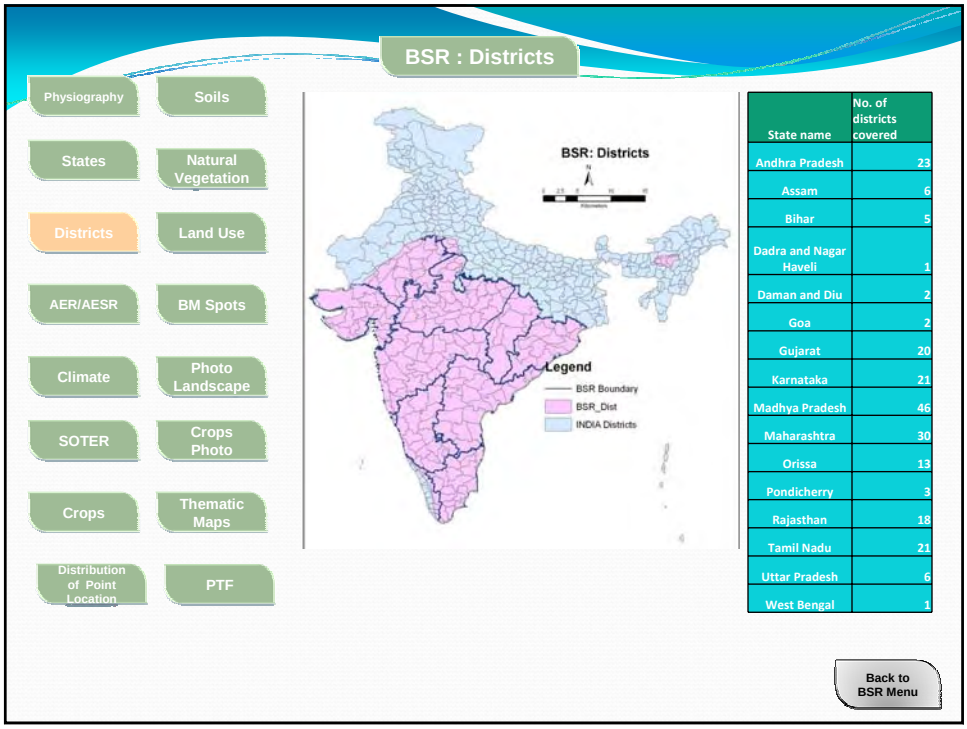
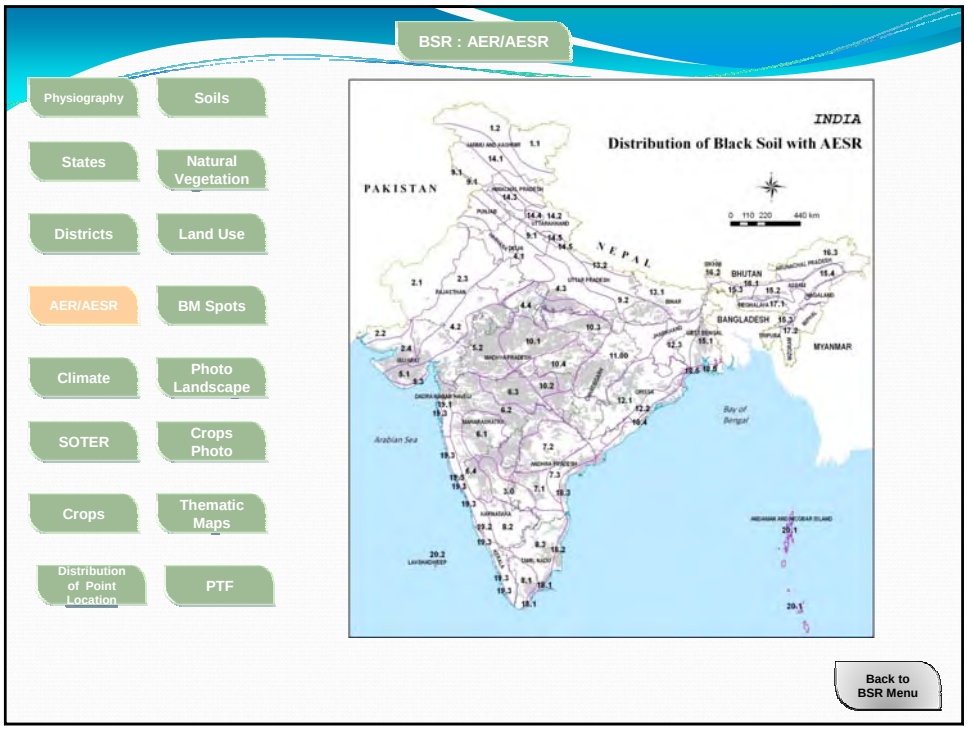


