SESSION 9 – Show-Casing Potential Soil Carbon Practises on Various LULC

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India

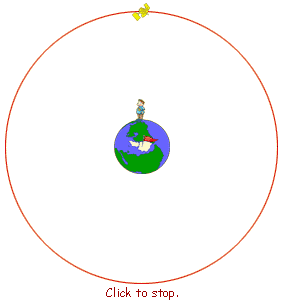
ESA Symposium on Earth Observation for Soil Protection and Restoration

SAC Campuses

Brief about Our Centre

Main Campus *Started as ESCES in 1967*

Delhi Earth Station



Bopal Campus

Soil Health v/s Soil Quality

- **Soil quality** is the capacity of soils within landscapes to sustain biological productivity, maintain environmental quality and promote plant and animal health (**Quantitative for Scientists)**.

- **Soil health** is the 'fitness' (or condition) of soil to support specific uses (e.g. crop growth) in relation to its potential as determined by the inherent soil quality and is more sensitive to anthropogenic disturbance and is severely limited in extreme environments (**Qualitative for farmers**)

- **Both of these terms** relate soil to other concepts of health such as environmental health, human health, plant health, and animal health.
- Soil health and soil quality are functional concepts that describe how fit the soil is to support the multitude of roles that can be defined for it. Therefore, soil quality can be regarded as soil health.

Soil health and SDG

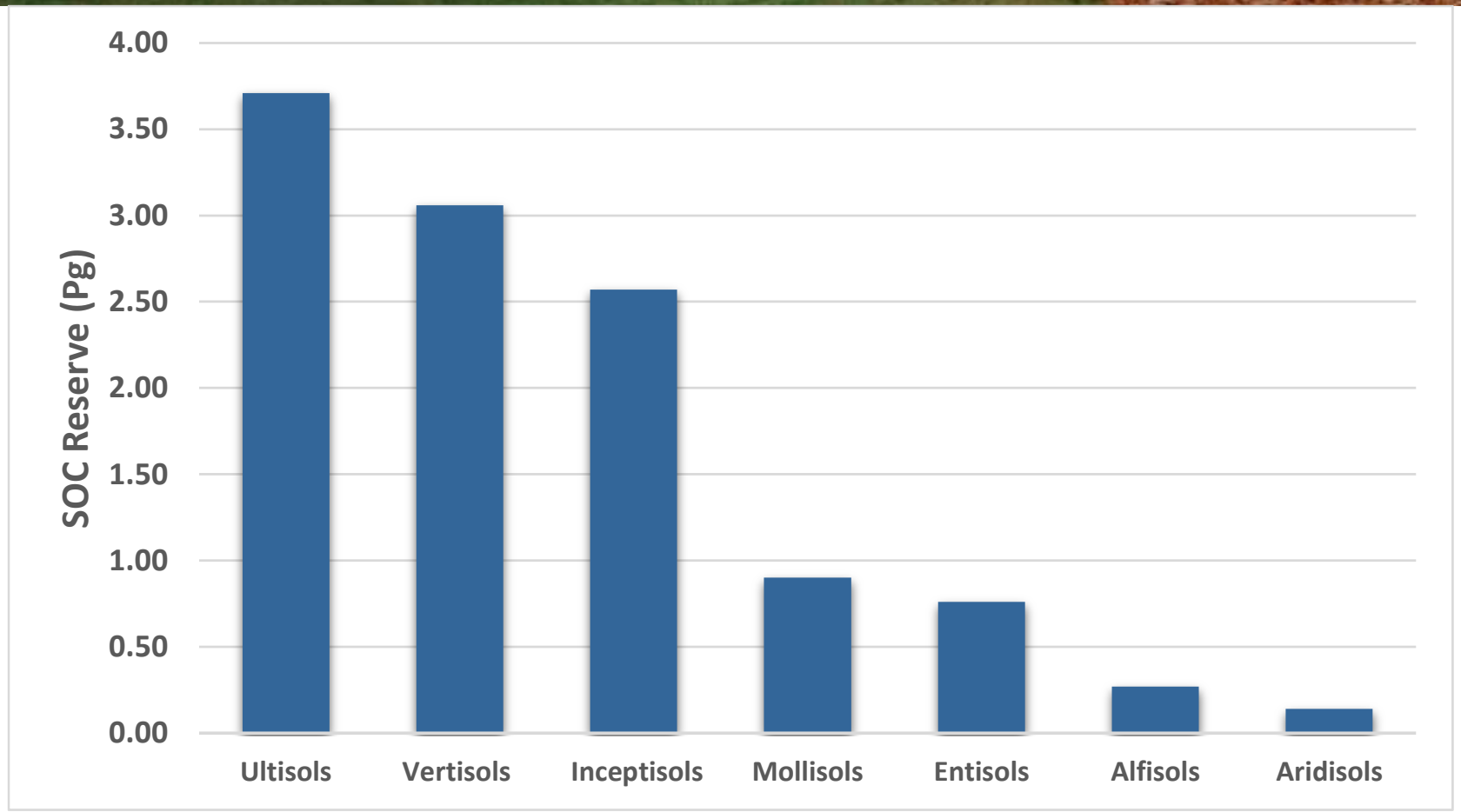
- **Goal 2: Ending Hunger –** In order to end hunger, superior food security will prove integral. However, improving soil health for greater productivity is vital since it directly influences around 95% of total food consumption.

- **Goal 3: Good Health and Wellbeing –** To increase health and wellbeing, increasing soil productivity for greater production of healthy and nutritious foods may be important. Moreover, since the soil determines a crop's final nutrient level, promoting greater nutrient density in soils may prove valuable.

- **Goal 13: Climate Action** – As we have already outlined, promoting soil health to reduce inputs, minimize nutrient leaching and runoffs and promote carbon sequestration is vital.

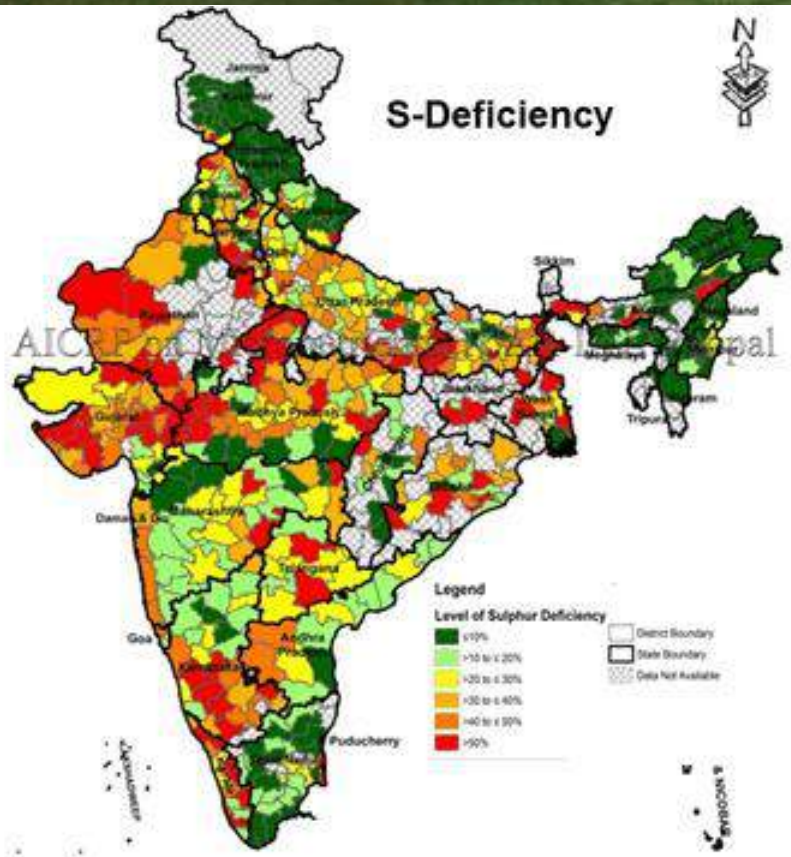
- **Goal 15**: **Reducing Desertification of Soils:** Unsurprisingly, Goal 15 of the Sustainable Development Goals – to reduce desertification and promote the restoration of degraded soils – is directly related to soil health.

