Optimization of spectral pre-processing techniques for estimation of surface soil properties from airborne AVIRIS-NG

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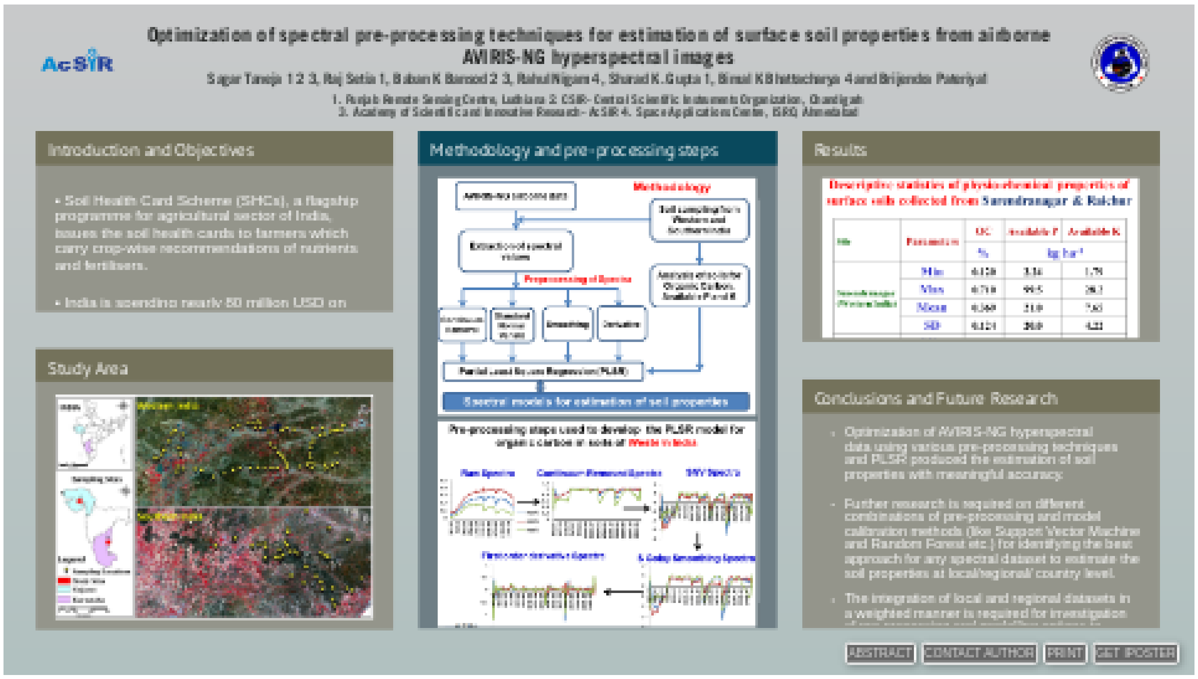
Abstract

Remote sensing approaches based on VIS-NIR spectroscopy can be used for getting near real-time information about soil fertility. However, the main challenge limiting the application of spectroscopy in soil fertility evaluation is finding suitable data pre-processing and calibration strategies. We have compared various pre-processing techniques using the reflectance spectra obtained from AVIRIS-NG hyperspectral images, for quantification of organic carbon (OC), available phosphorus (P) and available potassium (K) in the surface soils of Surendranagar area (Western parts of India) and Raichur (Southern parts of India). Surface (0 - 0.15 m) soil samples were collected from these two areas synchronously with the dates of the AVIRIS-NG campaign. The soil samples were air dried, sieved to <2 mm, and analyzed for OC, P, and K using standard methods. The AVIRIS spectra (spectral range of 380-2500 nm with an interval of 5 nm) corresponding to soil sampling points were extracted. The pre-processing steps were used in the order: Continuum Removal (Yes/No), Moving Window Abstraction (Yes/No), No transformation or Euclidean Normalization or Standard Normal Variate (SNV), No transformation or Savitsky-Golay (SG) first-order smoothing, and No transformation or first derivative OR second derivative. We have used the partial least squares regression (PLSR) to calibrate the model from pre-processed spectra. The PLSR with Continuum Removal, SNV, SG first-order smoothing, and first derivative was selected as the best algorithm for estimating soil properties from the Western parts of India, and the corresponding R2 were 0.77 for OC, 0.79 for P and 0.83 for K (RMSE <0.3 for all the parameters). The PLSR with Moving Window Abstraction, SG first-order smoothing, and second derivative were selected as the best algorithm for estimating soil properties from the Southern parts of India, and the corresponding R2 were 0.54 for OC, 0.49 for P and 0.56 for K (RMSE <0.3 for all the parameters). These results suggest that the optimization of AVIRIS spectra using various pre-processing techniques and modeling approaches is required for rapid and non-destructive assessment and monitoring of soil health for precision agriculture.

