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Investigation of spectral indices for mapping soil sodicity using Sentinel-2 multispectral satellite images

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ABSTRACT

Considerable area under saline/ sodic soils has been reported in Sharda Sahayak Canal Command of Uttar Pradesh. These areas need to be regularly monitored for planning and development purpose for which accurate mapping is essential. Sentinel-2 remote sensing data has potential of mapping salt-affected soils because of its high spatial and spectral resolution. In the present study, various spectral indices based on combinations of Sentinel-2 bands were investigated for mapping sodicity levels in Amethi and Pratapgarh districts. Salinity index-1 and salinity index-8 were found to have good correlations with soil parameters. Another important index, which can be used for mapping sodicity level, is the brightness index. Hence, salinity indices may be used for mapping sodicity in Sharda Sahayak Canal Command.

Keywords: Mapping, Salinity, sodicity, spectral indices, Sentinel-2

INTRODUCTION

There were many attempts to use the remote sensing data and its techniques to detect the salt affected soils (SAS). Soil salinity indices are principally adjusted to detect salt minerals in soils based on the different responses of salty soils to various spectral bands. A number of derivatives and alternatives to normalised difference vegetation index (NDVI) have been anticipated to discourse soils salinization monitoring and mapping (Montandon and Small, 2008). Different remote sensing indices such as salinity index (SI), brightness index (BI) and normalised difference salinity index (NDSI) in addition to normalised difference vegetation index (NDVI) were employed to investigate the means by which these indices work for soil salinity mapping in arid environment (Douaoui *et al*., 2006).

The salinity index (SI) which combines the blue and red bands is sensitive to the surface reflectance of salt-affected lands with sparse vegetation (Jiapaer *et al*., 2011). Elhag (2016) implemented and evaluated several soil salinity indices to detect soil salinity effectively and quantitatively. Out of 11 salinity indices, SI-3, SI-9 and brightness index were found to have significantly correlated with soil salinity parameters like pH, EC, etc. Zhang *et al*. (2015) used different bands of OLI-8 to develop a soil salinity detection algorithm based on Soil Salinity Information Extraction.

Remote sensing methods are faster, more effective and can cover large areas. They are increasingly used in studies and mapping soil properties (Mulder *et al*., 2011; Savin *et al*., 2019). Various spectral indices (salinity, vegetation and brightness indices) based on combination of remote sensing satellite bands are widely developed and applied (Table 1). This is facilitated by the improvement satellite image quality (spatial resolution) short imagery interval, free access to space images (Metternichet and Zinck, 2003; Allbed and Kumar, 2013). Regression analysis of soil salinity data and spectral indices make it possible to assess the degree of salinity and mapping saline soils (Allbed *et al*., 2014; Wu *et al*., 2014; Taghdosi *et al*., 2019).

Suleymanov *et al*. (2021) analysed relationships between the level of soil salinity and 15 spectral indices based on Sentinel-2A satellite imagery. Salinity index III = (G x R)/ B using quadratic