Soil Organic Carbon Status in India

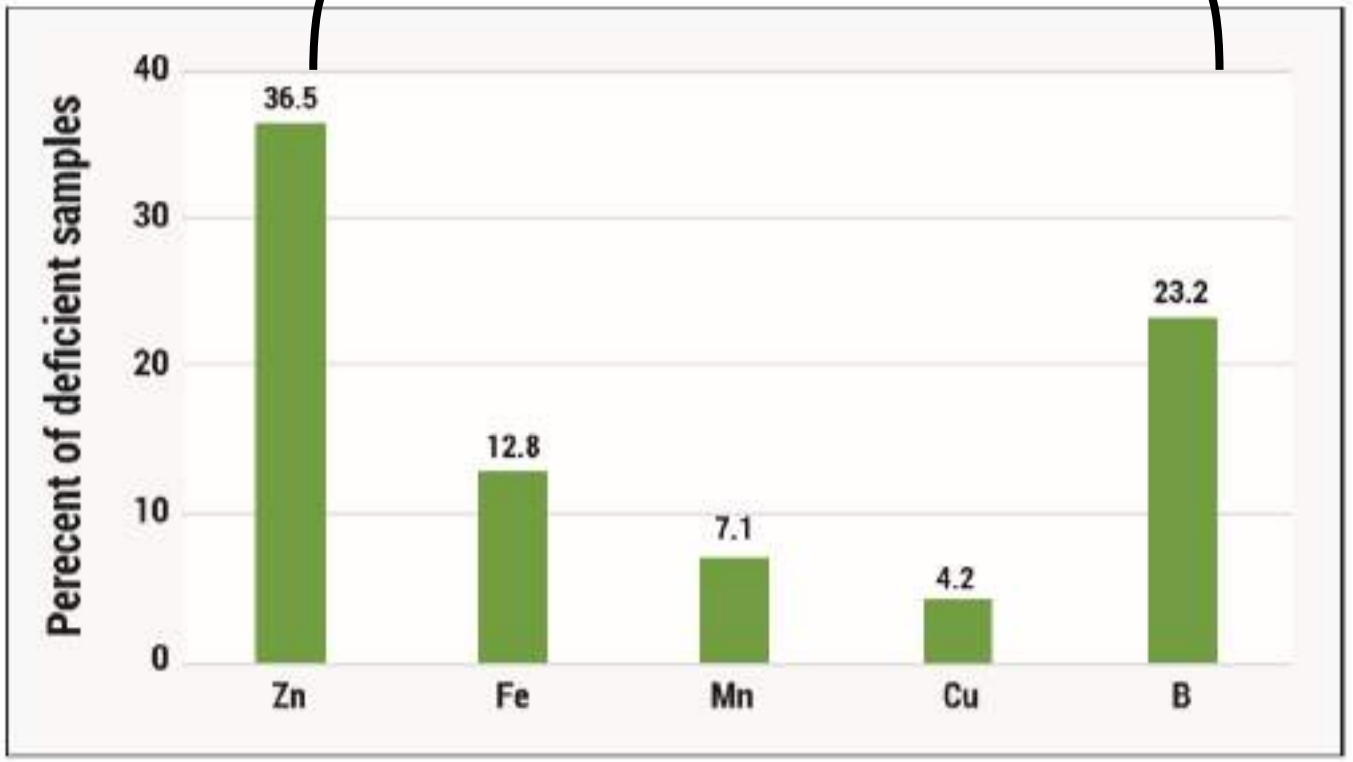


Source: Das et al. (2022), Soil Security 8 : 100071

Soil Micronutrient Status in India



Major contributors



Source: AICRP on micronutrient ICAR, 2017

Possible causes of soil health deterioration in India

- Soil erosion : 85.7 m ha
- Physical degradation : 1.07 m ha
- Chemical degradation : 17.45 m ha
  (like salt-affected soils, acidity etc.)
- Imbalanced nutrient use : NPK ratio of 7.7 :3.1 : 1 during 2021-22 (Ideal NPK Ratio = 4:2:1)
- Nutrient mining : Total negative balance of 9.7 Mt year for NPK
  In India, 75% of the soil are low in nitrogen, 15.5% are deficient in phosphorus, 6.9% are low in potassium and 55% are deficient in organic carbon (https://soilhealth.dac.gov.in/home)
- Extractive farming practices : Crop residue burning (common in NW India), removal of crop residues, excessive tillage, flood based irrigation, and indiscriminate use of chemicals

Current status of soil data in India

Soil Survey

Most of Indian soils have been mapped on 1:250,000 scale and the legacy data are available on

krishikosh (https://www.krishikosh.egranth.ac.in)

Bhoomi (https://www.bhoomigeoportal-nbsslup.in)

Status of soil survey in India

Indian Organisation	Kind of survey & mapping scale	Coverage (M ha)
NBSS&LUP	• Small scale soil mapping (1:250000) • Soil resource mapping (1:50000) • Detailed soil survey (1:4000/15000) • Detailed soil survey (Sujala III project) • Detailed soil survey (LRI flagship programme)	300.50 198.40 8.48 1.0 50 blocks
SLUSI	Rapid reconnaissance survey for watershed prioritization (1:50000) Land degradation mapping (1:50000) Detailed soil survey (1:4000/15000) Soil resource mapping (1:50000) under NRIS programme	200.0 65 districts 13.50 89 districts
SAC ISRO	Land degradation mapping (1:50000) http://vedas.sac.gov.in	Whole country
NRSC ISRO	Waste land mapping (1:50000) Soil resource mapping (1:50000) under NRIS (DOS) (http://bhuvan.nrsc.gov.in)	Whole country 200

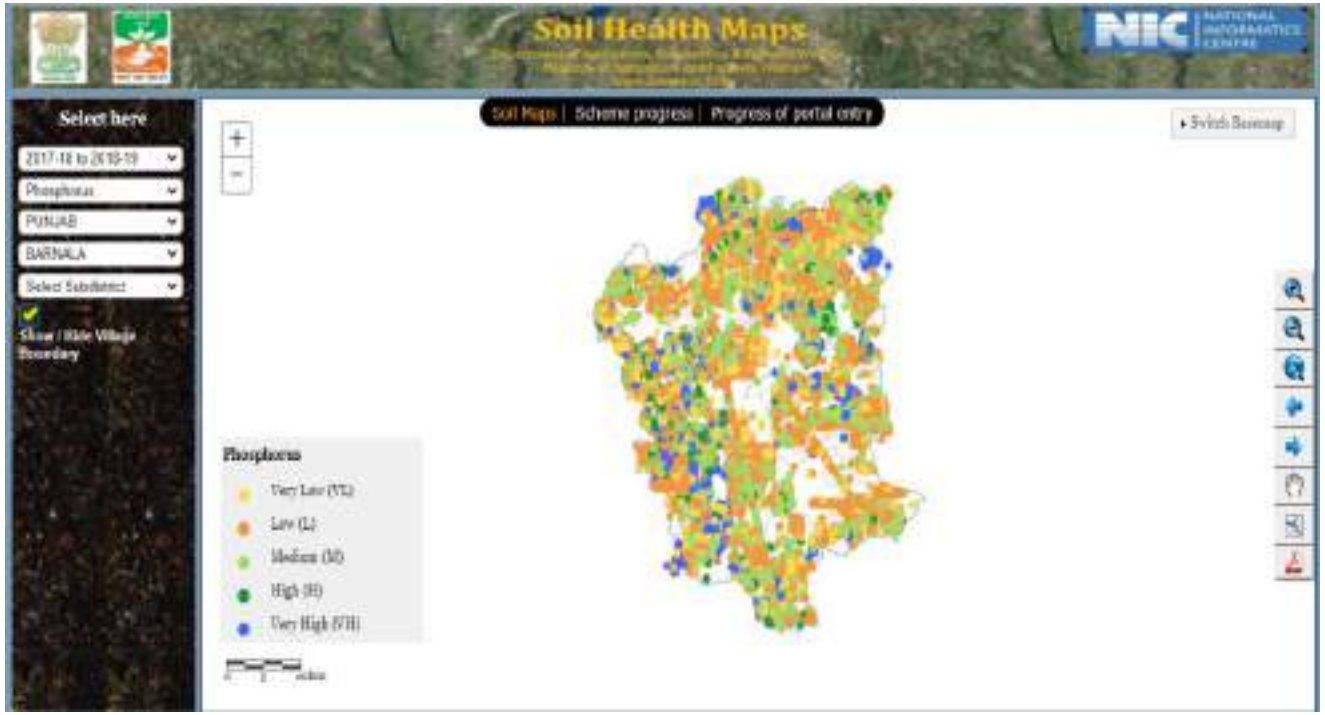
Soil Fertility

- Soil Health Card from(0-20 cm) https://soilhealth.dac.gov.in/soil-health-map/
- (12 parameters: N P K (Macro Nutrient), Zn, Fe, Cu, Mn, Bo (Micro nutrient), pH, EC and OC (physical parameters))
- Soil Grid data at 250 m resolution (six depth interval 0-200 cm) https://soilgrids.org/
- (11 parameters: BD, CEC, Vol fraction of Coarse fragmentation, Clay, N, pH, Sand, Silt, SOC, Org C density, Og C stock)

but this data is on global scale (derived using machine learning techniques and may not be applicable for precision agriculture

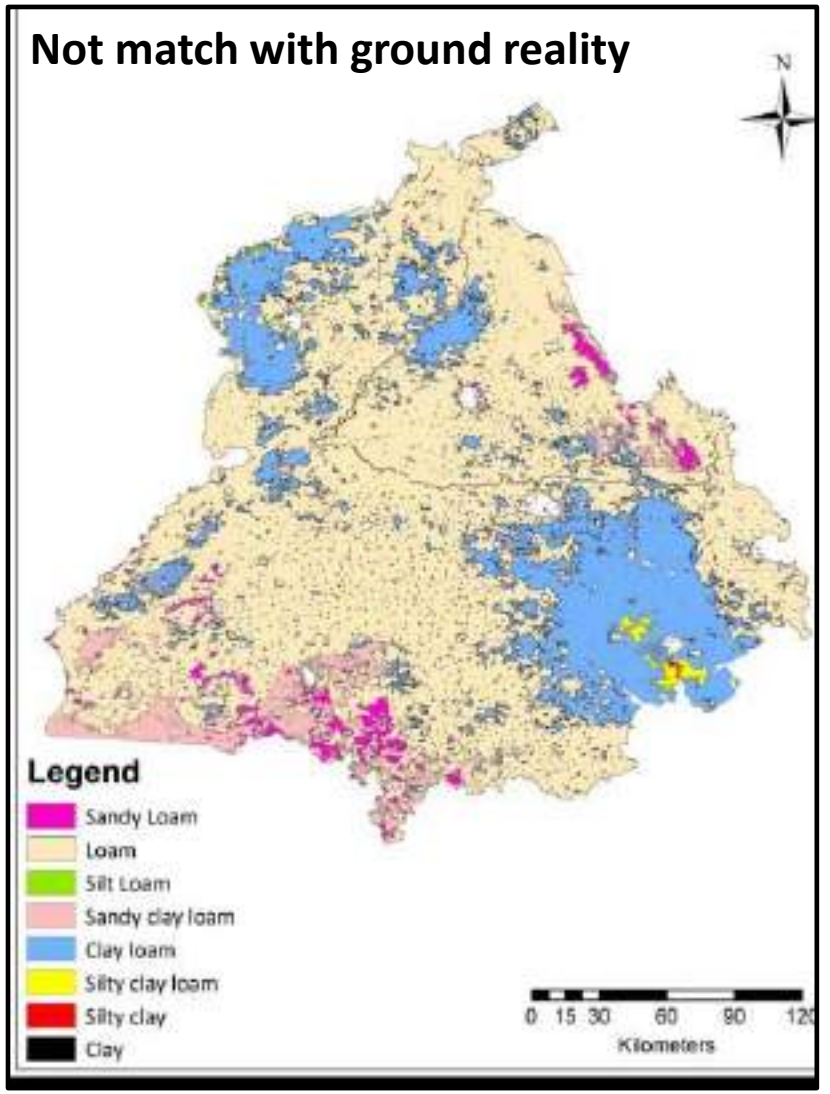
GIS based assessment of soil fertility

Point data of Soil Health Card available on the Dashboard developed by Ministry of Agriculture and Farmers Welfare, Govt of India



