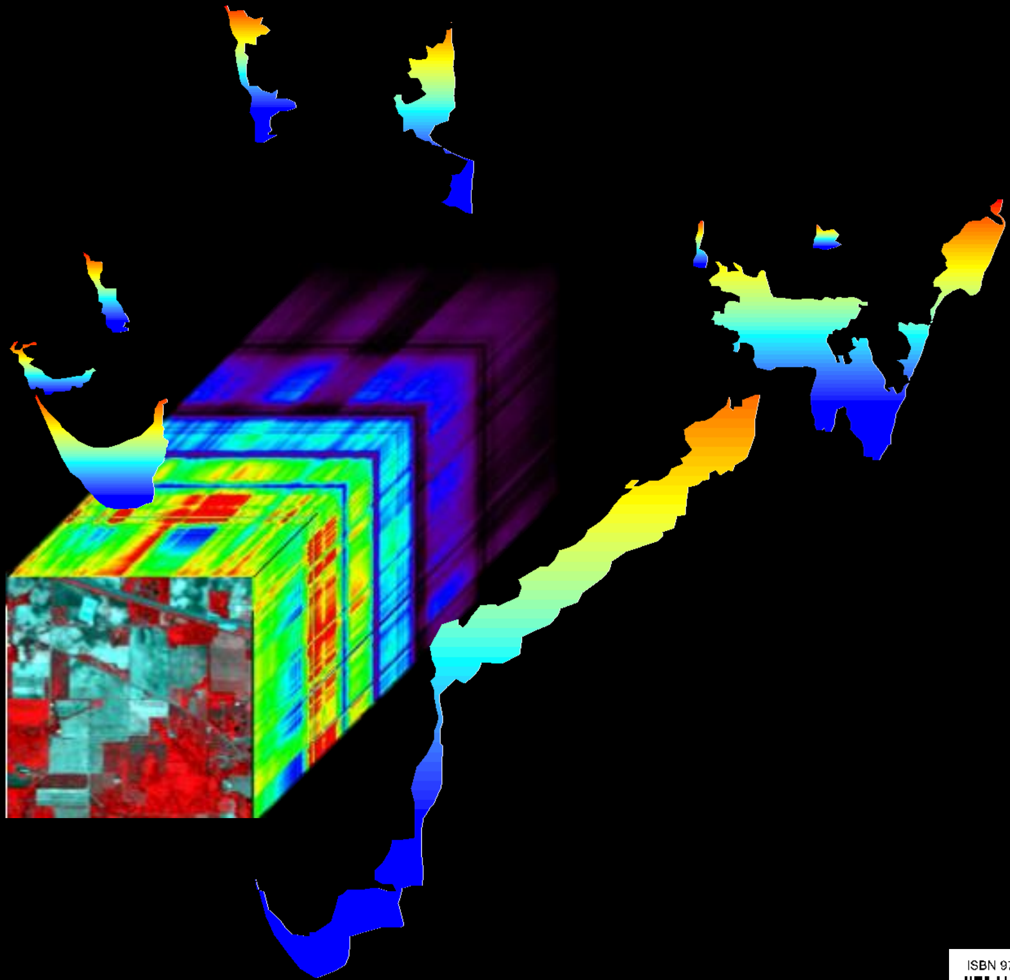
Spectrum of India



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आ. सी. किरण कुमार / A. S. Kiran Kumar
अध्यक्ष / Chairman

MESSAGE

Indian Earth Observation satellite missions play a pivotal role in generating valuable information required for natural resources management by employing sensors on board in different electro-magnetic wavelengths. Over the years, advances in sensor technology have led to development of hyperspectral imagers which collect data in large number of contiguous narrow bands spanning a vast region of the electromagnetic spectrum.

The requirements of users on space-based products and services put forward a unique challenge for ISRO to develop advanced imaging sensors. In this context, the collaborative program between ISRO and JPL, NASA on hyper-spectral remote sensing and imaging spectroscopy is one such endeavour towards achieving the precision in sensor technology and advanced application requirements.

AVIRIS-NG developed by JPL is being used by ISRO to acquire Hyperspectral data over India covering diverse ecosystems. In Phase-1 of this campaign Hyperspectral data was collected over 57 sites in India. Various academic institute and scientific organizations have participated during the airborne campaign (December 2015 to March 2016) and large amount of hyperspectral data over the multiple natural targets was collected. The campaign provided unique opportunity to scientific community to develop spectral libraries, algorithms and models which are precursor to the India's future hyperspectral missions.

It is heartening to note that an excellent compilation has been brought out through contributions of ISRO scientists on various themes using data from the phase-1 airborne campaign with AVIRIS-NG. I appreciate the sincere efforts to bring out this scientific compilation.

आ सी किरण कुमार
(आ सी किरण कुमार) 13/7/17
(A. S. Kiran Kumar)

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तपन मिश्रा
निदेशक
Tapan Misra
Director

सत्यमेव जयते

PREFACE

Space Applications Centre (ISRO), Ahmedabad is involved in designing and developing imaging, non-imaging payloads and is engaged in the development of advanced techniques, value-added products using satellite data for societal benefits. In the space age, significant progress has been made to strengthen the remotely sensed observations through electro-optical sensors and microwave radar-radiometer systems onboard ISRO's satellites. The development of space-borne hyperspectral sensors is a challenging task and is in the process of realization. The airborne hyperspectral data from AVIRIS-NG sensor system provides unique opportunity in understanding the three-dimensional data cube, its calibration and validation. The utilization of such valuable data calls for the newer development of the algorithms, data processing and customized solutions for societal benefits. The coordinated effort by campaign and science teams facilitated the acquisitions of hyperspectral airborne data and ground-truth over 57 sites in India. This Centre has archived these data and is engaged in disseminating the same to scientific community of India through a geoportal called VEDAS. Different trainings are being organized to develop the skill of using hyperspectral data which would help in practical applications of hyperspectral data from ISRO's future satellite-based hyperspectral missions. Research support has also been extended to academia especially to doctoral students through Announcement of Opportunity (AO) programme.

The present compilation of research articles contains the initial science results using the hyperspectral data from phase-1 airborne campaign with AVIRIS-NG. I hope this would help the students and initial learners to develop deeper insight on the data and their practical utility.

तपन मिश्रा

Place: Ahmedabad
Date: 10 July 2017

(तपन मिश्रा) / (Tapan Misra)
निदेशक / Director

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Dr. Y.V.N. Krishna Murthy
Director

FOREWORD

AVRIS –NG is one of the important aerial missions undertaken for Hyperspectral mapping in the country under the Indo –US cooperation in Science mission. The flights over Indian sub-continent were conducted during Dec,2015 to March,2016 period where in hypespectral data was collected for diverse terrain covering themes like Agriculture , Forestry, Geology and Water . This is one of the unique missions wherein scientific team from ISRO and NASA-JPL collaborated for providing Science data to the country. Various researchers were benefited by this progamme and they had opportunity to work with one of the best science data in the area of hyper spectral domain. The present Science meet on the phase-1 of the activity is an important milestone wherein the team will be discussing the data processing results for the benefit of the academic community of the country and also to interact with the science team member of AVIRIS programme to understand data products and their related use to create larger user base of the these scientific data products. NRSC has also contributed significantly in conducting flight operations effectively to ensure maximum data have been collected for this mission in shortest period of time. I understand many important results would be discussed covering various themes which will play a significant role in planning future applications on space platform. I wish this meet a grand success.