State name	No. of districts covered
Andhra Pradesh	23
Assam	6
Bihar	5
Dadra and Nagar Haveli	1
Daman and Diu	2
Goa	2
Gujarat	20
Karnataka	21
Madhya Pradesh	46
Maharashtra	30
Orissa	13
Pondicherry	3
Rajasthan	18
Tamil Nadu	21
Uttar Pradesh	6
West Bengal	1



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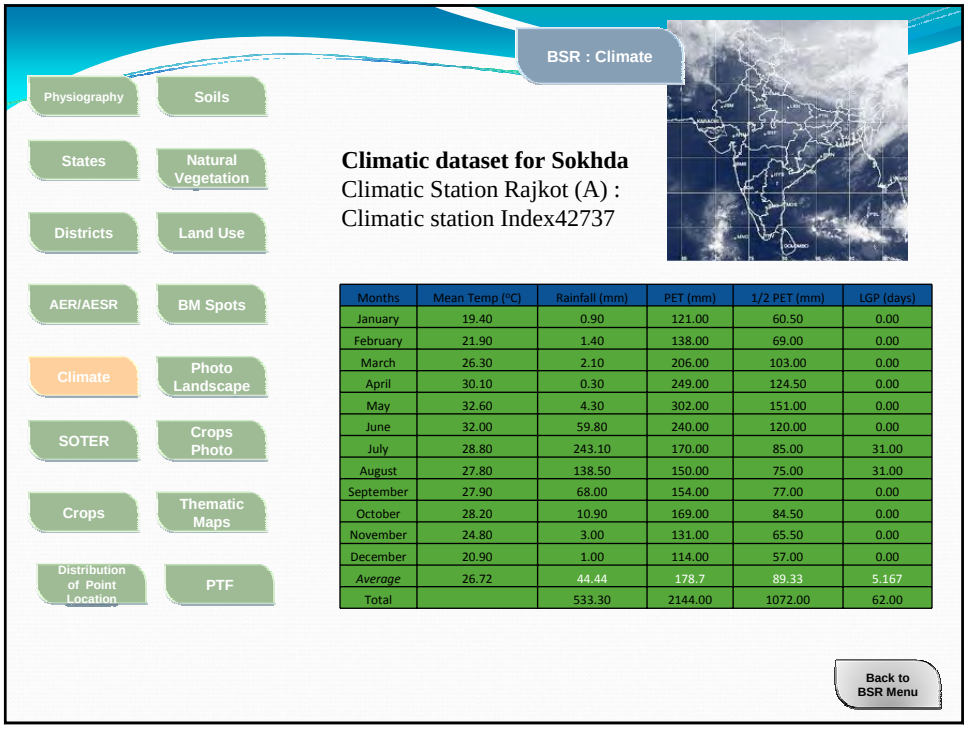
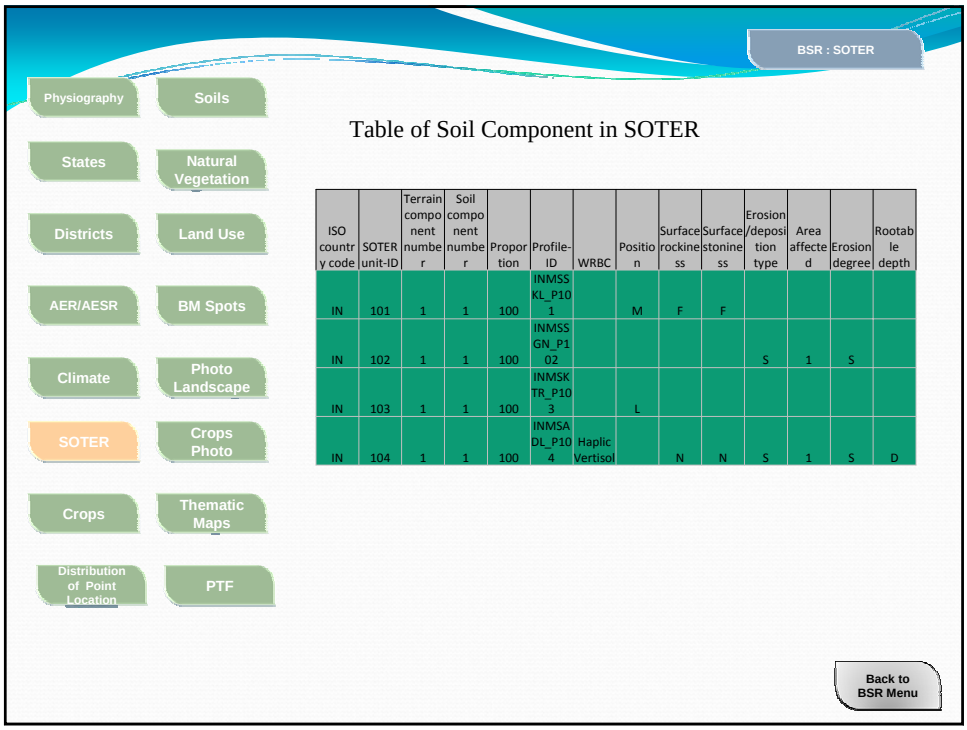