Optimization of spectral pre-processing techniques for estimation of surface soil properties from airborne AVIRIS-NG hyperspectral images



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PRESENTED AT:

INTRODUCTION AND OBJECTIVES

• Soil Health Card Scheme (SHCs), a flagship programme for agricultural sector of India, issues the soil health cards to farmers which carry crop-wise recommendations of nutrients and fertilisers.

• India is spending nearly 80 million USD on SHCs.

• SHCs are based on laboratory analysis of samples to quantify soil properties. These methods are generally time consuming and expensive, requiring many consecutive steps and often involve toxic and corrosive reagents.

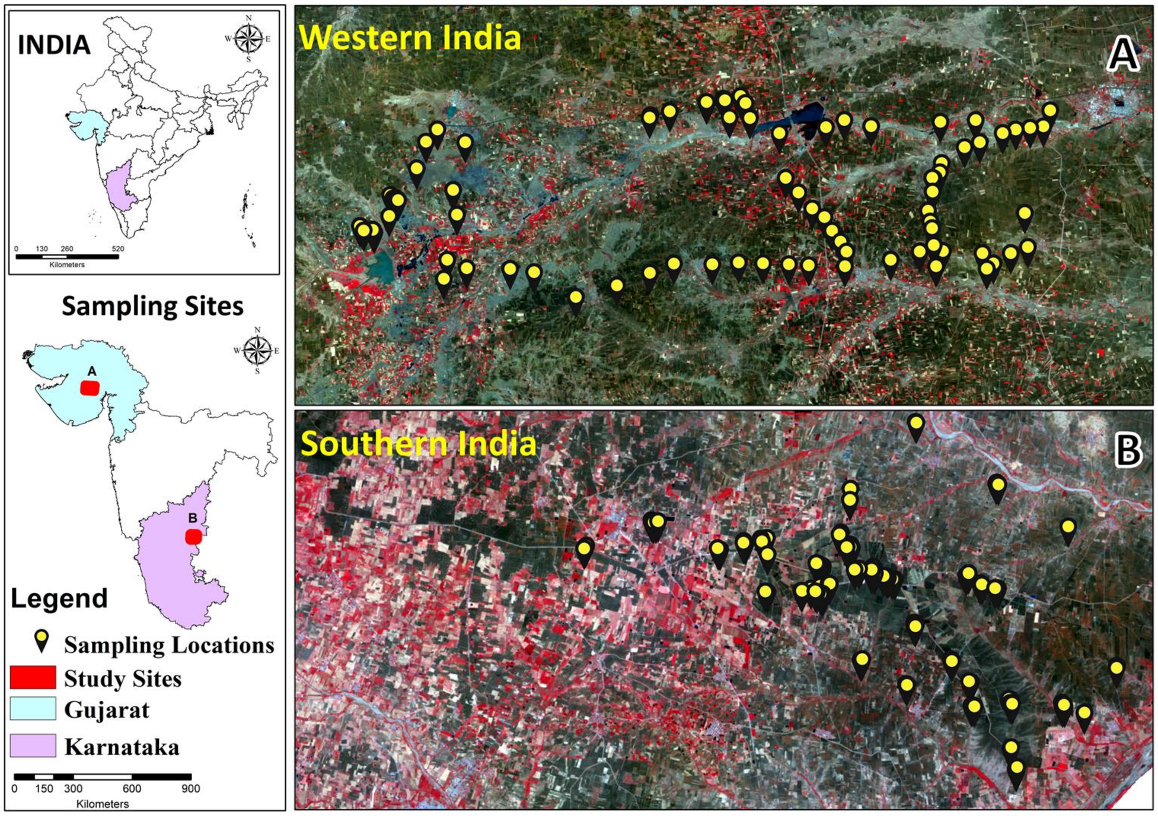
• Visible-near infrared and mid infrared spectroscopy are quick and relatively inexpensive, and almost no sample preparation is required.