कृष्ण मूर्ति

(Y.V.N.Krishna Murthy)

July 08, 2017

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PRELUDE

Several Hyper-Spectral Spectrometer (HSS) instruments are available for hyperspectral imaging to provide data with high spatial resolution from airborne and ground-based platforms. The satellite-based HSS missions are able to provide data over the globe however suffers with low SNR problem. Several application studies have also been demonstrated by Indian scientists using ground based and spaceborne sensors. Keeping the future potential in tandem with the development of advanced technology, to provide the required ground truth data, science understanding, techniques development and applications demonstrations for present and future ISRO space imaging spectrometer missions, ISRO and NASA have designed joint airborne hyperspectral science campaign over India in 2015. In the first phase, data over 57 sites, covering various themes, such as agriculture, forest, geology, water, urban, coastal etc. have been acquired. The initial results of the research performed with the data has been compiled and presented here with combined effort of scientists and engineering team of ISRO centres and researchers from various institutes as well as academia. It has been a great experience for science team members of AVRIS-NG Airborne Hyperspectral Campaign, working with an excellent hyperspectral payload data. The team is grateful to the support extended by Shri A. S. Kirankumar, Chairman, ISRO. The constant encouragement and review on the progress of airborne campaign and scientific data archival, dissemination, analysis by Shri Tapan Misra, Director, SAC, Ahmedabad is gratefully acknowledged. The cooperation extended by Dr. V. K. Dadhwal, Ex-Director and Dr. Y.V.N. Krishnamurthy, present Director, NRSC, Hyderabad for the aircraft operations in a time-scheduled manner is acknowledged. The entire team is highly benefitted by the support provided by JPL, NASA for their AVIRIS-NG payload for hyperspectral airborne campaign for the first time in India and basic data products of imaging spectroscopy for scientific analysis. We hope to develop much more scientific understanding and various application potential with the present dataset and future acquisitions.

Raj Kumar

(डॉ. राज कुमार)
(Dr. Raj Kumar)

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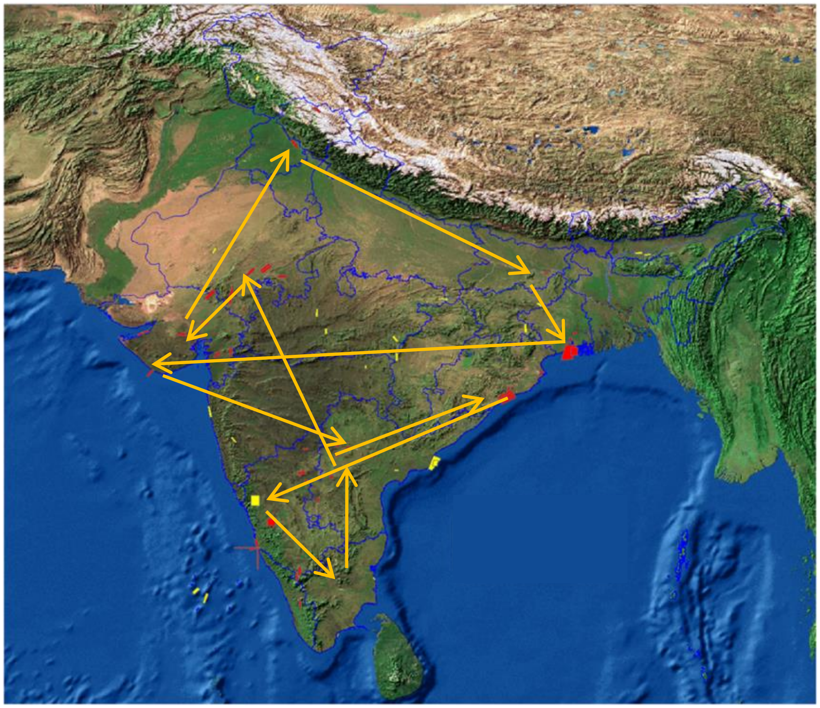
AVIRIS-NG

Airborne Visible and Infra-Red Imaging Spectrometer – Next Generation (AVIRIS-NG), of JPL (Jet Propulsion Laboratory), NASA, has been used for the ISRO-NASA airborne campaign on-board an ISRO B200 aircraft. There are about 430 narrow continuous spectral bands in VNIR and SWIR regions in the range of 380-2510 nm at 5 nm interval with high SNR (>2000 @ 600 nm and >1000 @ 2200 nm) with accuracy of 95% having FOV of 34 deg and IFOV of 1 mrad. Ground Sampling Distance (GSD) vis-à-vis pixel resolution varies from 4-8m for flight altitude of 4-8 km for a swath of 4-6 km.

B200 aircraft and AVIRIS-NG instrument

Campaign diary



The first phase of airborne hyperspectral campaign has been organized with AVIRIS-NG payload over 22840 km2 area in 57 sites in India for 84 days during December 16, 2015 to March 6, 2016 under the ambit of ISRO-NASA joint initiative for HYperSpectral Imaging (HYSI) programme.

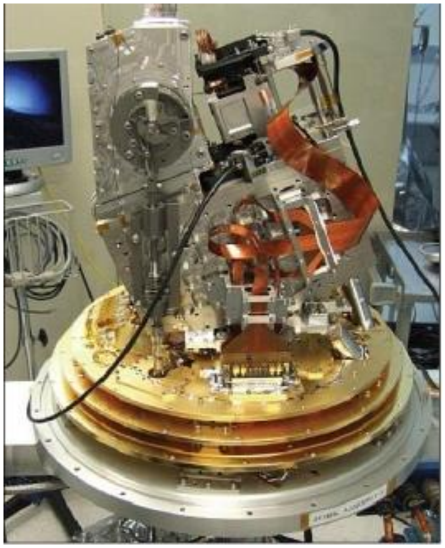
The flight campaign was organized from nine airport bases. More than 200 people participated in the field campaigns corresponding to date of flight. Weather forecast from MOSDAC was used for effective and efficient flight planning and field data collection.

Airport	Duration	No. of sites	Area in sqkm
Begumpet	16th to 21st Dec 2015 25th to 29th Jan 2016	12	2650
Bhubaneswar	22nd to 28th Dec 2015	6	3780
Mangalore	29th Dec 2015 to 02nd Jan 2016	5	3491
Coimbatore	03rd to 08th Jan 2016	5	1416
Phase inspection	*12th to 24th Jan 2016*		
Udaipur	31st Jan to 05th Feb 2016	8	3697
Ahmedabad	06th to 16th Feb 2016 06th to 09th Mar 2016	10	2788
Chandigarh	17th to 21st Feb 2016	4	835
Patna	22nd to 24th Feb 2016	3	396
Kolkata	24th Feb to 06th Mar 2016	4	3787
End of campaign	*84 days*	*57 sites*	*22840*