Table 1. Calculated spectral indices for soil salinity mapping

Acronym	Spectral index	Formula	Equation for sentinel 2	Source
SI 1	Salinity Index 1	$\sqrt{B \times R}$	$\sqrt{B2 \times B4}$	Khan et al. 2005
SI 2	Salinity Index 2	$\sqrt{G \times R}$	$\sqrt{B3 \times B4}$	Khan et al. 2005
SI 3	Salinity Index 3	$\sqrt{G^2 \times R^2 + NIR^2}$	$\sqrt{(B3)^2 + (B4)^2 + (B8)^2}$	Douaoui et al.2006
SI 4	Salinity Index 4	$\sqrt{G^2 \times R}^2$	$\sqrt{(B3)^2 + (B4)^2}$	Douaoui et al.2006
BI	Brightness Index	$\sqrt{R^2 + NIR^2}$	$\sqrt{(B4)^2 + (B8)^2}$	Khan et al. 2005
S I	Salinity Index I	$\frac{B}{R}$	$\frac{B2}{B4}$	Abbas and Khan 2007 Abbas et al. 2013
S II	Salinity Index II	$\frac{B-R}{B+R}$	$\frac{B2-B4}{B2+B4}$	Abbas and Khan 2007 Abbas et al. 2013
SIII	Salinity Index III	$\frac{G \times R}{B}$	$\frac{B3 \times B4}{B2}$	Abbas and Khan 2007 Abbas et al. 2013
S IV	Salinity Index IV	$\frac{B \times R}{G}$	$\frac{B2 \times B4}{B3}$	Abbas and Khan 2007
S V	Salinity Index V	$\frac{R \times NIR}{G}$	$\frac{B4 \times B8}{B3}$	Abbas and Khan 2007
S VI	Salinity Index VI	$\frac{G + R + NIR}{2}$	$\frac{B3 + B4 + B8}{2}$	Douaoui et al.2006
S VII	Salinity Index VII	$\frac{G + R}{2}$	$\frac{B3 + B4}{2}$	Douaoui et al.2006
S VIII	Salinity Index VIII	$\frac{SWIR1 - SWIR2}{SWIR1 + SWIR2}$	$\frac{B11 - B12}{B11 + B12}$	Bouaziz et al. 2011
S IX	Salinity Index IX	$\frac{SWIR1}{SWIR2}$	$\frac{B11}{B12}$	Bouaziz et al. 2011
NDVI	Normalized difference vegetation index	$\frac{NIIR - R}{NIIR + R}$	$\frac{B8 - B4}{B8 + B4}$	Rouse et al. 1973
NDSI	Normalized difference salinity index	$\frac{R - NIIR}{R + NIIR}$	$\frac{B4 - B8}{B4 + B8}$	Khan et al. 2005

B, G, R, NIR, SWIR- blue, green, red, near infrared, shortwave infrared bands, respectively statistical relation showed the best correlation values with salinity level (R =0.89, R^2 =0.79). In general, they found that highest correlation values were observed with indices based on three visible bands (B, G, R).

MATERIALS AND METHODS

Sentinel-2A/2B multispectral satellite images (spatial resolution: 10-60m) for the periods Nov. 2022 and May 2023) were downloaded and pre-processed in an open source software QGIS. Different spectral indices were generated using Sentinel-2 bands mainly B1- blue, B2- green, B4- red and B8- NIR. GPS points of soil samples collected from two districts, Amethi and Pratapgarh were overlaid on raster maps of spectral indices (SI1, SI3, SI5, SI7 & SI8) to extract the spectral values corresponding to these points.

RESULTS AND DISCUSSION

Correlation analysis between soil parameters (pH, EC, OC, Na, K, pHe, ECe, ESP and CEC) and spectral indices (SI1, SI3, SI5, SI7 and SI8). Salinity index-8 was found to have good correlations with soil pH, pHe and ECe (R>0.5) for Amethi district. Salinity indices were both poorly and negatively correlated with EC and OC. Other parameters did not demonstrated good correlation with spectral indices (Table 2). In case of Pratapgarh district, pH and ESP have very good correlation with SI1. Salinity index-5 was found to have very good correlated with ESP of soil samples (R= 0.69). Soil parameters like EC, OC, ECe and CEC were poorly correlated with salinity indices (Table 3). LULC statistics in Sharda Canal Command of Amethi and Pratapgarh district were obtained by image classification methods (Table 4, 5).

Table 2. Correlations between soil parameters and spectral indices (Amethi)

	SI1	SI3	SI5	SI7	SI8
pH	0.422	0.091	0.058	0.275	0.521
EC	-0.211	-0.345	-0.399	-0.226	-0.114
OC	0.066	-0.149	-0.134	-0.016	0.182
Na	0.372	0.180	0.168	0.196	0.370
K	-0.388	-0.432	-0.507	-0.337	-0.283
pH_e	0.628	0.321	0.309	0.431	0.664
EC_e	0.537	0.318	0.284	0.387	0.565

Number of observations: 12

Table 3. Correlations between soil parameters and spectral indices (Pratapgarh)

	SI1	SI3	SI5	SI7	SI8
pH	0.510	0.434	0.433	0.495	0.413
EC	0.387	0.377	0.398	0.368	0.299
OC	-0.188	-0.083	-0.11	-0.208	-0.076
Na	0.525	0.511	0.543	0.511	0.442
K	0.525	0.511	0.543	0.511	0.442
pHe	0.476	0.425	0.427	0.440	0.429
ECe	0.370	0.336	0.366	0.342	0.323
CEC	-0.301	-0.428	-0.444	-0.266	-0.308
ESP	0.672	0.647	0.691	0.676	0.600