Source: Ministry of A&FW, Govt of India

Surface Soil texture: 250 m soil grid data



Spatial assessment of soil fertility

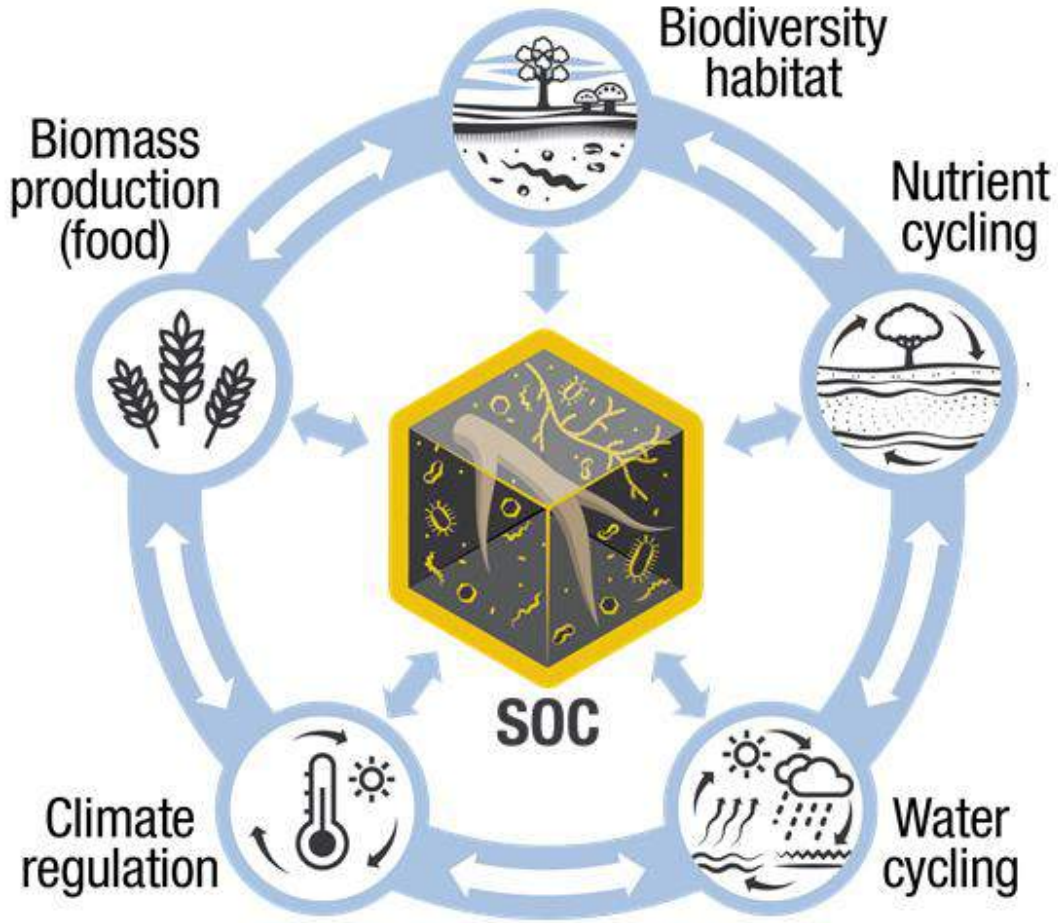
- Legacy soil fertility data is fragmented due to methods of sampling and analysis

- Most legacy data not geo-tagged, therefore not useful due to strong spatial structure of soil properties.

Current Requirement : Rapid assessment of soil properties on spatial and temporal scale

Soil Carbon Multifunctionality

Every year more than 10 million hectares of soil are being degraded due to soil C loss



Challenges:

Food, water, and biodiversity protection, under energy, climate change

Gaps:

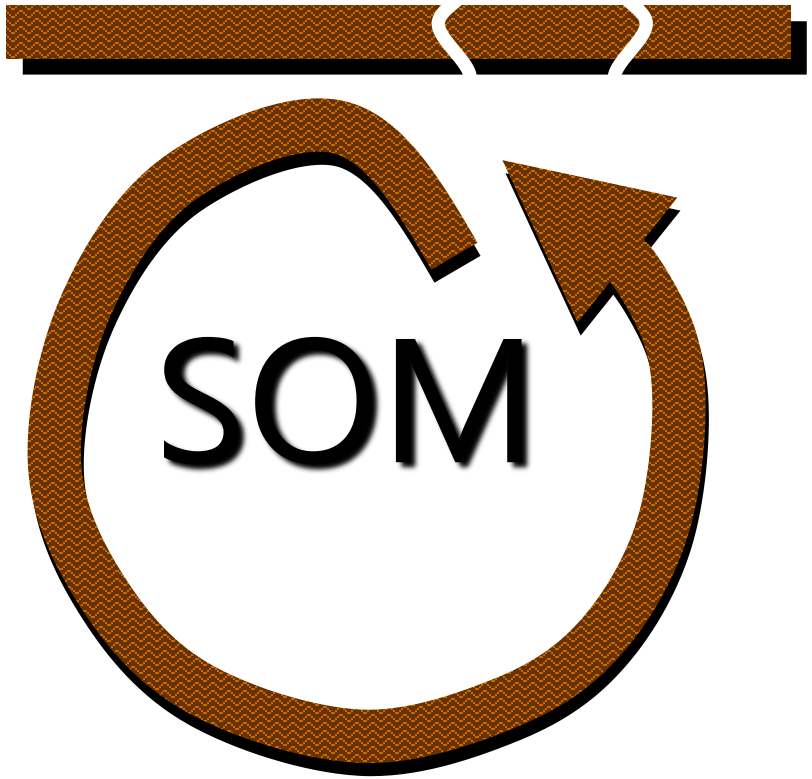
Current soil observations based on laboratory measurements are too expensive and cannot be extrapolated in both space and time.

Solutions:

A combination of remote and proximal infrared spectral data, AI & Machine Leaning with computational power for
A Soil Carbon Measurement and Monitoring System

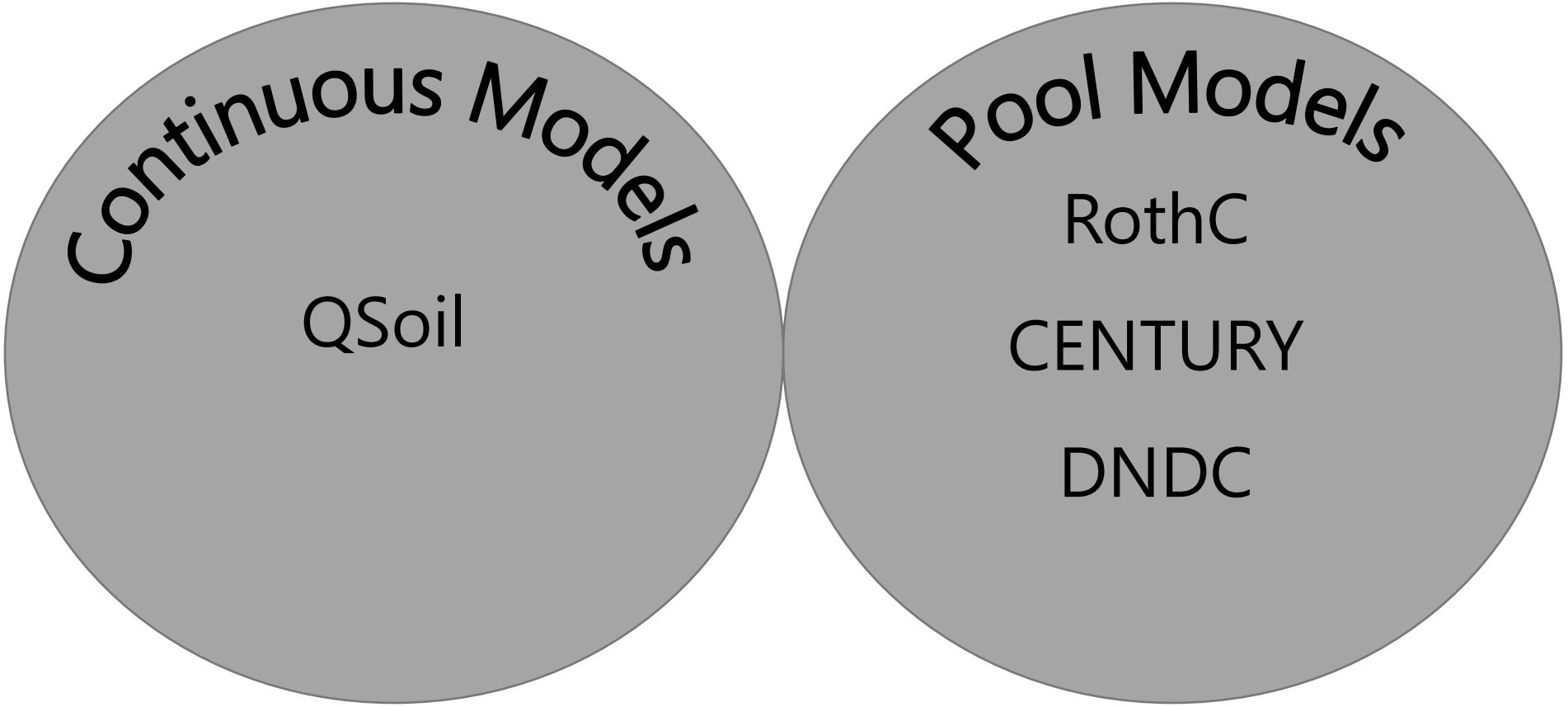
What do SOM models do?