B200 aircraft captured in air by science team member

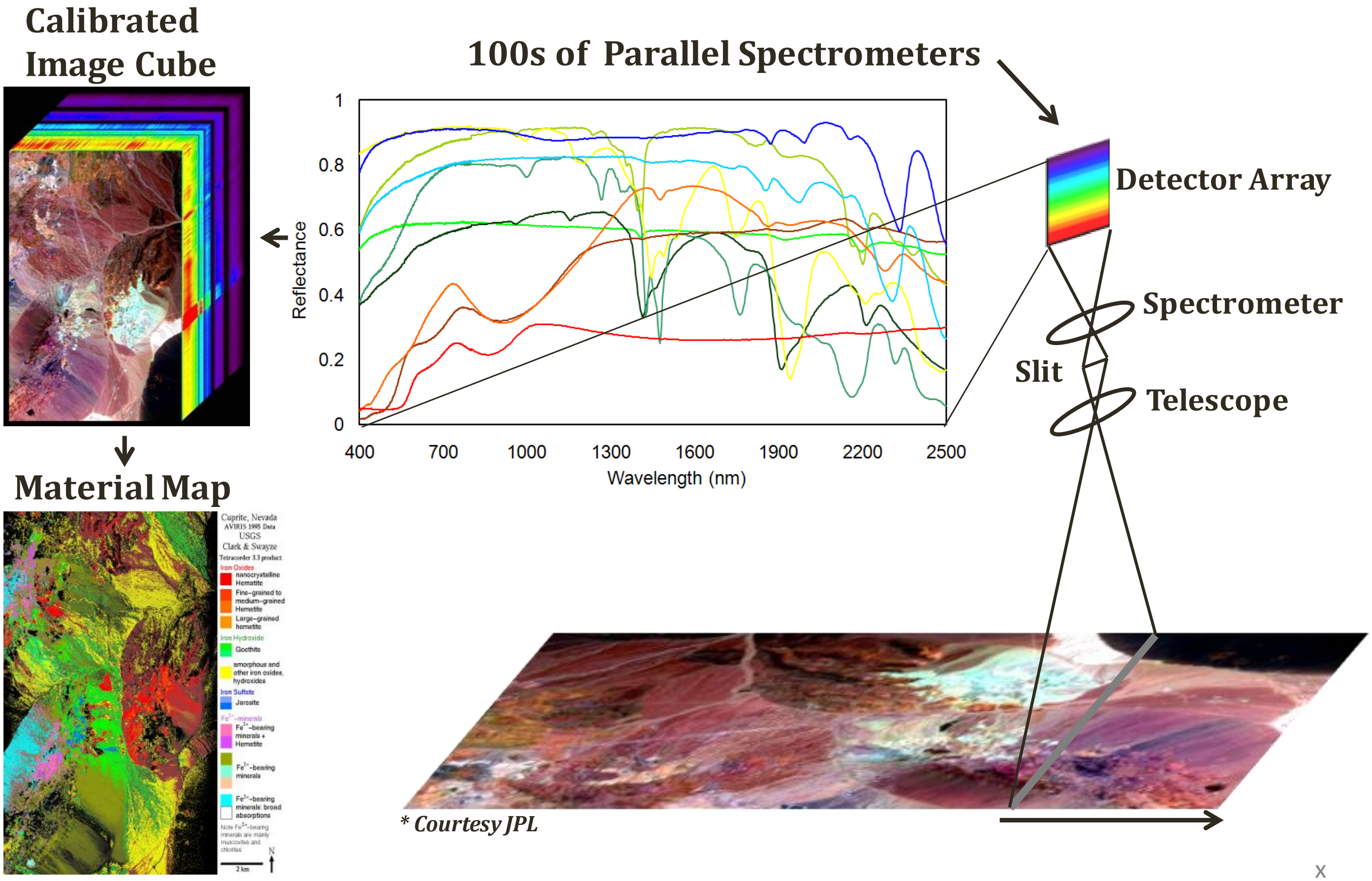
Instrument specification

Parameter	Value	Units
IFOV	1	mrad
FOV	34	deg.
Spectral range	380-2510	nm
Spectral sampling	5	nm
SNR @ 600 nm SNR @ 2200 nm	>2000 >1000	
Weight	450	kg
Spectral cross track	>95%	across FOV
Spectral IFOV variation	>95%	spectral direction



Imaging Spectroscopy

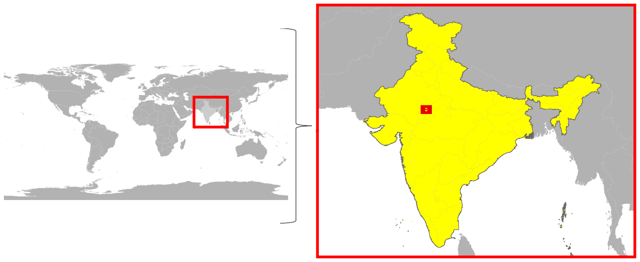
Imaging Spectroscopy or Hyperspectral sensing (HSS) of Earth's land and ocean environments is based on the principles of spectroscopy, either reflectance or emission spectroscopy, over shortwave (0.3 to 3 μm) and longwave (5 to 50 μm) spectrum. Interaction of energy with the molecular and structure of surface materials results into characteristic or diagnostic absorption or emission features in the reflectance or emittance spectra. These diagnostic features occur due to changes in energy state of molecules as a function of electronic or vibrational transitions. The former occurs predominantly at shorter wavelengths due to changes in energy state of electrons bound to atoms or molecules or lattices. The latter occurs generally in longer wavelength due to stretches and bendings where overtones occur at sums or multiples of the fundamental vibration frequencies. HSS refers to 100-200 spectral bands, generally in continuum with relatively narrow band interval (5–10 nm), in contrast to Multi-Spectral Sensing (MSS) that refers usually to 5-10 discrete wide bands (bandwidths 50-400 nm).



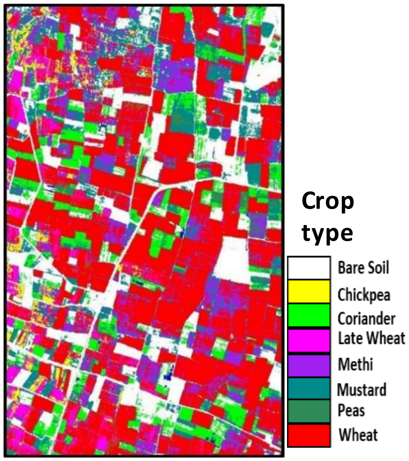
AGRICULTURE & SOILS

Field crop discrimination

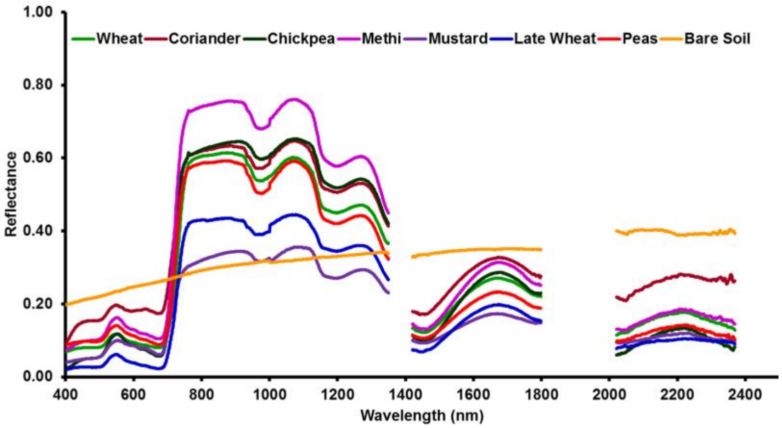
Rahul Nigam, Rajsi Kot, and B. K. Bhattacharya



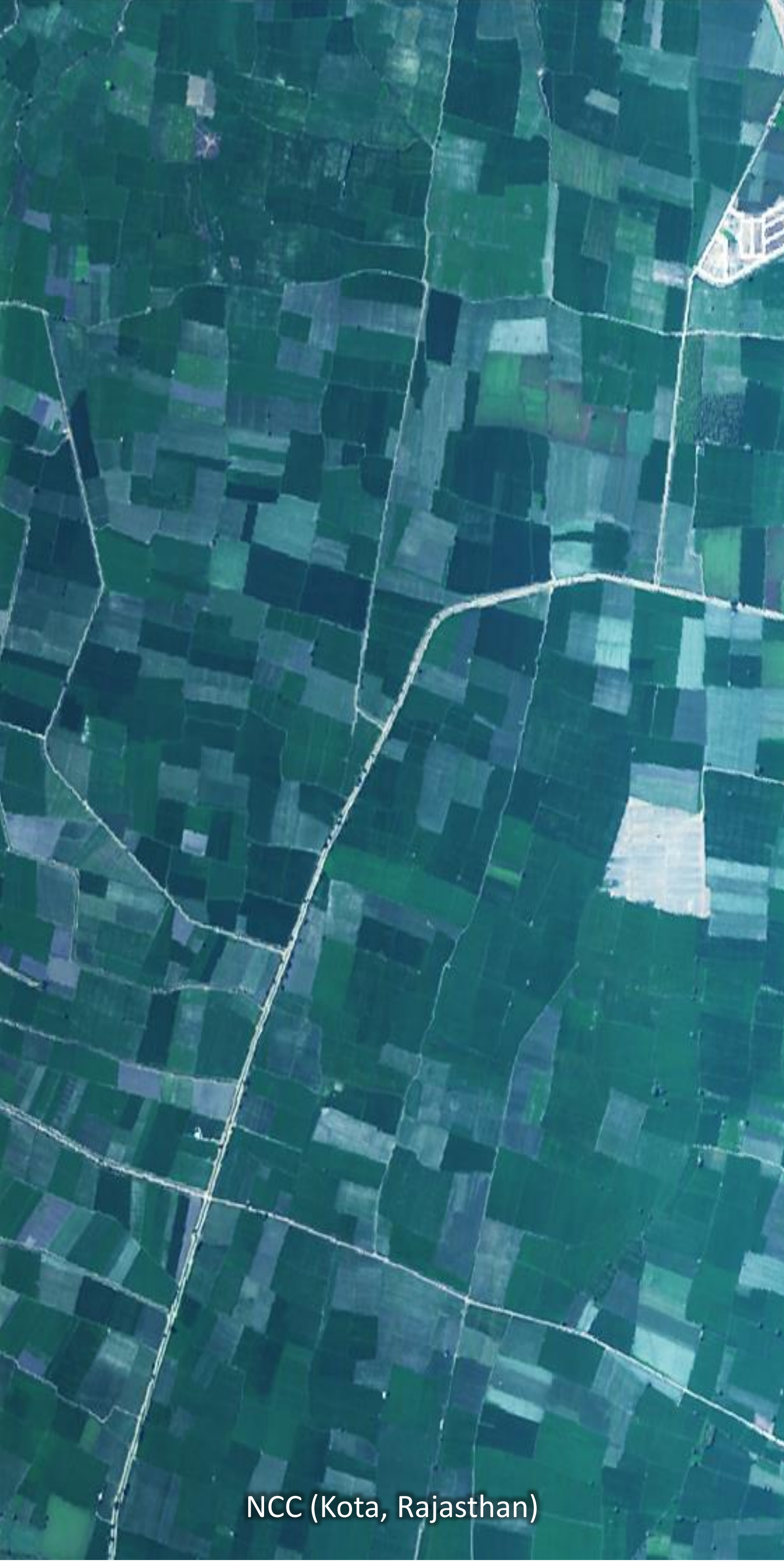
Accurate and efficient crop discrimination is a key requirement for precision agricultural management. In the present study, homogeneous agricultural area of Kota, Rajasthan was selected to perform classification. Major crops in Kota were alsi, beans, chickpea, coriander, garlic, wheat, methi (fenugreek), mustard and peas. Crop classification was successfully achieved using supervised classification technique spectral angle mapper (SAM) over Kota. SAM calculates the angle between the reference spectrum in n-dimension space. For Kota, overall classification accuracy 86.4% and kappa coefficient 0.84 was achieved.