Number of observations: 15

Table 4. LULC statistics in Sharda Canal Command of Amethi district (May 2022)

Class#	LULC Class	Area (m^2)	Area (ha)	Area (%)
1	Sodic soils	151310100	15131.01	5.50
2	Water/ water bodies	40009900	4000.99	1.45
3	Builtups/ sandy areas	683797400	68379.74	24.85
4	Vegetation/ plantation	1030998700	103099.87	37.47
5	Bareland / fallow land	844528600	84452.86	30.69
	Total	2750644700	275064.47	

Table 5. LULC statistics in Sharda Canal Command of Pratapgarh (May 2022)

Class#	LULC Class	Area (m^2)	Area (ha)	Area (%)
1	Sodic soils	3865700	386.57	0.10
2	Water/water bodies	17161800	1716.18	0.46
3	Builtups/sandy areas	1295752000	129575.2	34.92
4	Vegetation/plantations	700008100	70000.81	18.87
5	Bareland/fallowland	1693753500	169375.35	45.65
			371054.11	

Spectral indices including salinity indices, Normalised Difference Salinity Index (NDSI) and NDVI were applied to map salinity levels by the researchers. Out of these indices, Normalised Difference Vegetation Index (NDVI) failed to map salinity level, reason being this index is mainly used for differentiation of vegetation. Very few studies found NDSI to be suitable index for mapping of salinity levels (Douaoui *et al*., 2006; Sahana *et al*., 2021).

Although, salinity indices were found good but not all indices except SI1, SI9 and brightness index. The present study also supplements results of other studies and concludes that SI1 and SI8 were found suitable for mapping sodicity levels in the studied districts. (Figure 1, 2 & 3).