CH_4 CO_2



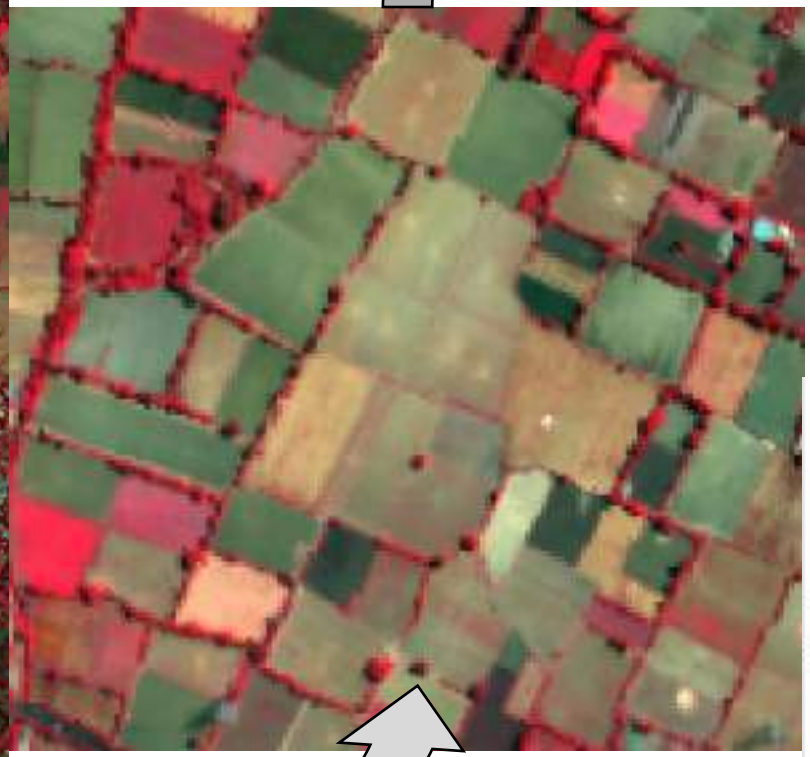
SOM models simulate
- -SOM turnover,
- -losses of CO_2,
- -losses of CH_4 and
- -change in C stocks

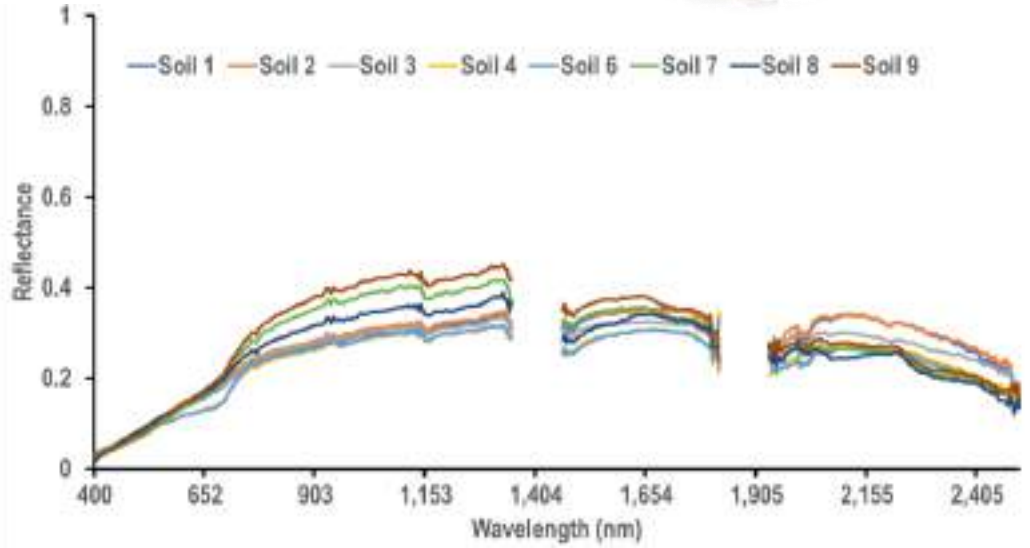
How do SOM models work?



Spectral characterization

ISRO-NASA AVIRIS-NG Science Mission





Estimation of soil organic carbon from spectra

Landsat 8 | RS-1 & 2 | Sentinel-2

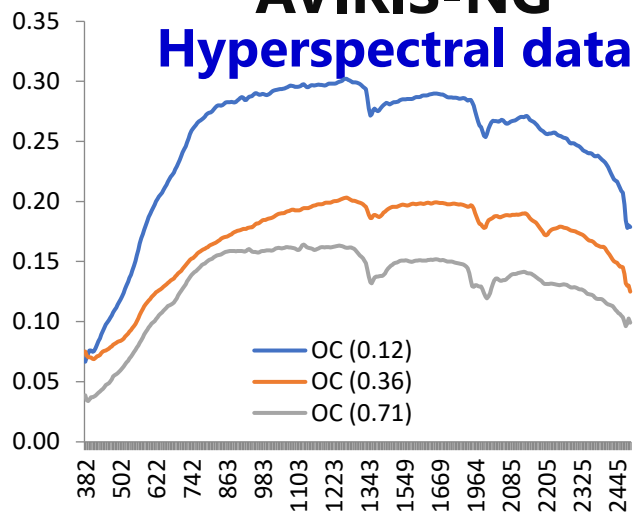
Multispectral data

Spectral Indices/Bands

No significant relationship among different indices and soil properties

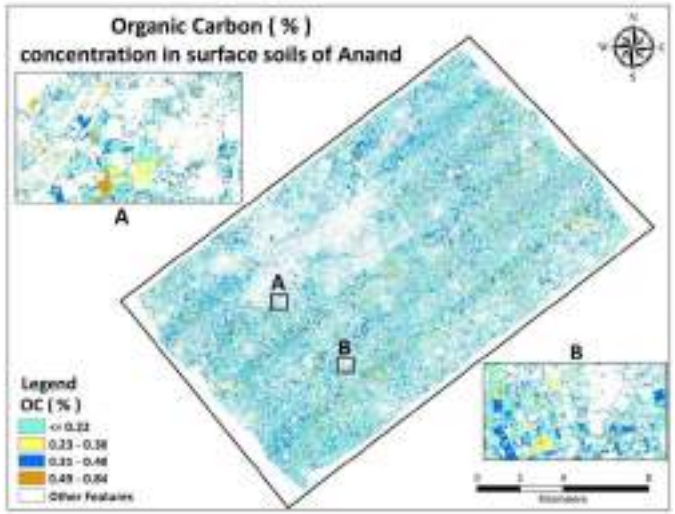
Spectral Indices
Transformed Soil Adjusted Vegetation Index (TSAVI)
Green Optimized Soil Adjusted Vegetation Index (GOSAVI)
Normalized Difference Soil Index (NDSI)
Soil Index (SI)
Soil Conditioning Index (SCI)
Coloration Index
Hue Index
Saturation Index
Redness Index
Brightness Index
Bare soil Index (BI)

AVIRIS-NG
Hyperspectral data

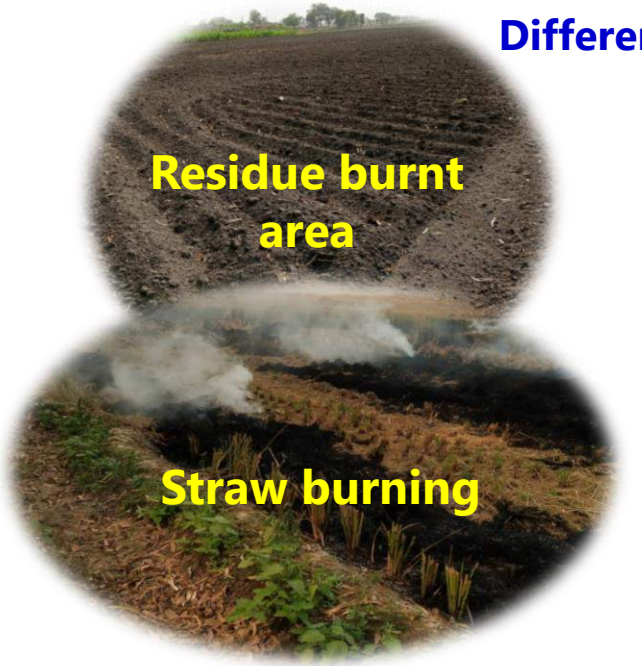


R^2=0.86

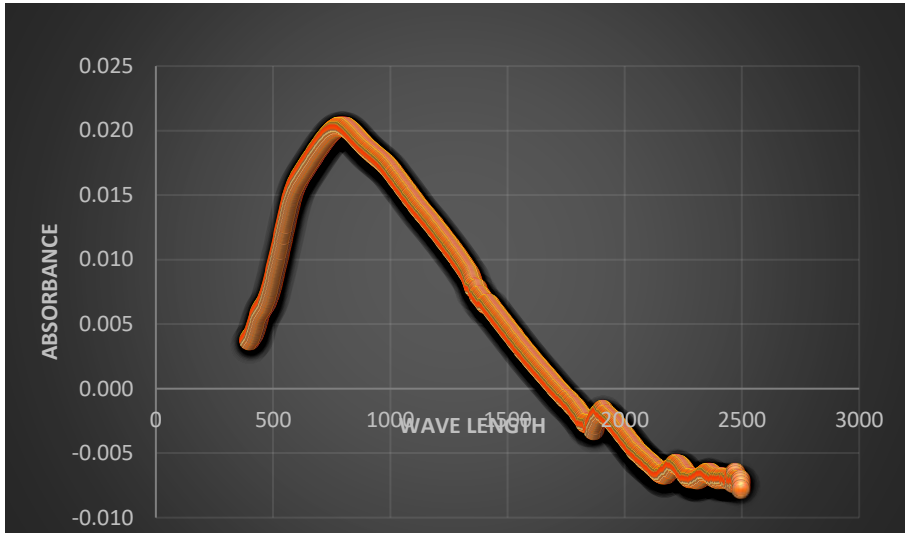
Important Wavelengths (nm):
526 - 567
1032- 1443
1700-2010
2069 - 2184
2234 - 2485
2139 - 2204



Estimation of soil organic carbon in crop residue burnt areas using hyperspectral data