Crop classification by spectral angle mapper over homogeneous agricultural area



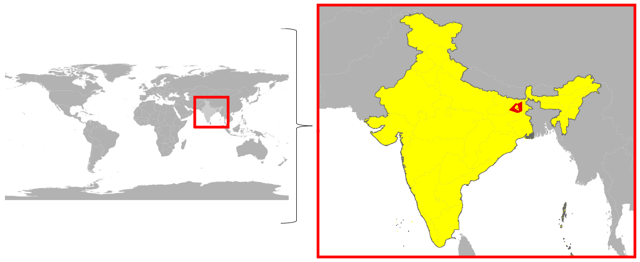
Spectral response of various crops over Kota


NCC (Kota, Rajasthan)

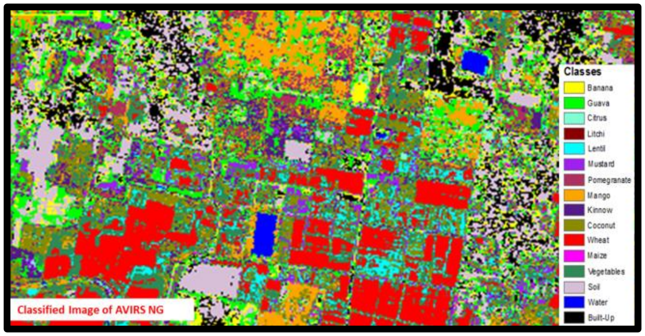

Classified image (Kota, Rajasthan)

Orchard crop discrimination

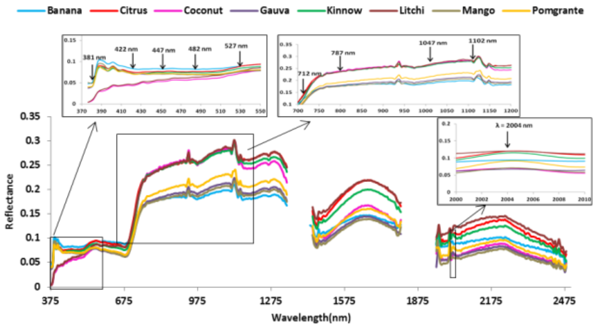
R. N. Sahoo, V. Bajpai, N. Paul, G. Krishna, B. Das, H. Patra, N. Mridha et al.



Accurate mapping of orchard crops using multispectral remote sensing has been challenge due to poor discrimination with less number of discrete bands and mixed pixel effect. This study was undertaken to explore potential of hyperspectral data to discriminate eight horticultural crops in Sabour, Bhagalpur region of Bihar. The pre-processed ground reference spectral data were statistically analyzed using ANOVA to find significant wavebands for discrimination. Spectral separability between each pair of fruit crops was computed using JM distance technique. The performance of selected wavebands were evaluated by using linear discriminant analysis (LDA). The Species were classified using Spectral Angle Mapper (SAM) method by using end members spectra collected through AVIRIS NG. The resultant 10 optimum spectral bands were identified for discriminating fruit crops. Discriminative power of the wavelengths was further assessed on the basis of overall accuracy (91.67%) using LDA.