Months	Mean Temp (°C)	Rainfall (mm)	PET (mm)	1/2 PET (mm)	LGP (days)
January	19.40	0.90	121.00	60.50	0.00
February	21.90	1.40	138.00	69.00	0.00
March	26.30	2.10	206.00	103.00	0.00
April	30.10	0.30	249.00	124.50	0.00
May	32.60	4.30	302.00	151.00	0.00
June	32.00	59.80	240.00	120.00	0.00
July	28.80	243.10	170.00	85.00	31.00
August	27.80	138.50	150.00	75.00	31.00
September	27.90	68.00	154.00	77.00	0.00
October	28.20	10.90	169.00	84.50	0.00
November	24.80	3.00	131.00	65.50	0.00
December	20.90	1.00	114.00	57.00	0.00
Average	26.72	44.44	178.7	89.33	5.167
Total		533.30	2144.00	1072.00	62.00



ISO country code	SOTER unit-ID	Terrain component number	Soil component number	Proportion	Profile-ID	WRBC	Position	Surface rockiness	Surface stoniness	Erosion/deposition type	Area affected	Erosion degree	Rootable depth
IN	101	1	1	100	INMSSKL_P101		M	F	F				
IN	102	1	1	100	INMSSGN_P102					S	1	S	
IN	103	1	1	100	INMSKTR_P103		L						
IN	104	1	1	100	INMSADL_P104	Haplic Vertisol		N	N	S	1	S	D