• The main challenge limiting the application of spectroscopy in soil fertility evaluation is finding the suitable data pre-processing and calibration strategies.

Objectives:

To compare various pre-processing techniques using the reflectance spectra obtained from AVIRIS-NG hyperspectral images for quantification of organic carbon, available phosphorus (P) and available potassium (K) in the surface soils

STUDY AREA

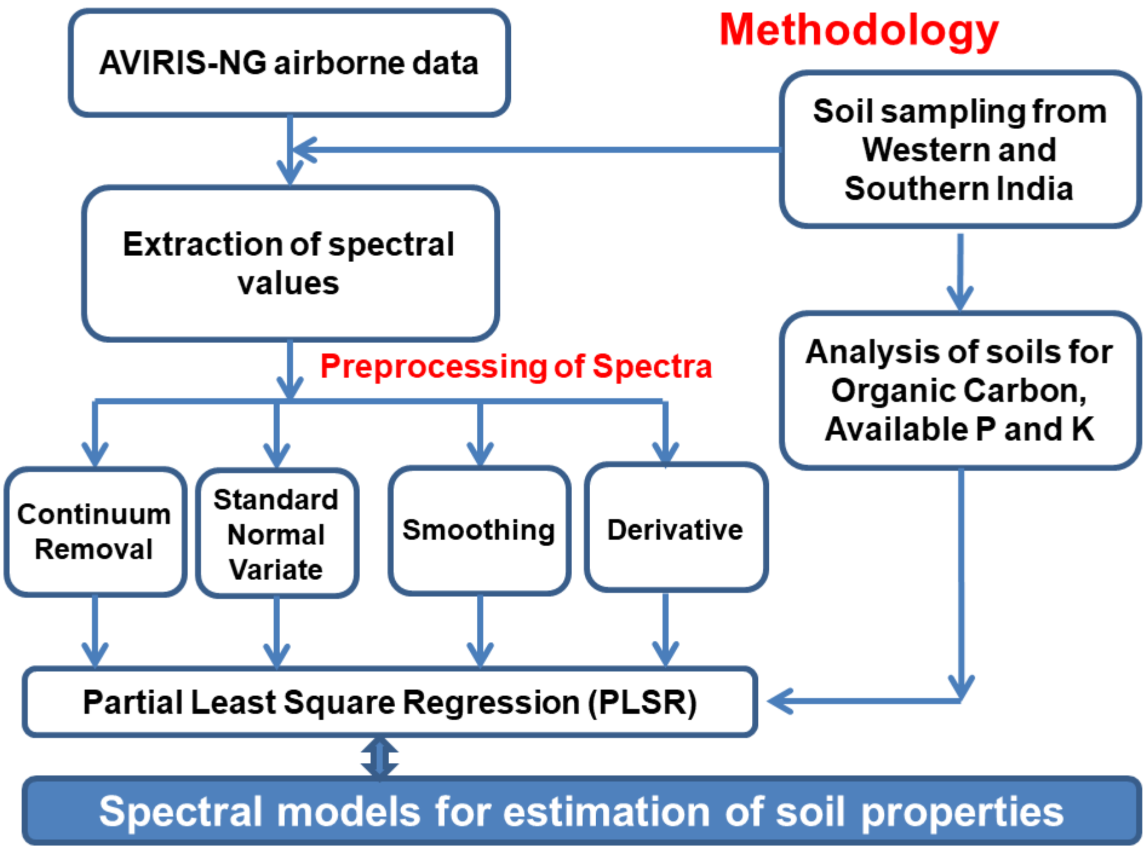


• Surface soil samples were collected from Surendranagar, Gujarat (Western India) and Raichur, Karnataka (Southern India).

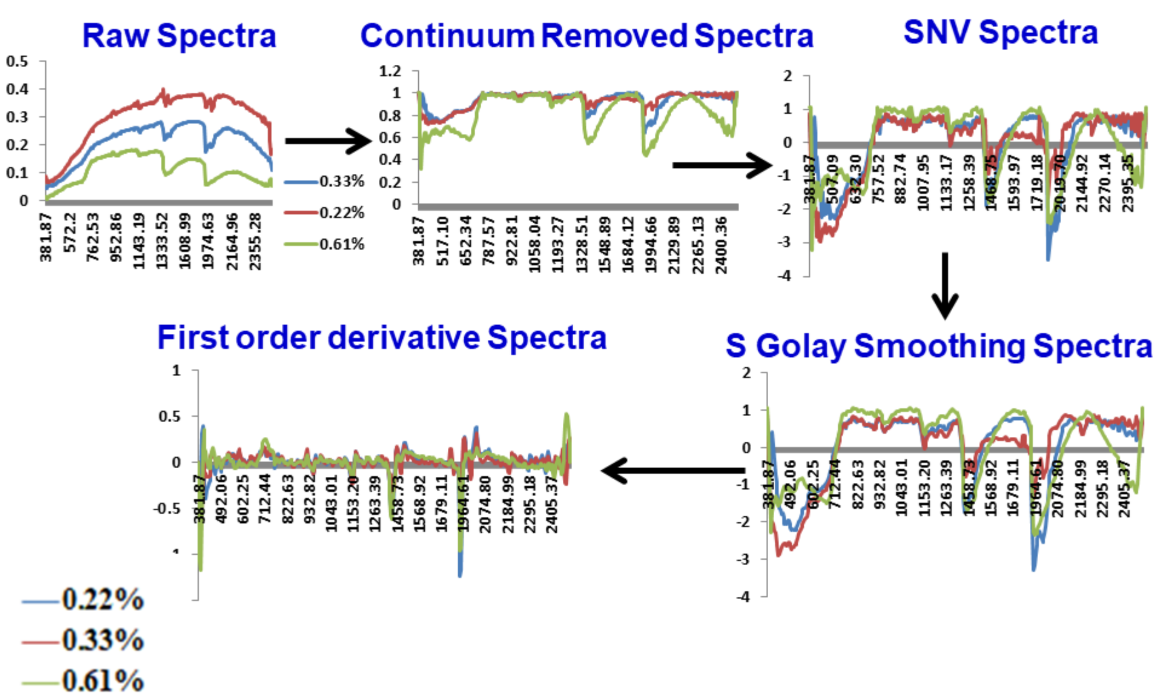
• Number of samples = 90 for Western India and 106 for Southern India