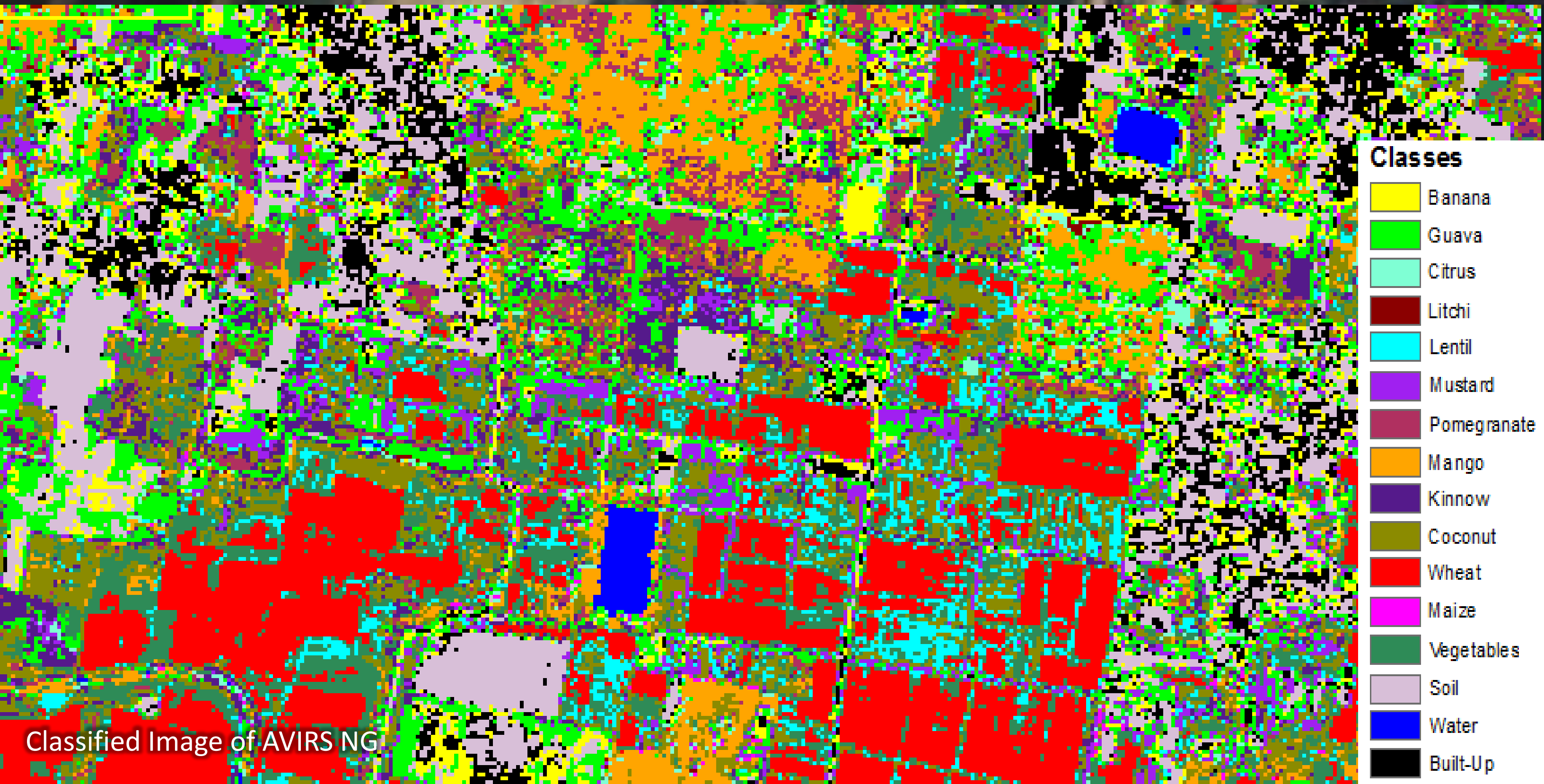


Segregation of orchard crops in Bhagalpur region, Bihar



Sensitive Bands for discrimination of orchard crops

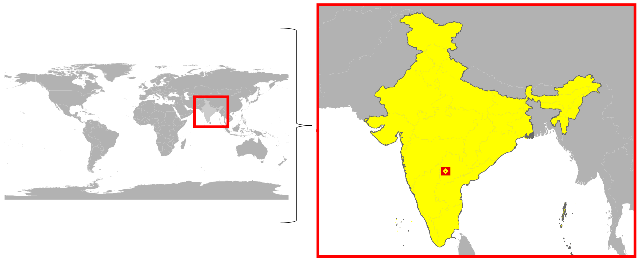

Natural colour composite (NCC) of Orchard area, Sabour, Bhagalpur, Bihar



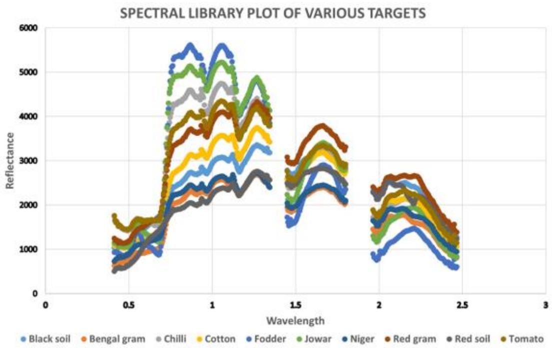
Classified Image of AVIRS NG

Soil discrimination

Anil Kumar, Justin George K. and A. Senthil Kumar



Precise identification and estimation of various soil types and crops in an area is vital for planning and adoption of various agricultural and land resources management practices. This study demonstrated the application of AVIRIS-NG data for discrimination of specific crop/soil types. The spectral profile of various targets/classes including different soil types and crops were collected during field campaign. For crop/soil type discrimination, spectral similarity analysis between pure ground spectra generated and AVIRIS image Spectra for different classes (crop and soil types) was done. AVIRIS data of ICRISAT was classified using the generated precise ground spectra for identification of various crop and soil types using segmentation based support vector machine with linear kernel classifier.



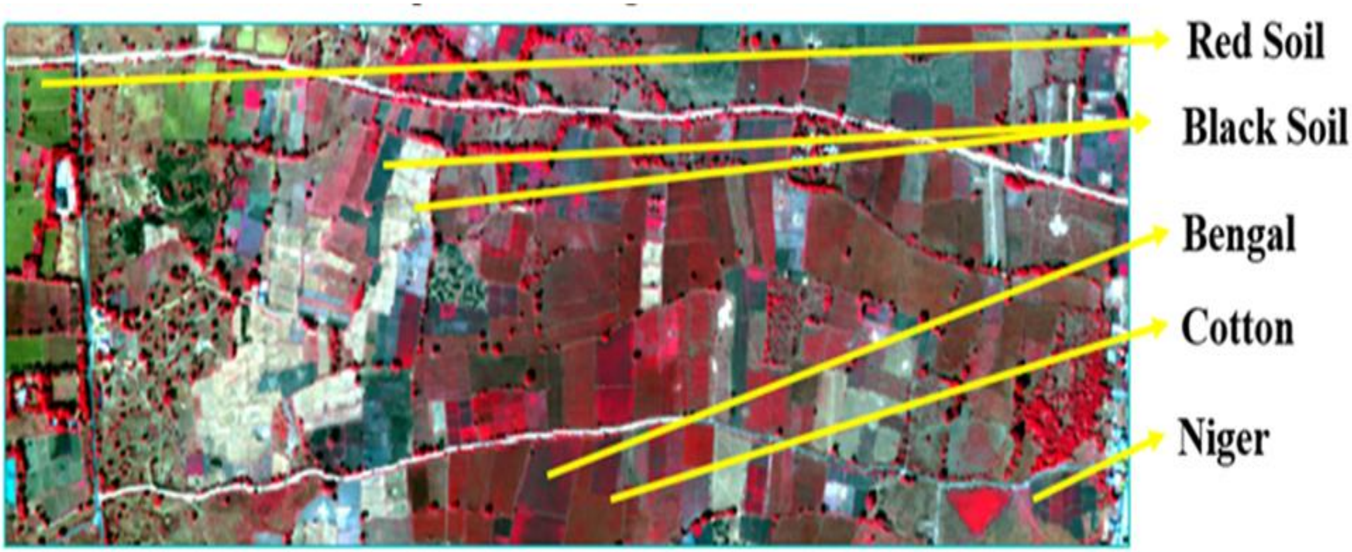
Spectral Profiles of Various target classes

Similarity Scores

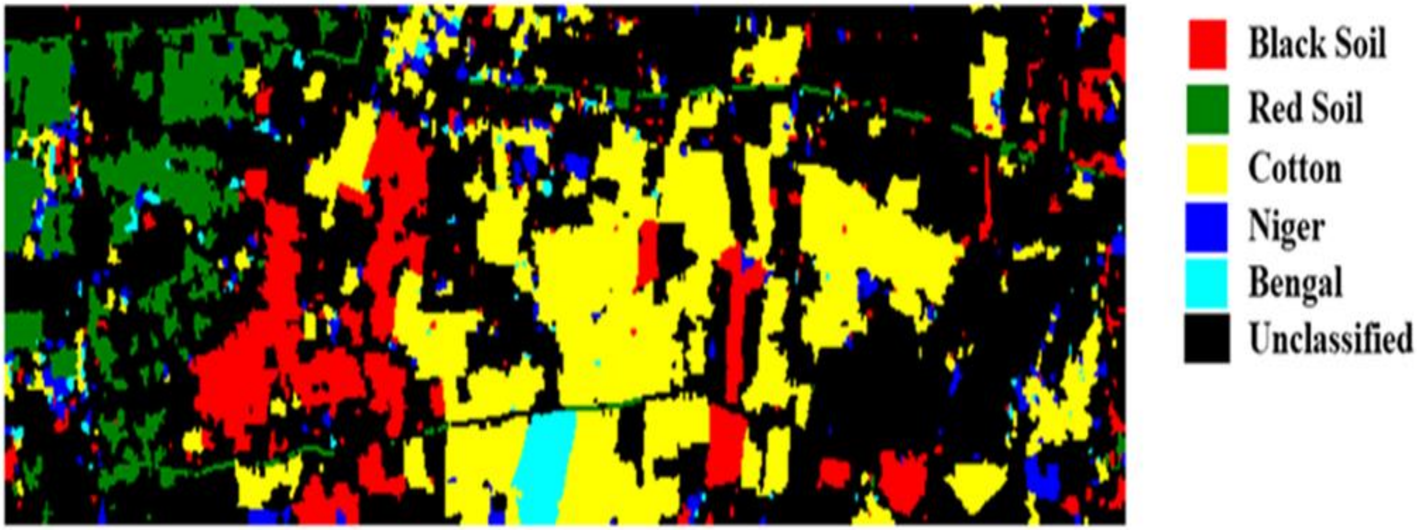
Symbology	Crop/Soil	Similarity Score
	Jowar	0.897
	Chilli	0.838
	Fodder Grass	0.798
	Tomato	0.785
	Cotton	0.735
	Red Gram	0.708
	Bengal	0.698
	Niger	0.671
	Black Soil	0.590
	Red Soil	0.497