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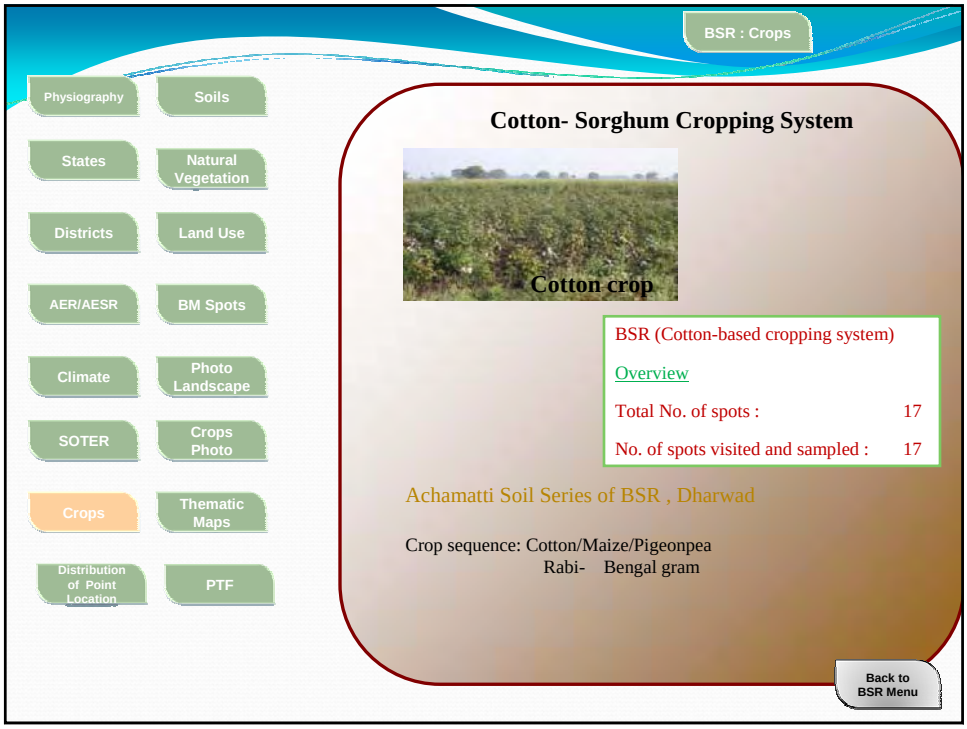

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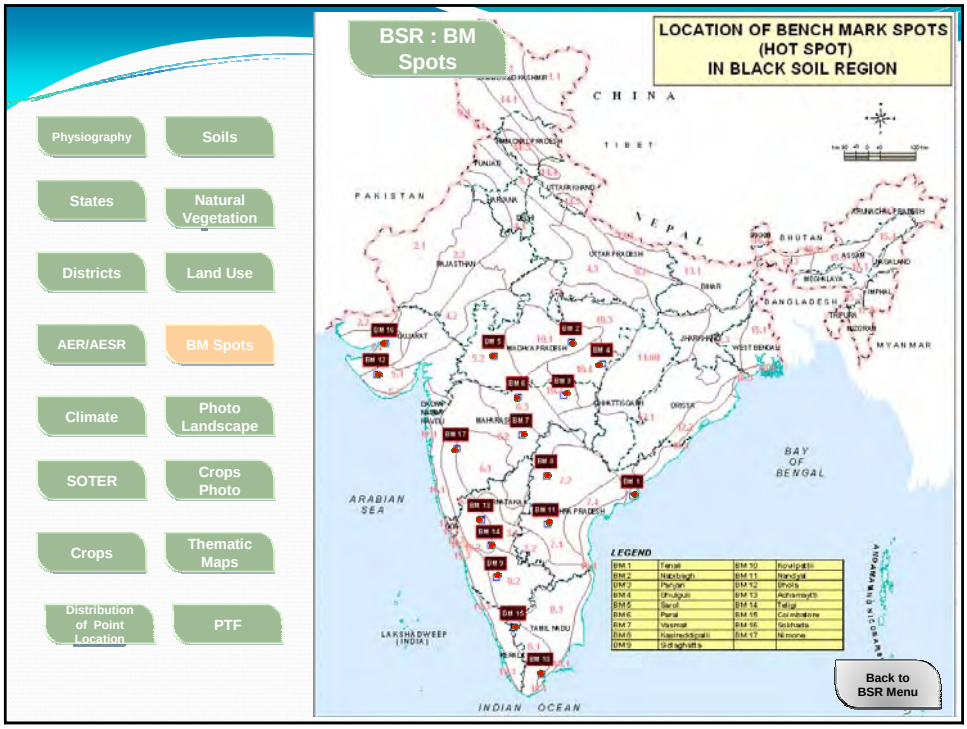