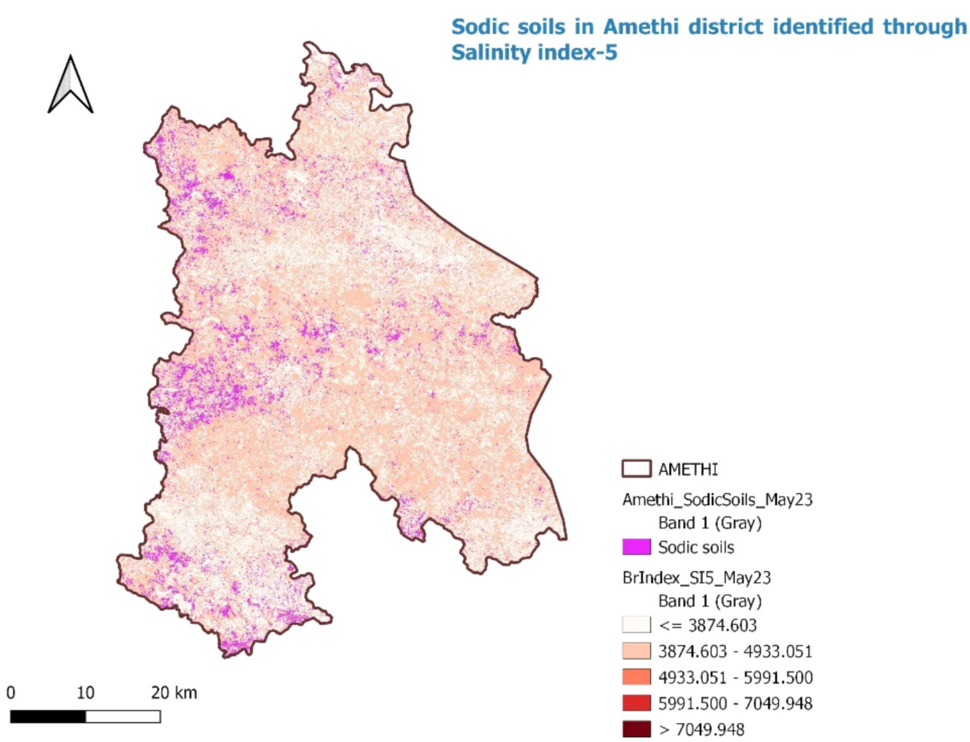

Fig. 1. Identification of sodic soils by brightness index in Amethi district

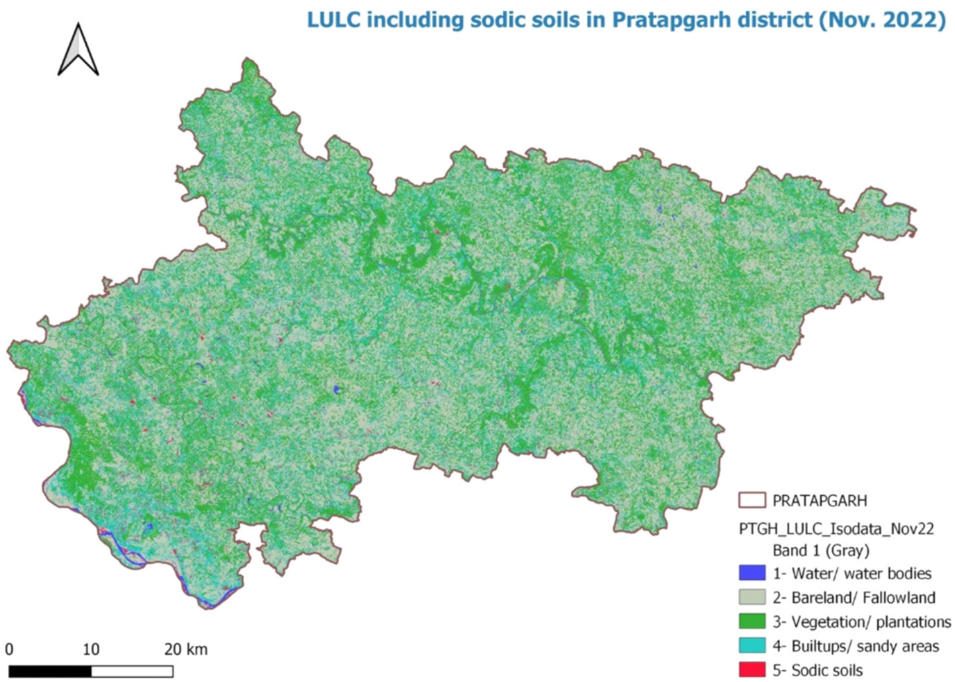

Fig. 2. Land use-land cover (LULC) of Pratapgarh district showing sodic soils in red colour