Spectral similarity analysis scores

AVIRIS Image of ICRISAT Area

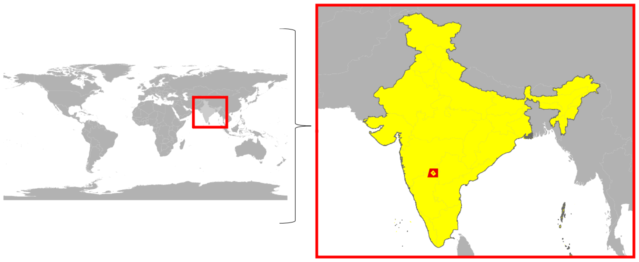


AVIRIS Classified Image using object based Support Vector Machine Classifier

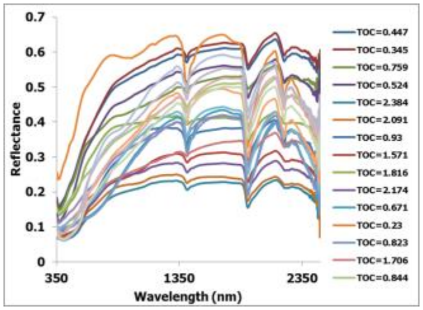


Soil organic carbon in crop fields

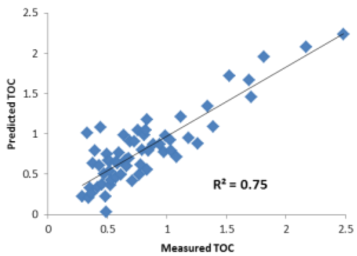
Rabi N. Sahoo, V. Bajpai, Himesh Patra, Gopal Krishna, Nilimesh Mridha et al.



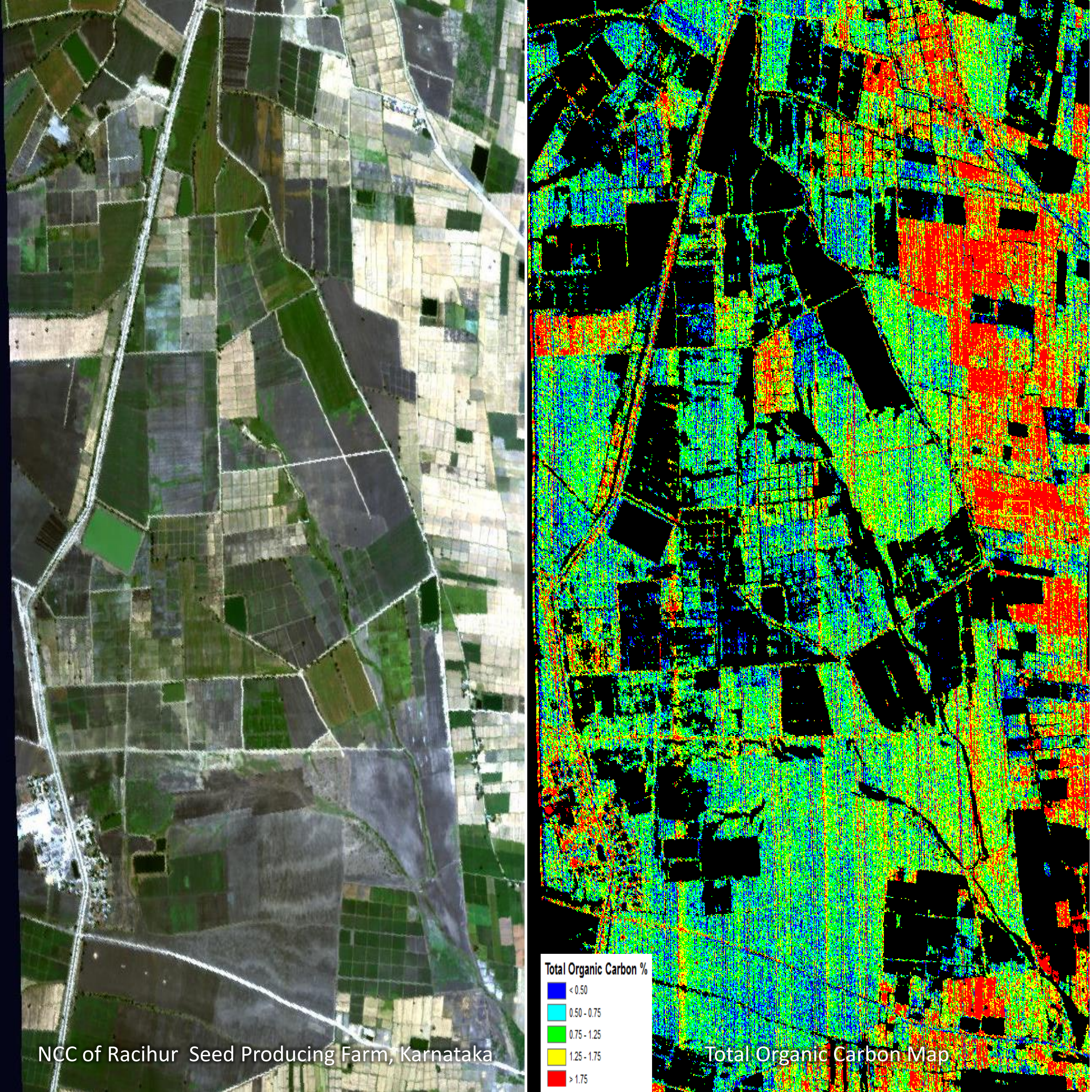
Total organic carbon (TOC) of soil was assessed using AVIRIS-NG for mapping soil organic carbon. Synchronized soil sampling and spectral data collection was done during field campaign. AVIRIS NG L2 surface reflectance image was also used to retrieve soil spectra using geolocations of soil sampling points. Predictive models were developed using Partial Least-Squares Regression (PLSR) and Step-wise Multiple Linear regression (SMLR) between extracted soil organic carbon, spectra collected at ground and from AVIRIS-NG L2 surface reflectance image in the sensitive band regions. A Jack-Knifing method was adopted to develop predictive models from 2/3rd data pairs followed by validation from 1/3rd data pairs. Then location specific model developed were used further for generating soil organic carbon map using AVIRIS-NG L2 reflectance image. Total organic carbon map of seed producing farm, Raichur, Karnataka, India is prepared.



Spectral Profiles at different level of TOC

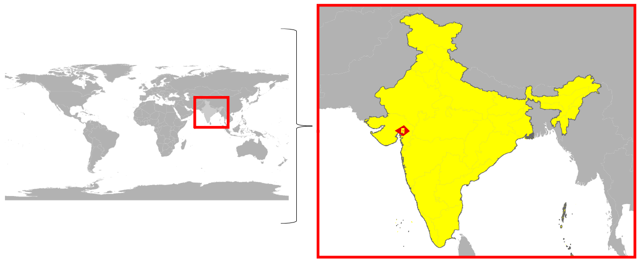


Measured Vs Predicted Total Organic Carbon

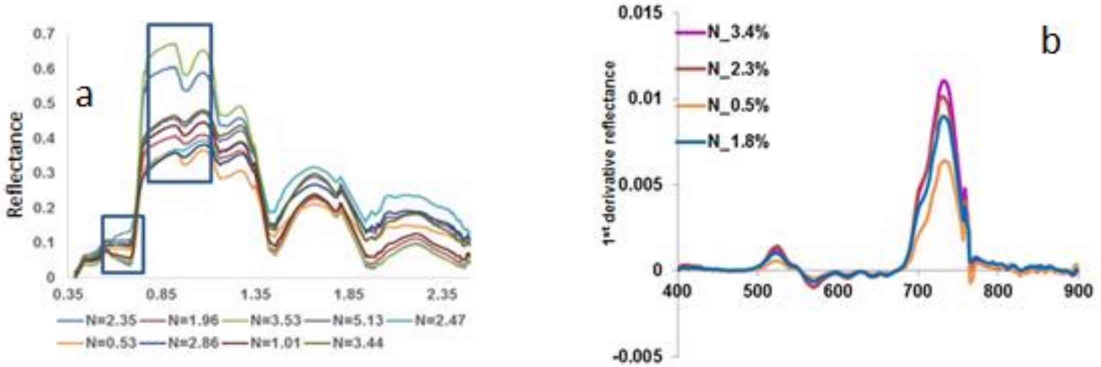

NCC of Racihur Seed Producing Farm, Karnataka
Total Organic Carbon Map
Total Organic Carbon %
< 0.50
0.50 - 0.75
0.75 - 1.25
1.25 - 1.75
> 1.75