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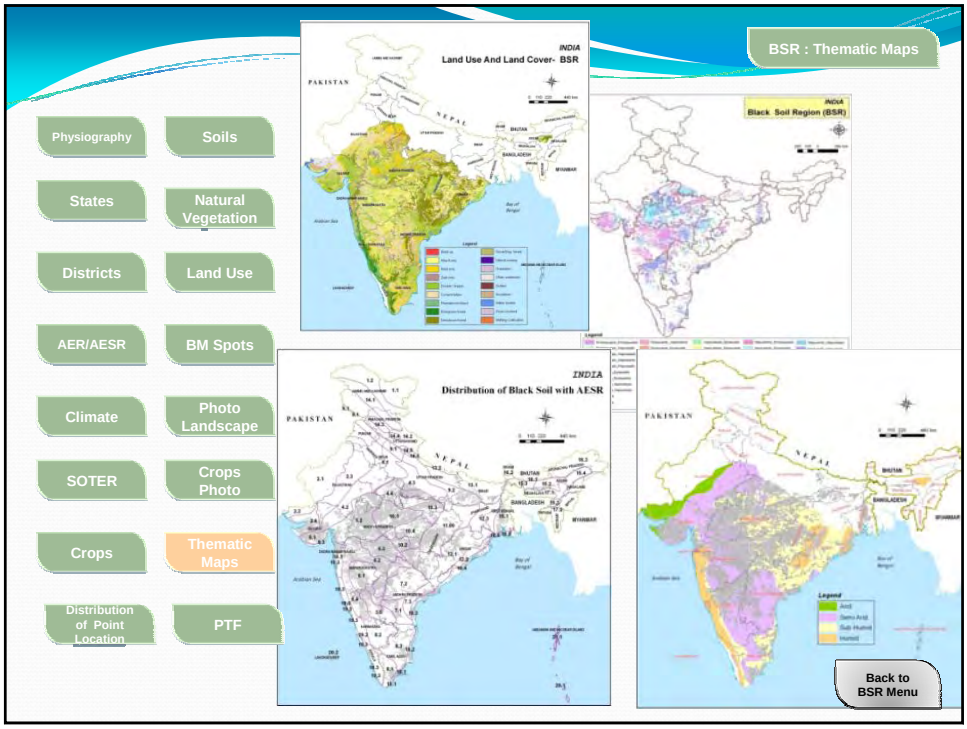

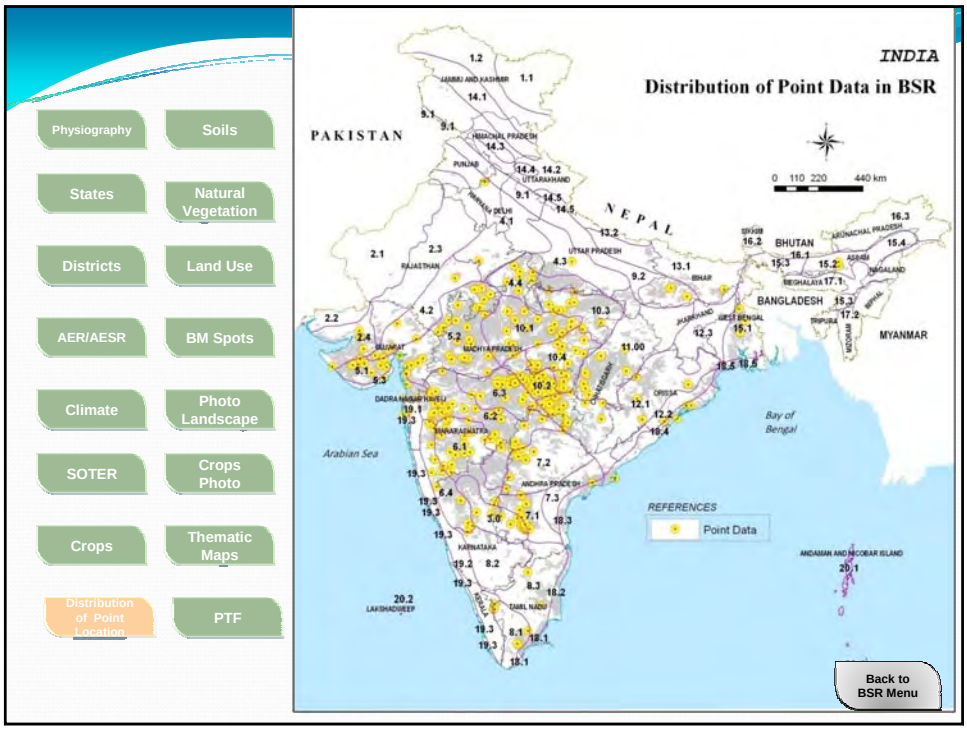

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PTF (Physical Parameters)