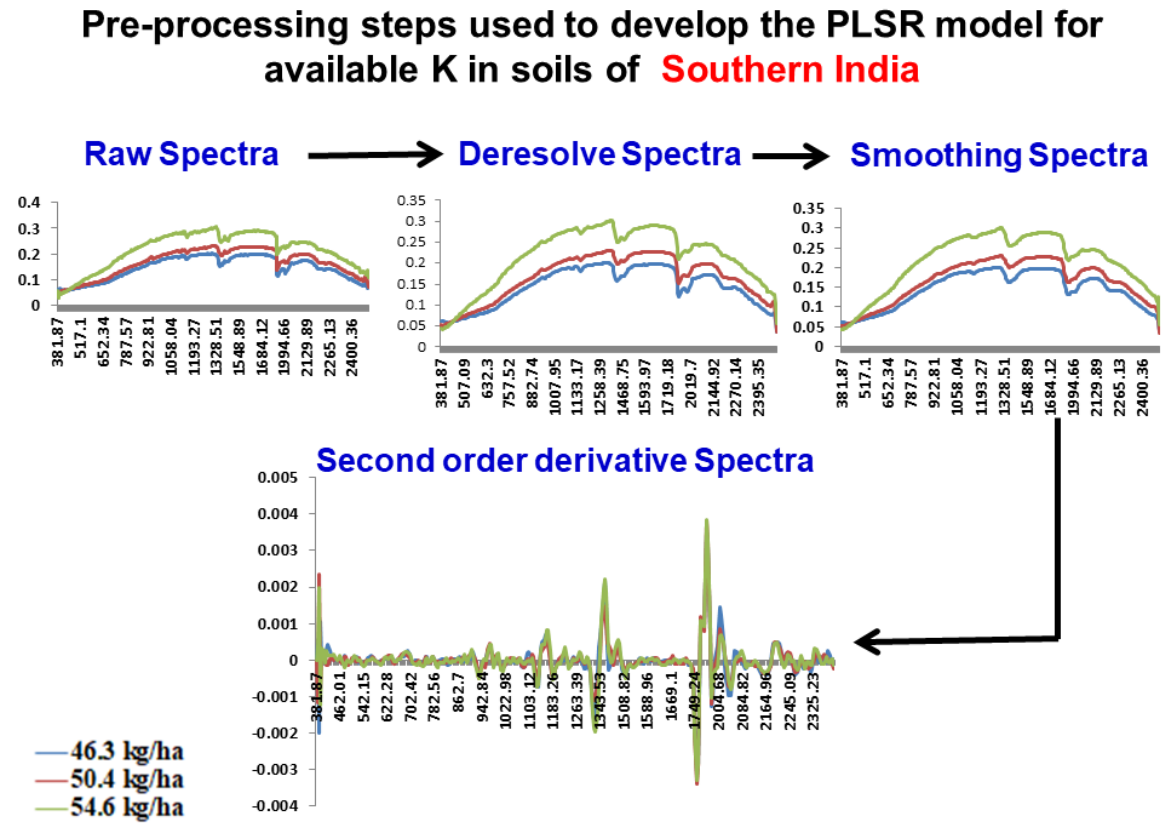
• Soil samples were analyzed for organic carbon, available P and available K using standard methods.

METHODOLOGY AND PRE-PROCESSING STEPS



Pre-processing steps used to develop the PLSR model for organic carbon in soils of Western India




Pre-processing steps used to develop the PLSR model for available K in soils of Southern India
Raw Spectra
Deresolve Spectra
Smoothing Spectra
Second order derivative Spectra
46.3 kg/ha
50.4 kg/ha
54.6 kg/ha

RESULTS

Descriptive statistics of physio-chemical properties of surface soils collected from Surendranagar & Raichur

Site	Parameters	OC	Available P	Available K
		%	kg ha^{-1}	
Surendranagar (Western India)	Min	0.120	2.24	1.79
	Max	0.710	99.5	28.2
	Mean	0.369	21.0	7.65
	SD	0.124	20.0	4.22
Raichur (Southern India)	Min	0.138	43.2	0.896
	Max	0.853	63.8	156
	Mean	0.457	49.6	23.8
	SD	0.139	2.82	27.0

Descriptive statistics of physio-chemical properties of surface soils collected from Western and Southern India

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Pre-processing steps used to predict soil properties using AVIRIS-NG hyperspectral images