Nitrogen content of crop canopy

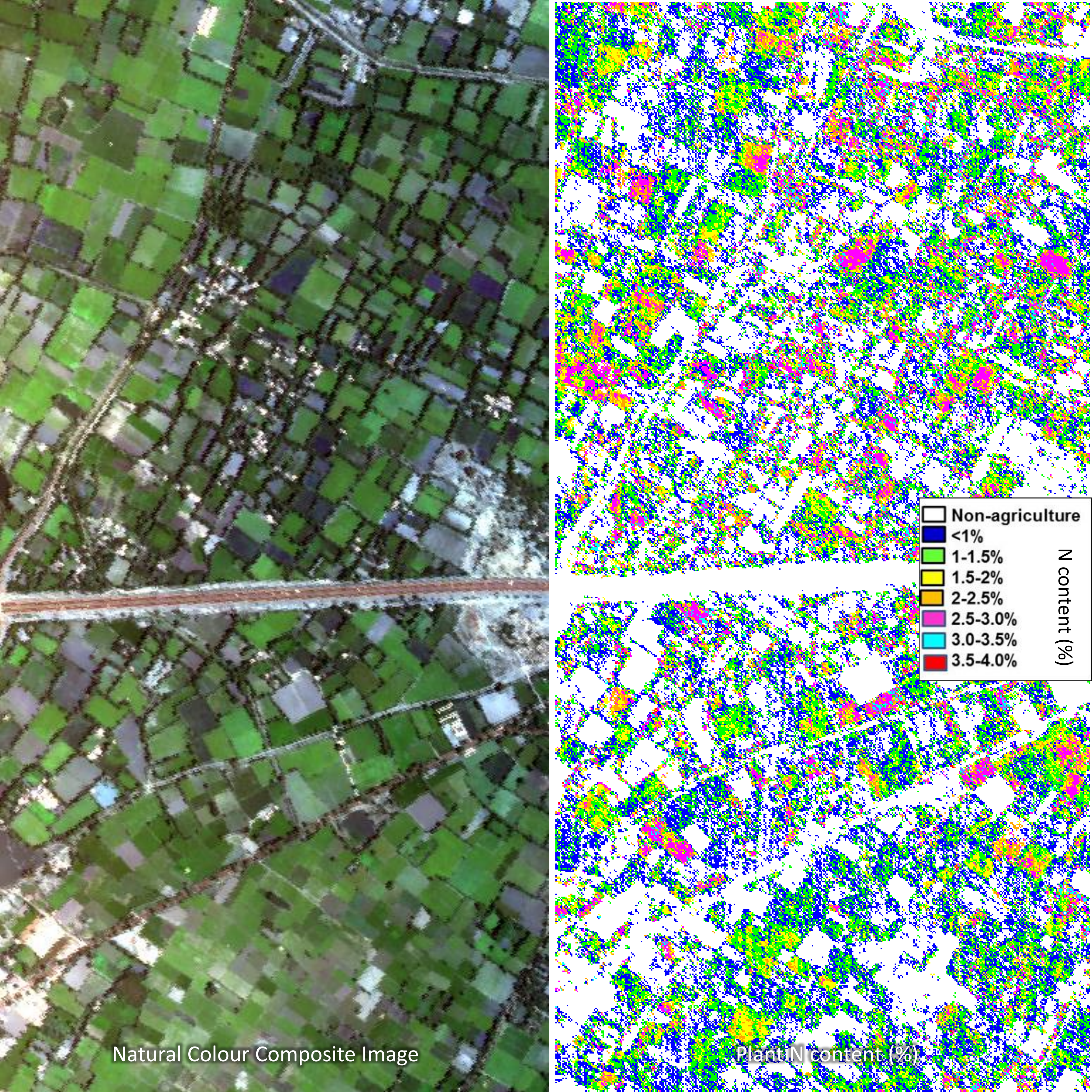
Rojalin Tripathy, K. N. Chaudhari, Mehul Pandya, and B. K. Bhattacharya



The estimation of plant nitrogen content is necessary to monitor the crop health and hence is an important plant parameter for modelling crop yield prediction. This study demonstrated the application of AVIRIS-NG data for plant N content estimation. The spectral signature of crop species with different N content was collected from 25 different sites using ASD spectro-radiometer. Spectral profile (reflectance and first derivative of reflectance) were also extracted from the AVIRIS-NG reflectance image. 10 different narrowband vegetation indexes were estimated from the ground spectra and were correlated to the plant N content. Multiple regression model was developed using the indexes from ground spectra and applied to that derived from AVRIS-NG image to generate the spatial plant N content map.

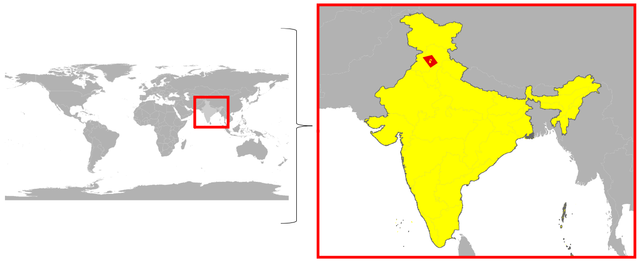


Spectral Profiles (a) reflectance Selected crops with different N and (b) first derivative of reflectance of wheat crop with different N content

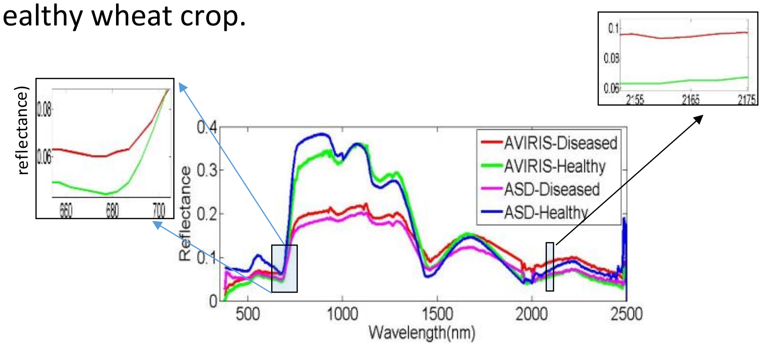

Natural Colour Composite Image
Plant N content (%)
Non-agriculture
<1%
1-1.5%
1.5-2%
2-2.5%
2.5-3.0%
3.0-3.5%
3.5-4.0%
N content (%)

Crop disease detection

Sujay Dutta and Somnath Paramanik

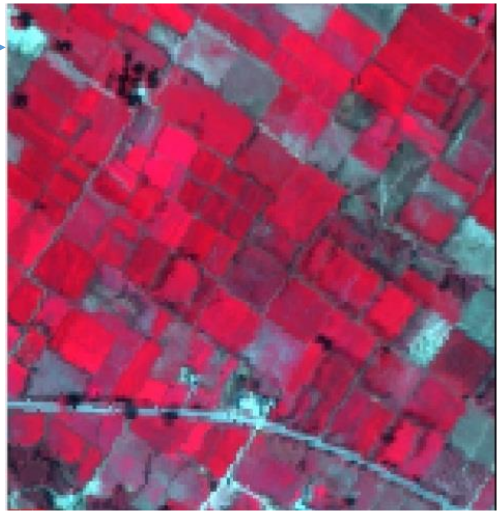


AVIRIS-NG hyperspectral airborne data was collected in parts of Punjab state for detection of yellow rust disease in wheat crops. Reflectance spectroscopy techniques for crop disease identification make use of characteristics of the reflectance spectrum. Main objective in this project work is the development of absorption depth algorithm after doing continuum removal and all those techniques. This absorption depth based classification has huge application in mineralogy mapping in geology field and it can also be used in agricultural classification purposes because every vegetation has different cell structure, water, nutrient content, bio-chemical properties and for that they have different spectral signature. In hyperspectral aspects it is precisely noticed that there have different absorption dip in a particular region. These characteristics help to identify or discriminate diseased versus healthy wheat crop.