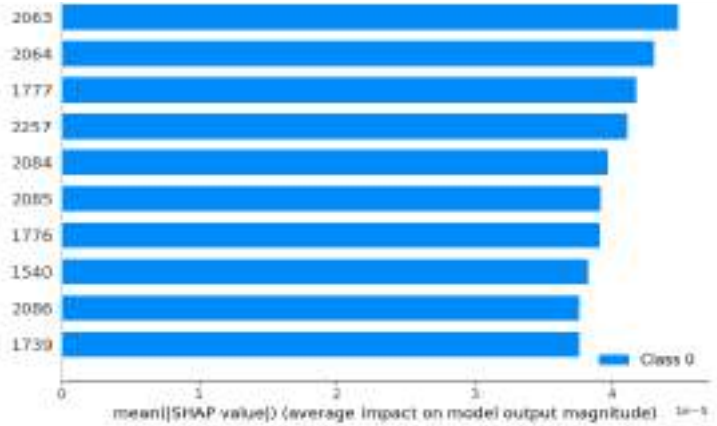


Difference in spectra of residue burning and non-burning sites

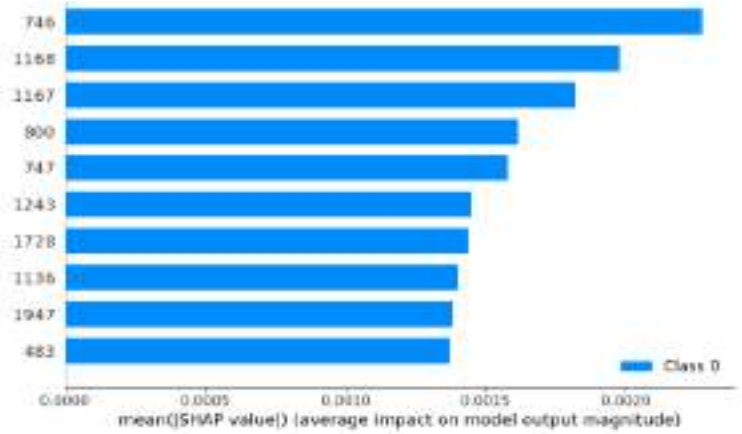


Study area : Ludhiana (Punjab state)

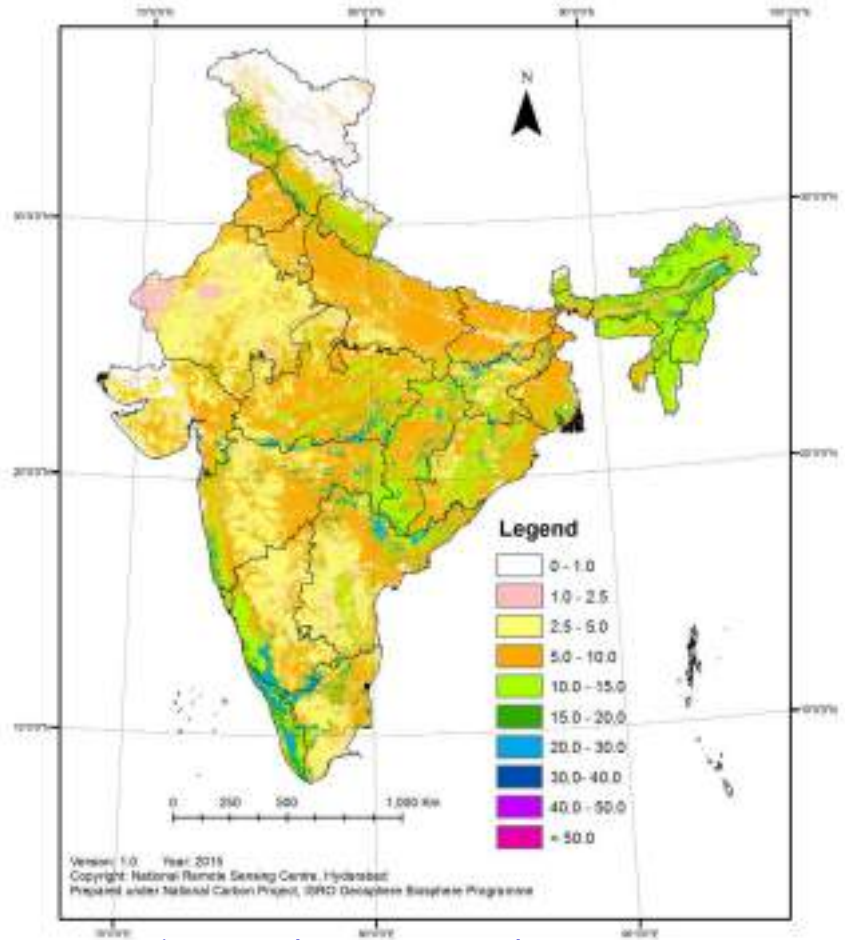
Wavelengths for estimating OC in residue burning fields



Wavelengths for estimating OC in non-residue burning fields)



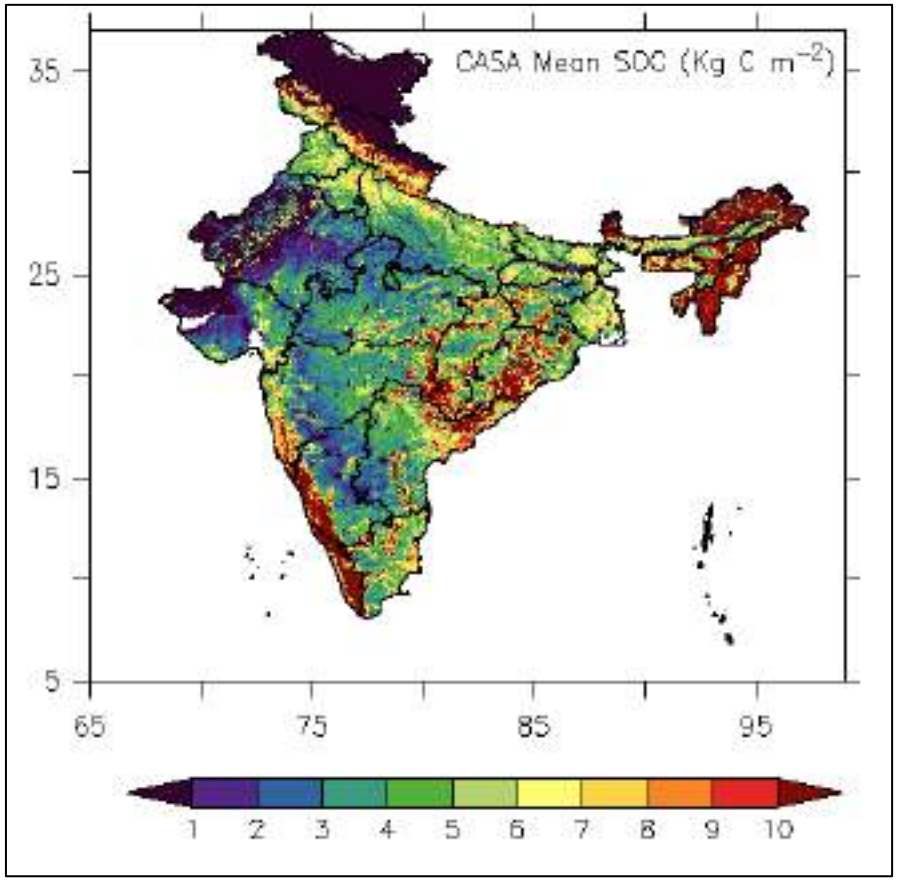
Soil organic carbon density (kg m^{-2}) of India



Source: Sreenivas et al. (2016) Geoderma 269 160–173

(Based on measured SOC)

Soil organic carbon simulated by the CASA Terrestrial Ecosystem model during 2008-2012