Western India

1. Raw Spectra
2. Continum Removal
3. Standard Normal Variate
4. Smoothing
5. First Order Derivative

Southern India

1. Raw Spectra
2. Deresolve
3. Smoothing
4. Second Order Derivative

Coefficient of determination (R^2) for the regression models derived for predicted soil properties using AVIRIS-NG hyperspectral images

Soil Properties	Western India		Southern India	
	R^2	Optimum Wavelength (nm)	R^2	Optimum Wavelength (nm)
Organic Carbon	0.77	481, 542, 547, 672-782, 997, 1153-1178, 1293, 1298, 1458, 1478-1503, 1759-1769, 1954-1964, 2014-2039, 2059, 2139, 2144, 2159, 2345	0.54	627, 672, 687, 1268, 1278, 1283, 1433, 1488, 1553-1769, 2034, 2039, 2074
Available P	0.79	582-592, 762, 1218, 1228, 1233, 1468, 1548, 1744, 1769, 1774, 1959, 1964, 2209	0.49	1498, 1503
Available K	0.83	521-682,922-942, 1228-1438,1468,1573,1759, 1764, 1769	0.56	487-987, 1268-1288, 1488-1588, 1734, 1979, 2164, 2195, 2240-2375

RMSE was less than 0.3 for all the three parameters of both sites

CONCLUSIONS AND FUTURE RESEARCH

- Optimization of AVIRIS-NG hyperspectral data using various pre-processing techniques and PLSR produced the estimation of soil properties with meaningful accuracy.
- Further research is required on different combinations of pre-processing and model calibration methods (like Support Vector Machine and Random Forest etc.) for identifying the best approach for any spectral dataset to estimate the soil properties at local/regional/ country level.

- The integration of local and regional datasets in a weighted manner is required for investigation of pre-processing and modelling options to estimate the soil properties from spectra with appropriate accuracy.

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ABSTRACT

Remote sensing approaches based on VIS-NIR spectroscopy can be used for getting near real-time information about soil fertility. However, the main challenge limiting the application of spectroscopy in soil fertility evaluation is finding suitable data pre-processing and calibration strategies. We have compared various pre-processing techniques using the reflectance spectra obtained from AVIRIS-NG hyperspectral images for quantification of organic carbon (OC), available phosphorus (P) and available potassium (K) in the surface soils of Surendranagar area (Western parts of India) and Raichur (Southern parts of India). Surface (0 - 0.15 m) soil samples were collected from these two areas synchronously with the dates of the AVIRIS-NG campaign. The soil samples were air dried, sieved to <2 mm, and analyzed for OC, P, and K using standard methods. The AVIRIS spectra (spectral range of 380-2500 nm with an interval of 5 nm) corresponding to soil sampling points were extracted. The pre-processing steps were used in the order: Continuum Removal (Yes/No), Moving Window Abstraction (Yes/No), No transformation or Euclidean Normalization or Standard Normal Variate (SNV), No transformation or Savitsky-Golay (SG) first-order smoothing, and No transformation or first derivative OR second derivative. We have used the partial least squares regression (PLSR) to calibrate the model from pre-processed spectra. The PLSR with Continuum Removal, SNV, SG first-order smoothing, and first derivative was selected as the best algorithm for estimating soil properties from the Western parts of India, and the corresponding R^2 were 0.77 for OC, 0.79 for P and 0.83 for K (RMSE <0.3 for all the parameters). The PLSR with Moving Window Abstraction, SG first-order smoothing, and second derivative were selected as the best algorithm for estimating soil properties from the Southern parts of India, and the corresponding R^2 were 0.54 for OC, 0.49 for P and 0.56 for K (RMSE <0.3 for all the parameters). These results suggest that the optimization of AVIRIS spectra using various pre-processing techniques and modeling approaches is required for rapid and non-destructive assessment and monitoring of soil health for precision agriculture.