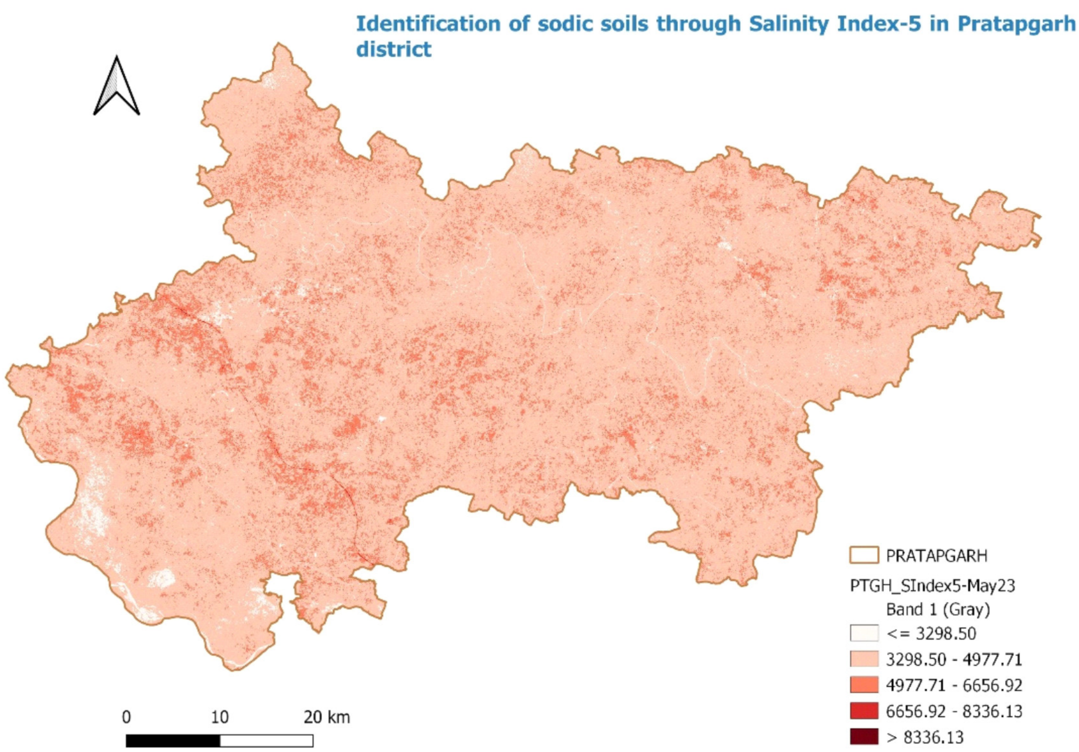

Fig. 3. Identification of sodic soils by salinity index-5 in Pratapgarh district

CONCLUSIONS

Sentinel-2 remote sensing data has shown potential of mapping salt-affected soils especially sodic soils in Sharda Sahayak Canal Command. Due to wide spectral resolution from VIS to NIR to SWIR, these data will be used for identification of various types of soils: saline or sodic. Salinity indices developed earlier by researchers were investigated to demonstrate their usefulness in identification of sodic soils. The encouraging results were obtained in case of Amethi and Pratapgarh districts of Uttar Pradesh. These results need to be further validated by adding more number of soil samples/ points.

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REFERENCES

Allbed, A. and Kumar, L. (2013). Soil salinity mapping and monitoring in arid and semi-arid regions using remote sensing technology: a review. *Advanced Remote Sensing*, 2(4), 373-385.

Allbed, A., Kumar, L. and Aldakheel, Y.Y. (2014). Assessing soil salinity using soil salinity and vegetation indices derived from IKONOS high spatial resolution imageries: Application in date palm dominated region. *Geoderma*, 230(231), 1-8.

Douaoui, A.E.K., Nicholas, H. and Walter, C. (2006). Detecting salinity hazards within semi-arid context by means of combining soil and remote sensing data. *Geoderma*, 134(1-2), 217-230.

Elhag, M. (2016). Evaluation of different soil salinity mapping using remote sensing techniques in arid ecosystems, Saudi Arabia. *Journal of Sensors*, DOI: 10.1155/2016/7596175.

Jiapaer, G., Chen, X. and Bao, A.M. (2011). A comparison of methods for estimating fractional vegetation cover in arid regions. *Agriculture and Forest Meteorology*, 15(12), 1698-1710.

Metternicht, G.I. and Zinck, J.A. (2003). Remote sensing of soil salinity: potential and constraints. *Remote Sensing of Environment*, 85, 1-20.

Montandon, L.M. and Small, E.E. (2008). The impact of soil reflectance on the quantification of the green vegetation fraction from NDVI. *Remote Sensing of Environment*, 112(4), 1835-1845.

Mulder, V.L., De Bruin, S., Schaepman, M.E. and Mayr, T.R. (2011). The use of remote sensing in soil and terrain mapping – A review. *Geoderma*, 162, 1-19.

Rizvi, R.H., Arora, S., Verma, C.L., Dubey, A.K. and Yadav, R.K. (2024). Spatial and temporal analysis of sodic soils in Sharda Sahayak Canal Command of Amethi district using Sentinel-2A/2B MSI data. *J. Soil Salinity & Water Quality*, 16(1), 48-55.

Sahana, M., Rehman, S., Patel, P.P., Dou, J., Hong, H. and Sajjad, H. (2021). Assessing the degree of soil salinity in the Indian Sunderban Biosphere Reserve using measured soil electric conductivity and remote sensing data driven salinity indices. *Arabian Journal of Geosciences*, 13, 1289.

Suleymanov, A., Gabbasova, I., Abakumov, E. and Kostecki, J. (2021). Soil salinity assessment from satellite data in the Trans-Ural steppe zone (Southern Ural, Russia). *Soil Science Annual*, 72(1), 132233. doi: 10.37501/soilsa/132233.

Taghadosi, M.M., Hassanlou, M. and Eftekhari, K. (2019). Retrieval of soil salinity from Sentinel-2 multispectral imagery. *European Journal of Remote Sensing*, 52(1), 138-154.

Wu, W., Mhaimeed, A.S., Al-Shafie, W.M., Ziadat, F., Dhehibi, B., Nangia, V. and De Pauw, E. (2014). Mapping soil salinity changes using remote sensing in Central Iraq. *Geoderma Regional*, 2(3), 21-31.

Zhang, T., Zhao, G., Chang, C., et al. (2015). Information extraction method of soil salinity in typical areas of the yellow river delta based on Landsat imagery. *Agricultural Sciences*, 6(1), 71-77.