BSR : Pedo Transfer Function

Physiography | Soils | States | Natural Vegetation | Districts | Land Use | AER/AESR | BM Spots | Climate | Photo Landscape | SOTER | Crops Photo | Crops | Thematic Maps | Distribution of Point Location | PTF

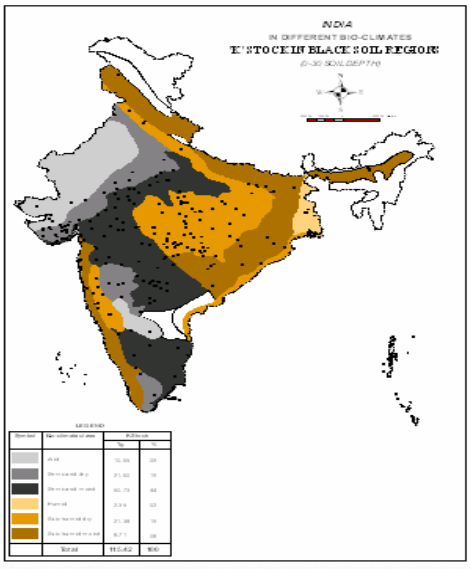
BD : 1.058-0.007 * (Clay) – 0.010 * (1500KPa) + 0.110 * pH

HC : 120.637-13.094*pH+1.151* Exch. (Ca/Mg)-0.102*Clay

PAWC :
- **Typic Haplusterts** — **(100kpa-1500kpa)*BD*Soil Depth**
- **Sodic Soil** — **(300kpa-1500kpa)*BD*Soil Depth**

Water Retention:
- 33 kpa — **22.388+0.443*Clay-0.149*ECP**
- 100 kpa — **9.006+0.429*Clay-0.071*ECP**
- 1500 kpa — **5.449+0.364*Clay-0.083*ECP**

BSR K stock - (Bioclimate)



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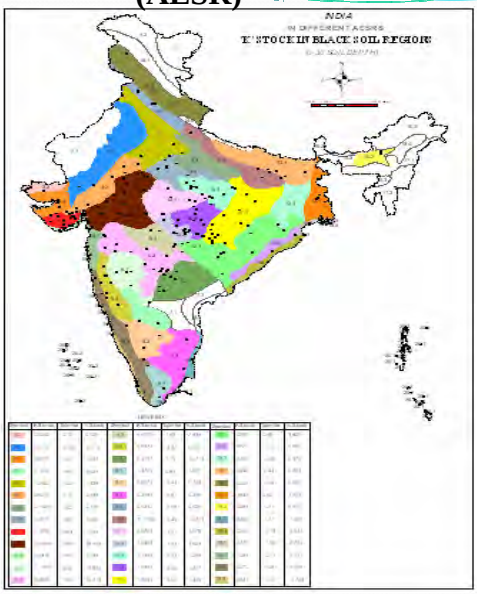
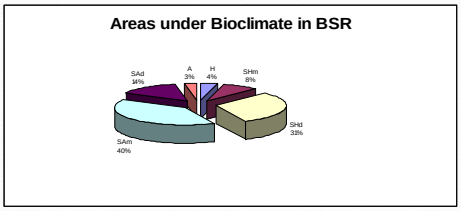
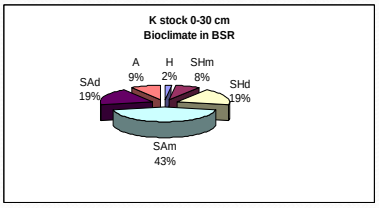
BSR K stock (AESR)