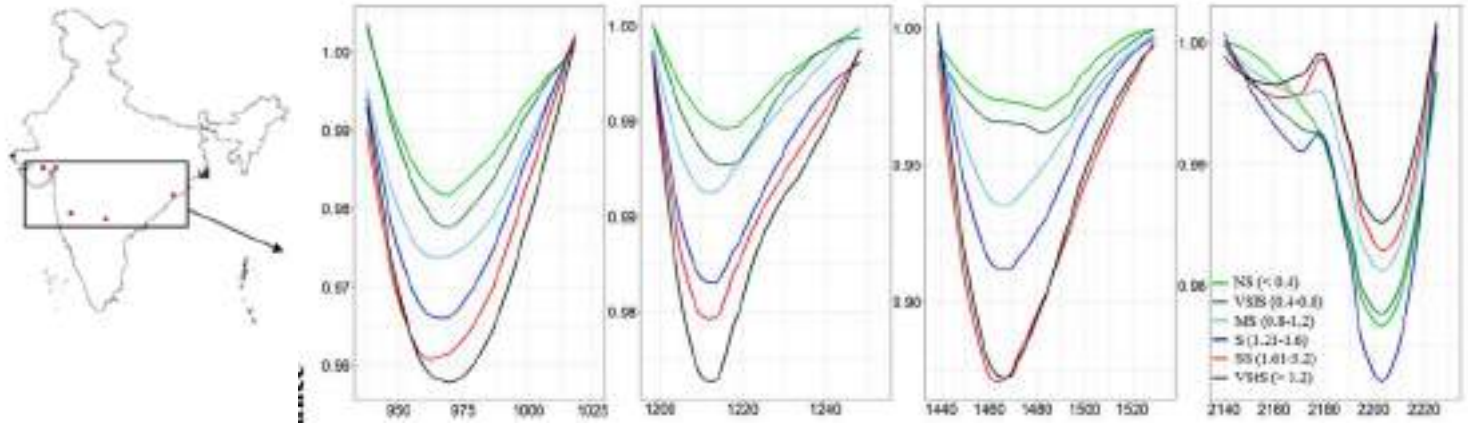


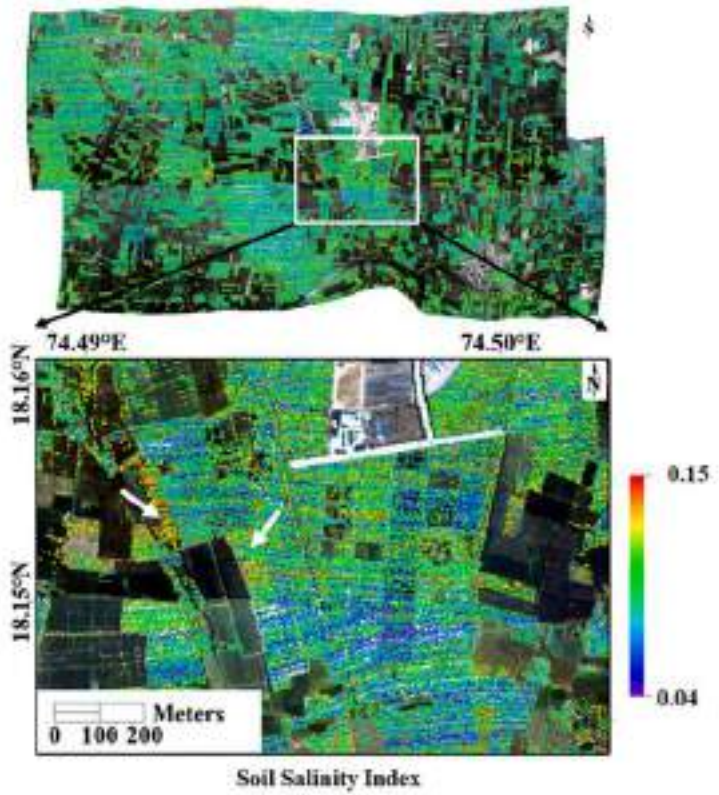
Source: Nayak et al. (2020): J Indian Soc Remote Sens 48, 553–561

(Based on Carnegie–Ames–Stanford Approach (CASA) model)

Soil Salinity Detection using Imaging Spectroscopy (AVIRIS_NG)

A new Salinity Index based on Information Theory





Salinity class	$EC_{1:2}$ (dSm^{-1})	HSSI
Non-saline	< 0.4	0–0.8
Very slightly saline	0.4–0.8	0.81–1.2
Moderately saline	0.8–1.2	1.21–1.5
Saline	1.21–1.6	1.51–1.8
Strongly saline	1.61–3.2	1.81 – 3
Very strongly saline	> 3.2	> 3

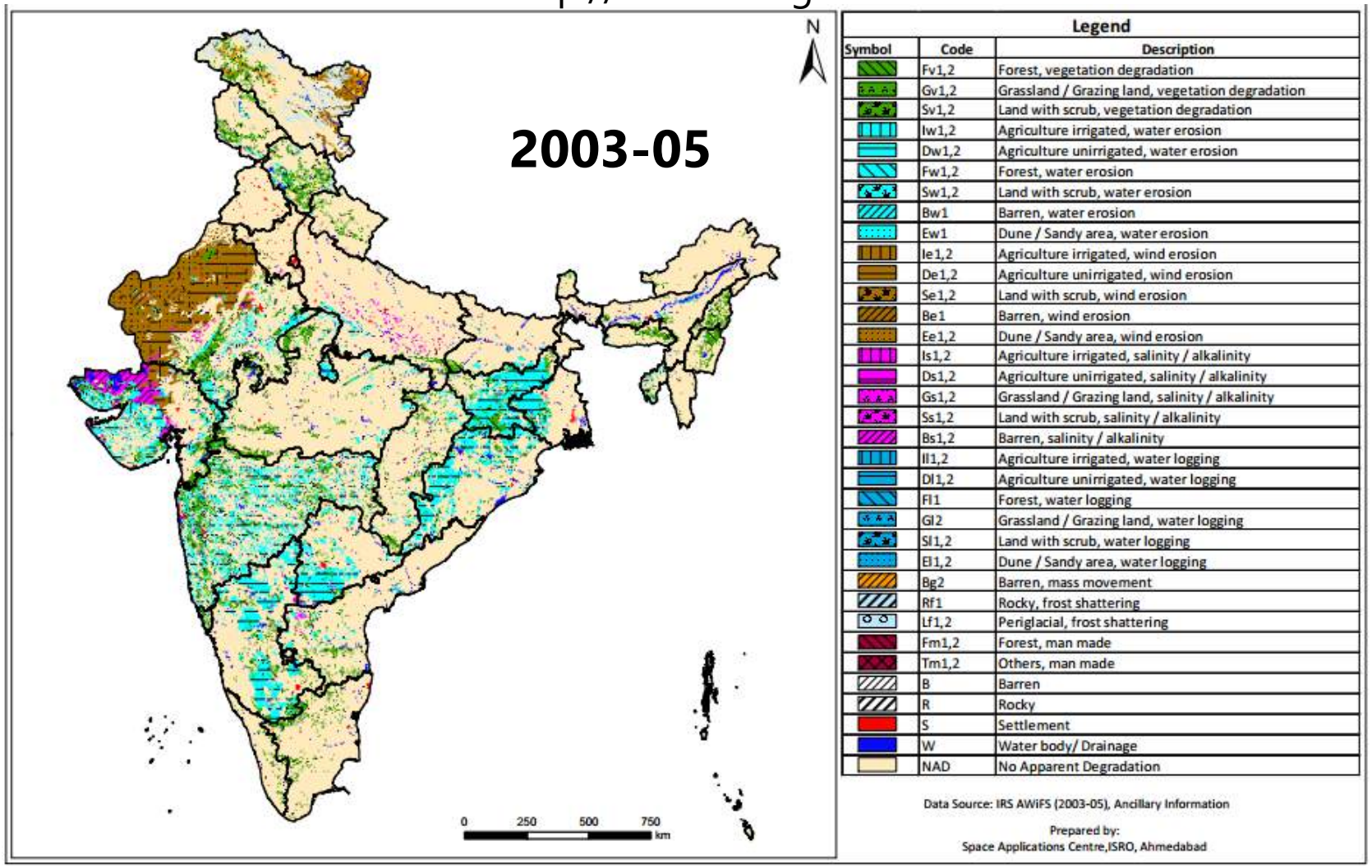
	HSSI1	HSSI2	SI	SI2	BI	NDSI	COSRI	SSI
EC	0.57	0.68	0.02	-0.06	-0.34	-0.1	0.16	0.21

Das et al., 2023

$$HSSI2 = W_{ANMB} * \frac{\sum_{i=937\,nm}^{1017\,nm} BD_i}{Max(BD_{1017\,nm})} + W_{BD1208} * \frac{BD_{1208nm}}{} + W_{BDR1478} * \frac{BD_{1478nm}}{Max(BD_{1533\,nm})} + W_{BNA2160} * \frac{BD_{2160nm}}{\sum_{i=2139\,nm}^{2230\,nm} BD_i}$$

Land degradation mapping using temporal multi-year multi-spectral IRS data

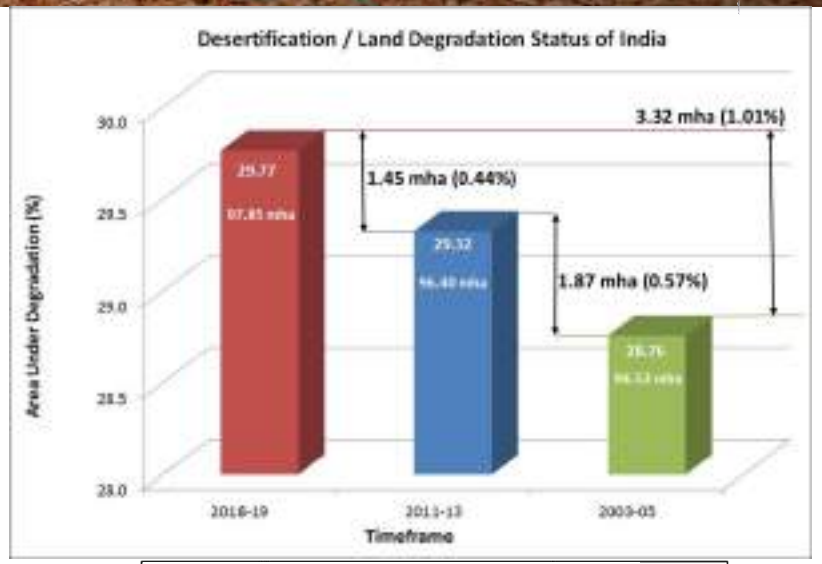
http://vedas.sac.gov.in

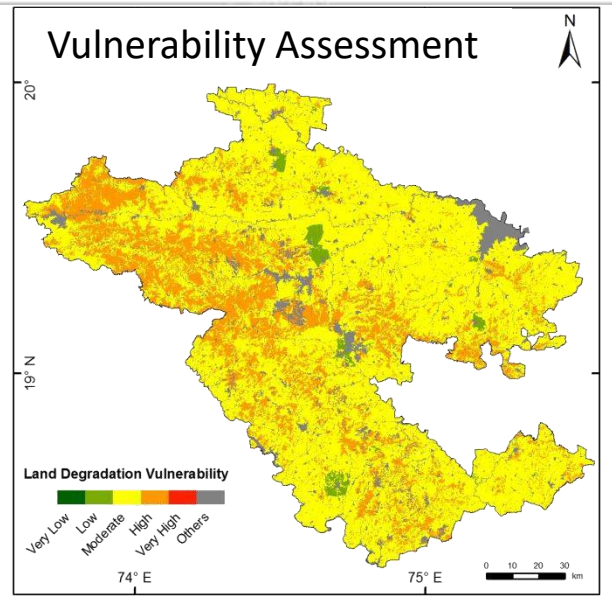


Legend		
Symbol	Code	Description
	Fv1,2	Forest, vegetation degradation
	Gv1,2	Grassland / Grazing land, vegetation degradation
	Sv1,2	Land with scrub, vegetation degradation
	Iw1,2	Agriculture irrigated, water erosion
	Dw1,2	Agriculture unirrigated, water erosion
	Fw1,2	Forest, water erosion
	Sw1,2	Land with scrub, water erosion
	Bw1	Barren, water erosion
	Ew1	Dune / Sandy area, water erosion
	Ie1,2	Agriculture irrigated, wind erosion
	De1,2	Agriculture unirrigated, wind erosion
	Se1,2	Land with scrub, wind erosion
	Be1	Barren, wind erosion
	Ee1,2	Dune / Sandy area, wind erosion
	Is1,2	Agriculture irrigated, salinity / alkalinity
	Ds1,2	Agriculture unirrigated, salinity / alkalinity
	Gs1,2	Grassland / Grazing land, salinity / alkalinity
	Ss1,2	Land with scrub, salinity / alkalinity
	Bs1,2	Barren, salinity / alkalinity
	Il1,2	Agriculture irrigated, water logging
	Dl1,2	Agriculture unirrigated, water logging
	Fl1	Forest, water logging
	Gl2	Grassland / Grazing land, water logging
	Sl1,2	Land with scrub, water logging
	El1,2	Dune / Sandy area, water logging
	Bg2	Barren, mass movement
	Rf1	Rocky, frost shattering
	Lf1,2	Periglacial, frost shattering
	Fm1,2	Forest, man made
	Tm1,2	Others, man made
	B	Barren
	R	Rocky
	S	Settlement
	W	Water body/ Drainage
	NAD	No Apparent Degradation