OBSERVATIONS

Share of K stock and that of Area of Bioclimate is similar





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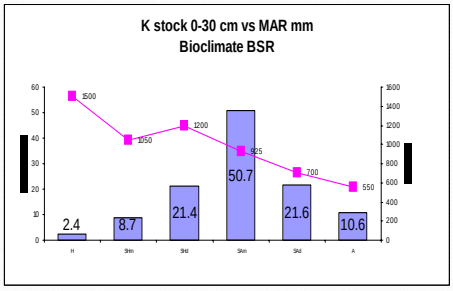
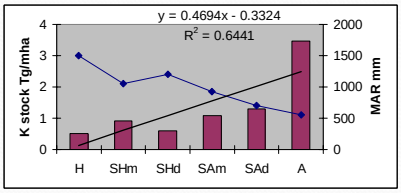
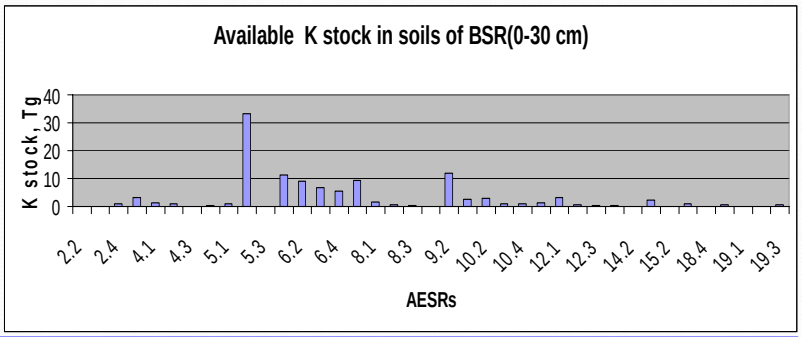


MAR vs K stock --no correlation



MAR vs K stock -- good correlation (r = 0.8)



TOTAL K STOCK = 115 Tg = 992 kg/ha K

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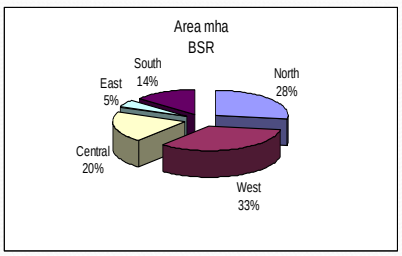
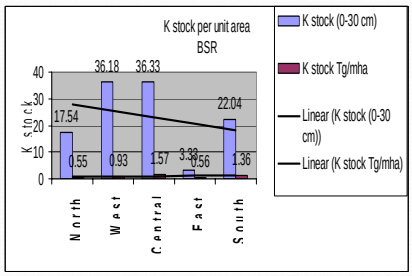
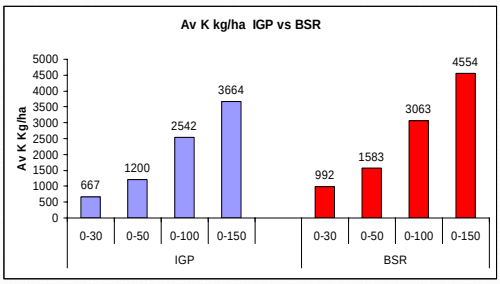




- **K stock in Western and Centarl India of BSR is high**
- **K stock/unit area is, however, higher in Central and Southern part of BSR**

K Reserve in IGP and BSR

Available K stock(Tg) Soils	Soil depths (cm)			
	0-30	0-50	0-100	0-150
IGP	29	52	111	160
BSR	115	184	356	530
Available K stock(Tg/mha) Soils				
IGP	0.66	1.19	2.54	3.66
BSR	0.99	1.58	3.06	4.55



BSR stocks 326 to 891 kg/ha K more than IGP soils in first 30 and 150 cm soil depth respectively