Data Source: IRS AWiFS (2003-05), Ancillary Information

Prepared by:
Space Applications Centre,ISRO, Ahmedabad



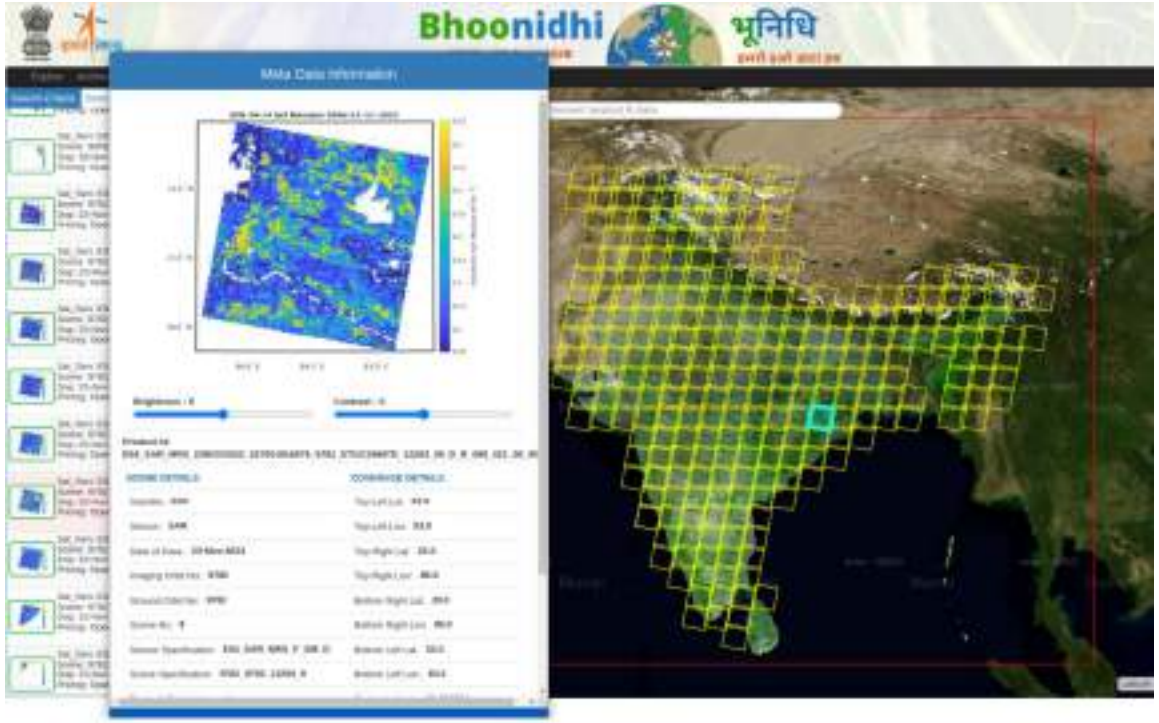


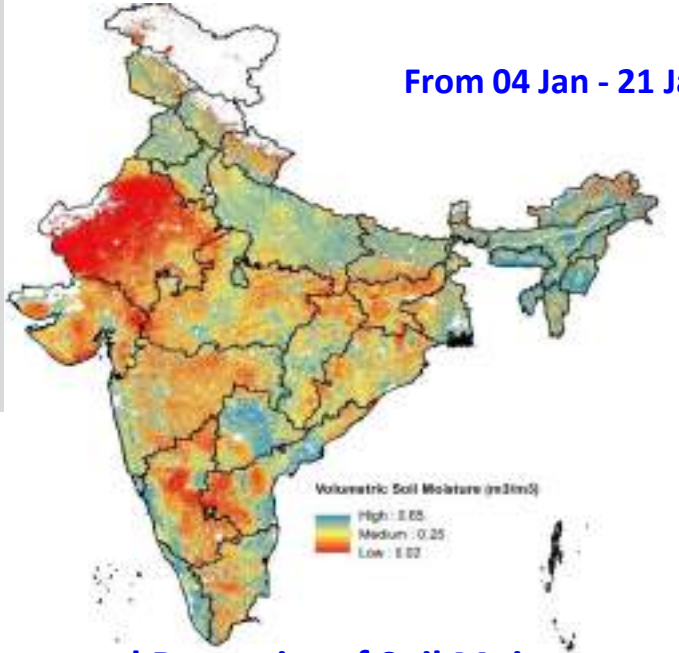
Statistics and charts of total area under desertification and process wise distribution of area undergoing desertification within different dryland regions

Process of Degradation	Area under Desertification (million ha)											
	2018-19				2011-13				2003-05			
	Arid	Semi-Arid	Sub-Humid	Total	Arid	Semi-Arid	Sub-Humid	Total	Arid	Semi-Arid	Sub-Humid	Total
Vegetation Degradation	2.87	13.69	6.84	23.39	2.86	13.48	6.65	22.99	2.81	13.39	6.34	22.55
Water Erosion	3.03	17.65	9.13	29.81	3.03	17.51	8.97	29.51	3.12	17.07	8.91	29.11
Wind Erosion	17.33	0.55	0.00	17.89	17.63	0.56	0.00	18.19	17.72	0.57	0.00	18.30
Salinity / Alkalinity	2.48	0.88	0.08	3.44	2.52	0.86	0.09	3.48	2.52	1.07	0.21	3.80
Water Logging	0.02	0.11	0.35	0.48	0.02	0.08	0.31	0.42	0.02	0.08	0.25	0.36
Mass Movement	0.85	0.12	-	0.97	0.84	0.11	-	0.96	0.76	0.11	-	0.87
Frost Shattering	3.05	0.47	0.01	3.53	2.94	0.46	0.01	3.41	2.74	0.43	0.01	3.18
Man Made	0.07	0.22	0.25	0.54	0.04	0.14	0.16	0.35	0.04	0.14	0.14	0.32
Barren	0.25	0.28	0.05	0.58	0.25	0.28	0.05	0.58	0.25	0.28	0.05	0.58
Rocky	0.30	0.96	0.02	1.27	0.30	0.97	0.02	1.29	0.29	0.97	0.02	1.28
Settlement	0.14	1.10	0.55	1.79	0.11	0.93	0.44	1.47	0.07	0.75	0.33	1.15
Grand Total	**30.40**	**36.02**	**17.28**	**83.69**	**30.54**	**35.40**	**16.70**	**82.64**	**30.35**	**34.85**	**16.28**	**81.48**

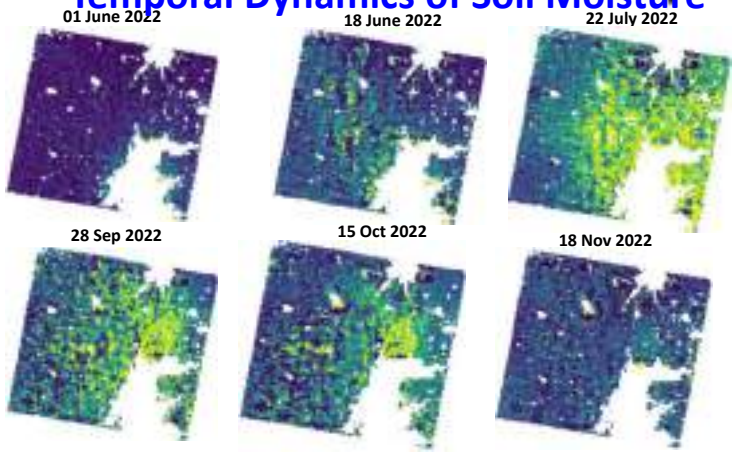
Moderate Resolution Operational Soil Moisture (500m) using EOS-04 (RISAT-1A) C-band SAR for Agricultural Applications

- ✓ SAC-ISRO developed ***Operational Algorithm and Software*** for generation of **High Resolution (500m) Soil Moisture Product,** using **EOS-04 (RISAT-1A) C-band SAR** data. Validated using in-situ field data carried out, and observed good agreement with **error of ubRMSE (<0.08 m^3/m^3)** over croplands under different crop conditions.
- ✓ **Operational 500m SM products** are already hosted over Bhoonidhi portal, NRSC for users/scientific communities (Min. of Agri. & FW as major user) with 17 days temporal frequency.
- ❑ In tandem with forthcoming **RISAT-1B (2024)**, operational soil moisture product will be available with effective **~9 days** temporal frequency.

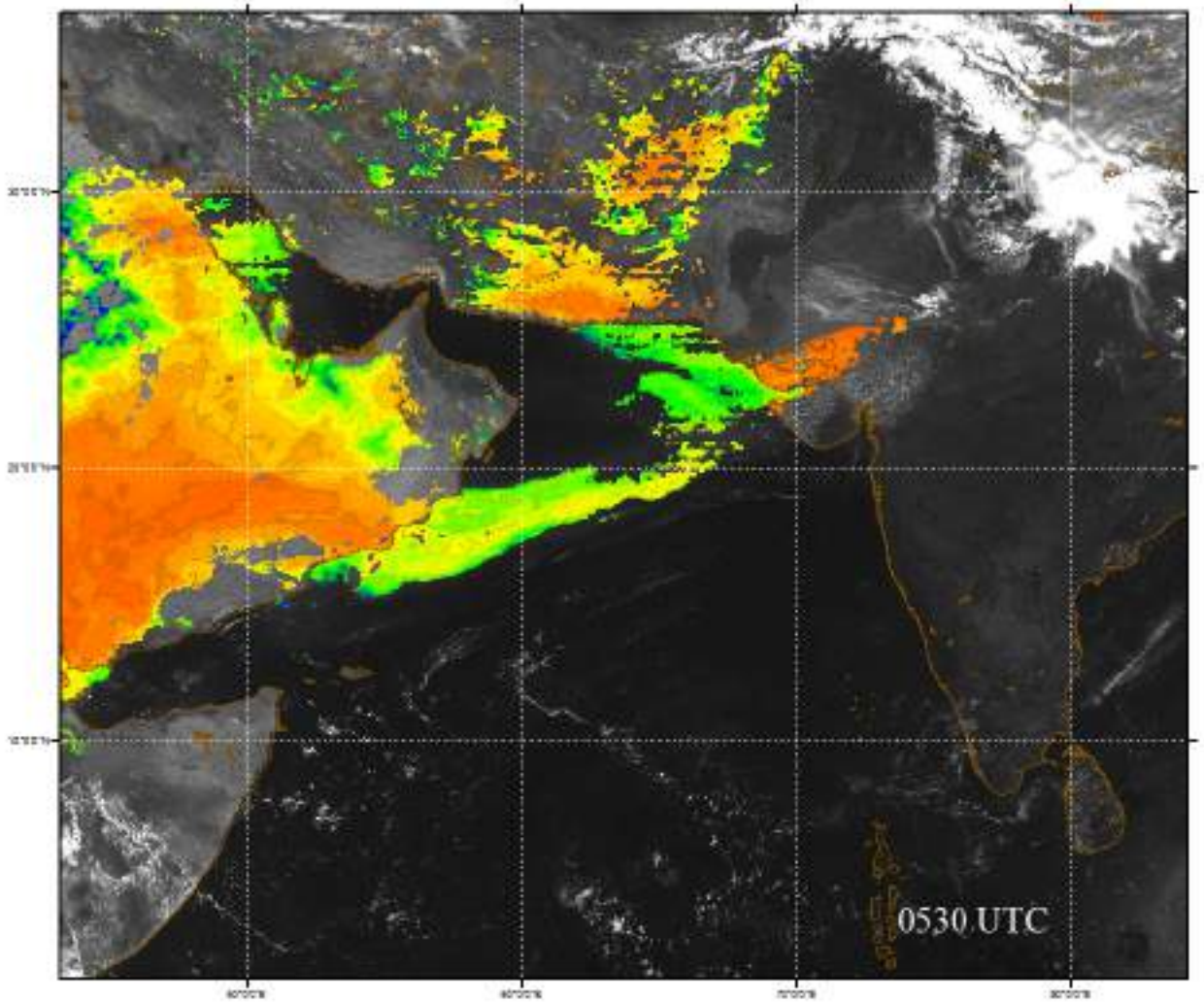




Temporal Dynamics of Soil Moisture

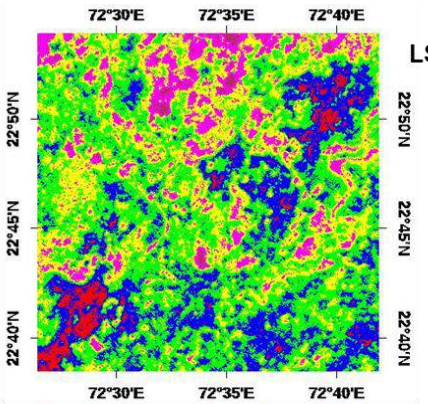


Dust Storm Detection from INSAT-3D



Marching towards farm scale water budget

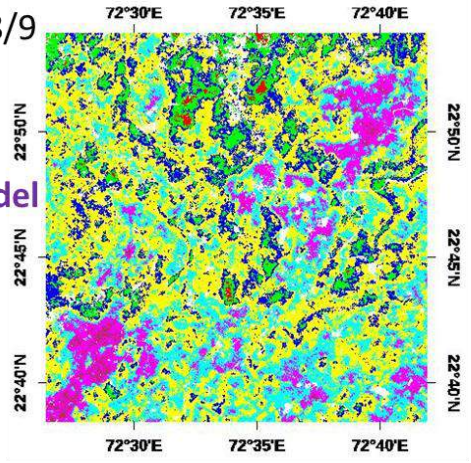
1st week of March

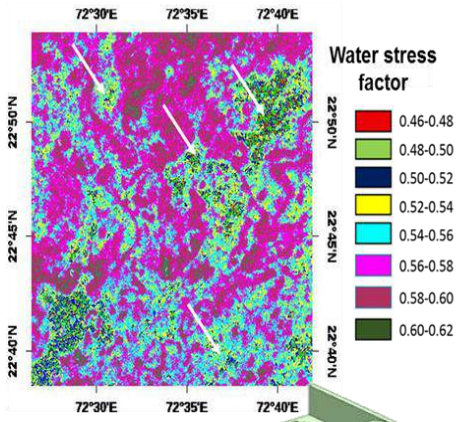


Spatial resolution 65m

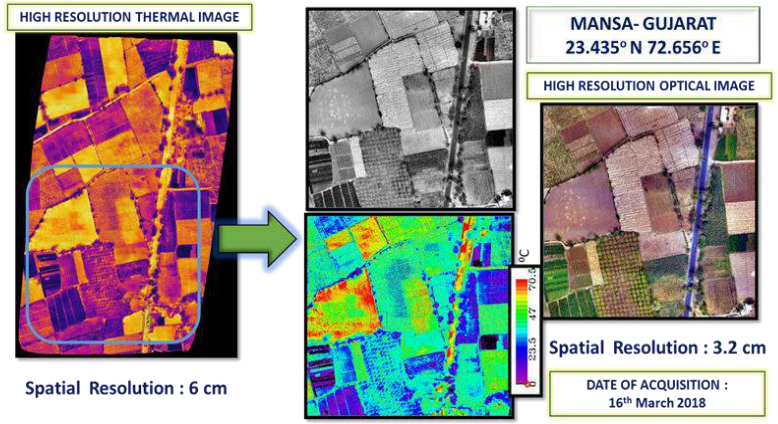
ECOSTRESS + Landsat 8/9

Surface Energy Balance (SEB) Model

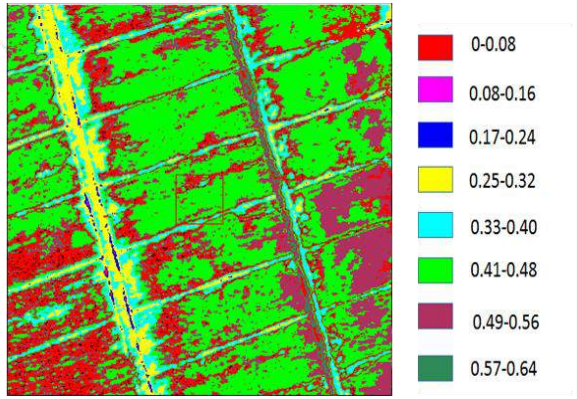


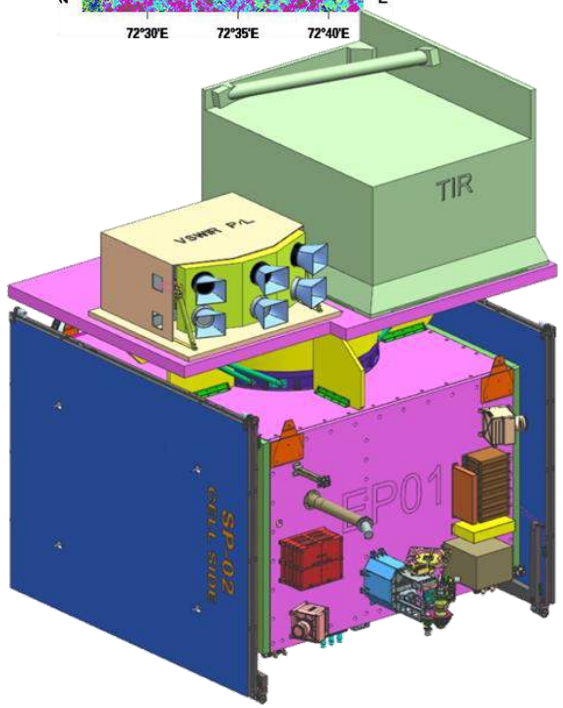


Drone thermal sensing



MOISTURE AVAILABILITY





ISRO-CNES

TRISHNA

57m, 3-day revisit,

11 bands

(7 optical + 4 TIR)

Way Forward

Potentials and challenges in Digital Soil Mapping:

- In India, huge legacy data is available, but harmonization of legacy data is required.
- Keeping in view of the current climate change scenario, digital soil mapping on 1:10,000 scale (Villages and watersheds) is required, but its success is a confluence of the following factors *(i) Availability of spatial data and covariates (including DEM) on 1;10000 scale (ii) Development of data-mining tools (including machine learning and AI) and GIS (iii) Geo-statistics (iv) Climate data*
- **Soil is a complex ecological system.** Hyperspectral imagery for DSM.
- Thermal Infrared data can potentially be used for DSM of **soil inorganic carbon or metal stresses**.

What is Next in Digital Soil Mapping?

- **Need for Dynamicity in DSM**: Introducing hyper-temporal remote sensing so the digital soil modelling can shift towards digital soil monitoring.
- Fusion of state-of-the-art process based models with traditional DSM for modelling of plant-soil nutrient feedback on spatio-temporal scale
- Linkage between soil contamination and plant accumulation and transfer to food chain.
- There is a need for DSM of soil physical-chemical or biological functions in holistic manner, in place of individual soil constituents for addressing the ecosystem services.
- Impact of climate change on soil carbon stocks and fractions for carbon sequestration & studies involving changes in soil GHGs (CO_2 or CH_4) emissions due to Land Use changes.

Thank You !!

ESA Symposium on Earth Observation for Soil Protection and Restoration