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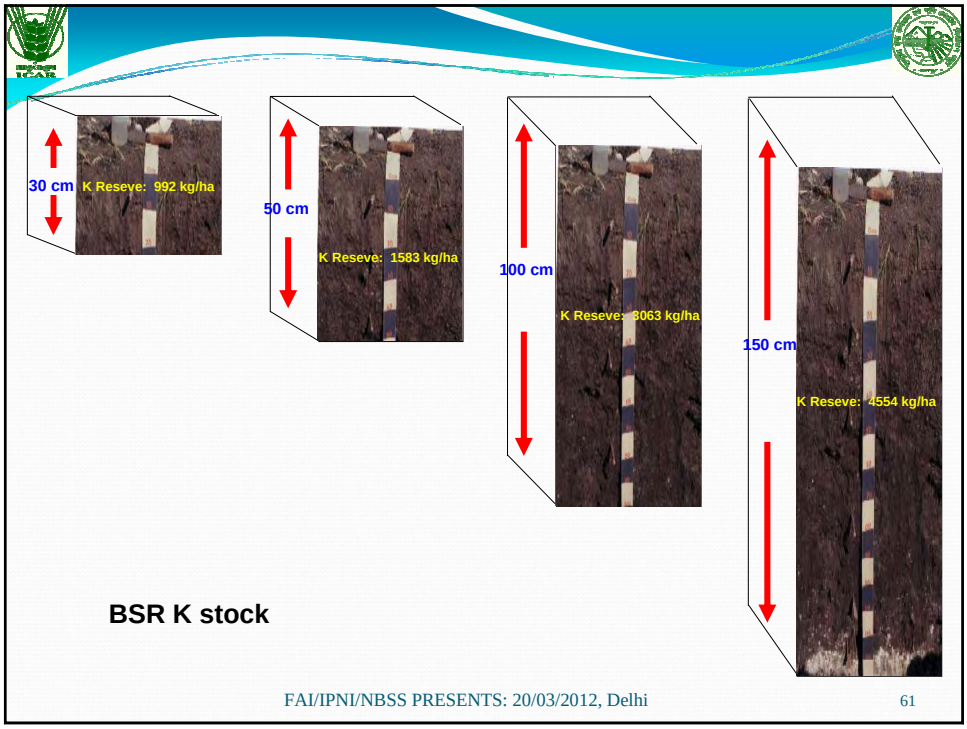

Inference

- Within BSR arid bio-climate has the potentiality to store more available K per unit area
- K reserve in soils of BSR permits more intensive cropping in the shrink-swell soils
- The relatively low reserve of IGP over BSR shows more K mining through intensive agriculture

Biotite Content, Low Charge Sm and K management

- ✓ **Despite the medium to high Av. K status of Shrink-Swell soils, agronomic experiments on Shrink-Swell soils of Central India indicated crop responses to K fertilizer treatments after two years of cropping by hybrid cotton.**

Therefore,
the presently Av. K status will not be sustainable for longer periods because the contents of sand and silt biotites are less

which ↓ ***dissolutes***

The Myth that Shrink-Swell soils are rich in Av. K that may not warrant the application of K fertilizers

- ✓ **The observed lack of K adsorption/fixation in S-S soils**

is due

the low layer charge of Sm

- ✓ **This property alongwith the limited leaching of K in poorly drained S-S soils is expected to**

favour

availability of K ions mostly in labile form i.e., in more available form

- ✓ **Therefore, dose of K fertilizers in such soils, if required, will be less due to small amount of Vm and HCS in these soils as compared to soils of the IGP, endowed with considerable amount of Vm and high charge Sm.**

- ✓ **In addition, NH_4^+ ion retention by low charge Sm of S-S soils is expected to be less and thus addition of K may not cause in reduction of crop yield as experienced elsewhere with high charge Sm.**

(Chen et al., 1989)

CONCLUSIONS

- **Layer charge of clay smectites decreases with depth**
- **Decrease in layer charge influences physical and chemical properties of Vertisols including the availability of K**
- **The availability of K is also regulated by the biotite content of these soils**
- **Recent study at NBSSLUP provides a rigorous but a reliable method to determine the biotite content**
- **The biotite content obtained this way might be useful for modelling sustainability of Av. K vis-à-vis soil micas**
- **The determination of layer charge of Sm appears to be mandatory for precise understanding of reaction relating to adsorption/fixation to K in soils for judicious application of K fertilizers**

(Nimkar, 2004)

ACKNOWLEDGEMENT

- **Part of the datasets has been taken from NAIP funded project on "Georeferenced Soil Information System for land use planning and monitoring soil and land quality for agriculture" (Comp. 4).**
- **ICAR**
- **Director, NBSS&LUP, Nagpur**

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Thanks