Discrimination of diseased and healthy wheat fields

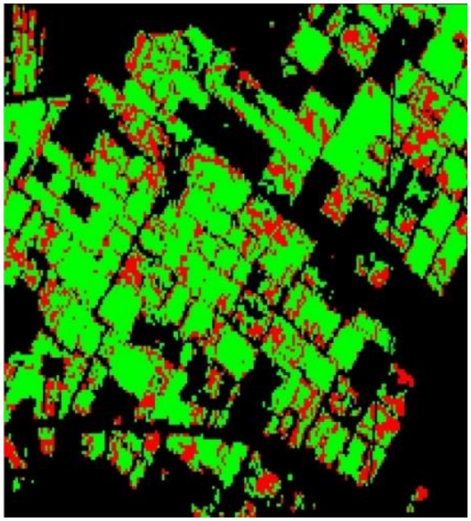
AVIRIS
Ropar



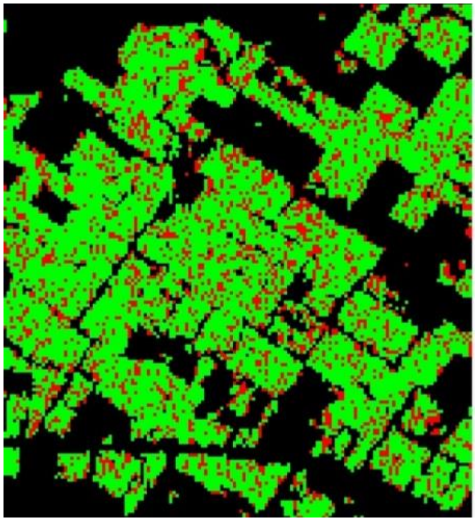
FCC Zoomed view

For healthy wheat spectral feature fitting (SFF) score is 0.914 and for wheat rust AVIRIS has 0.936 SFF w.r.t. field (ASD) data

Wheat mask



SAM classified image of healthy & diseased wheat



Absorption depth based classification in the range between 662 to 702 nm and 2155 to 2175 nm

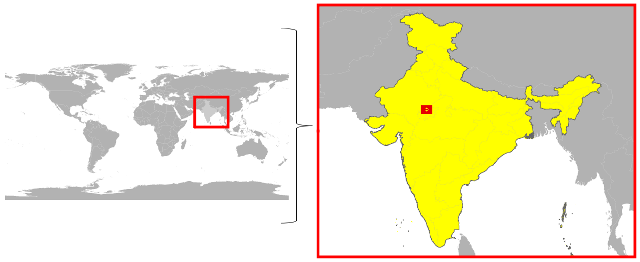
Normalized absorption depth x 100

3 - 6.8 (Diseased)

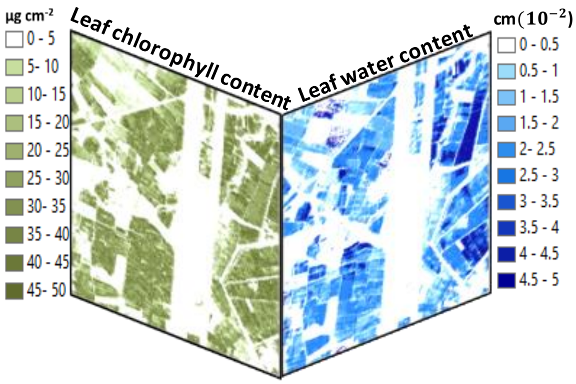
25 - 35.6 (Healthy)

Crop stress detection

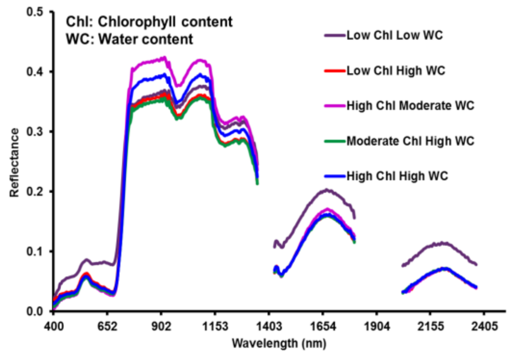
Rahul Nigam and B. K. Bhattacharya



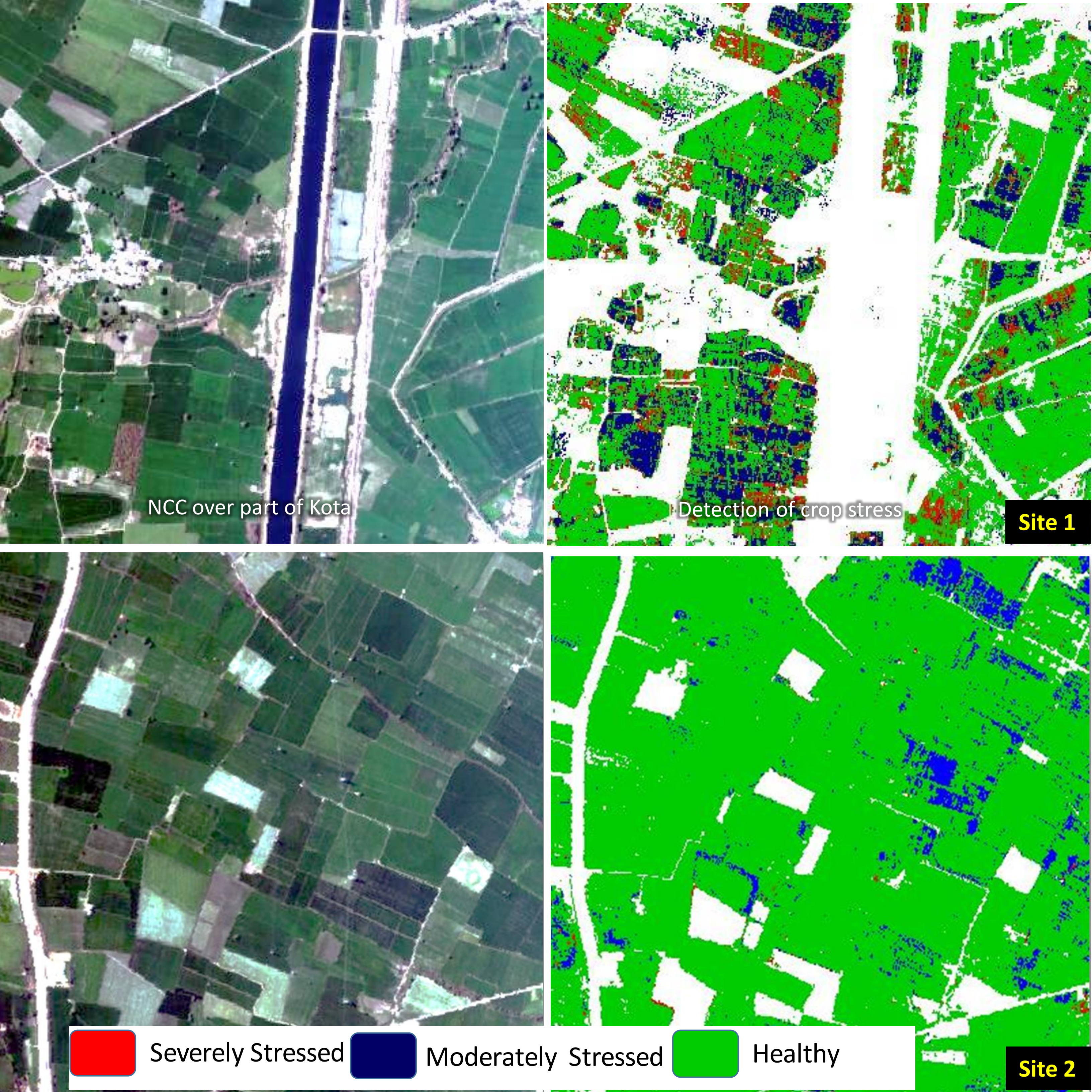
Crop biochemical parameters such as leaf chlorophyll and water content act as health indicators for crop growth and development. Any biotic and abiotic stress on crop leads to degradation in these two parameters. In the present study, two different sites at Kota (Rajasthan) were selected for retrieval of leaf chlorophyll and water content. Forward and inversion of canopy radiative transfer model was carried out to retrieve leaf biochemical content. To retrieve leaf chlorophyll six (451, 531, 551, 676, 700 µm) and water four (862, 1262, 1643, 2192 nm) AVIRIS-NG bands were used for inversion of CRT model. On the basis of retrieved chlorophyll and water content healthy, moderately and severely stressed agricultural area were identified.



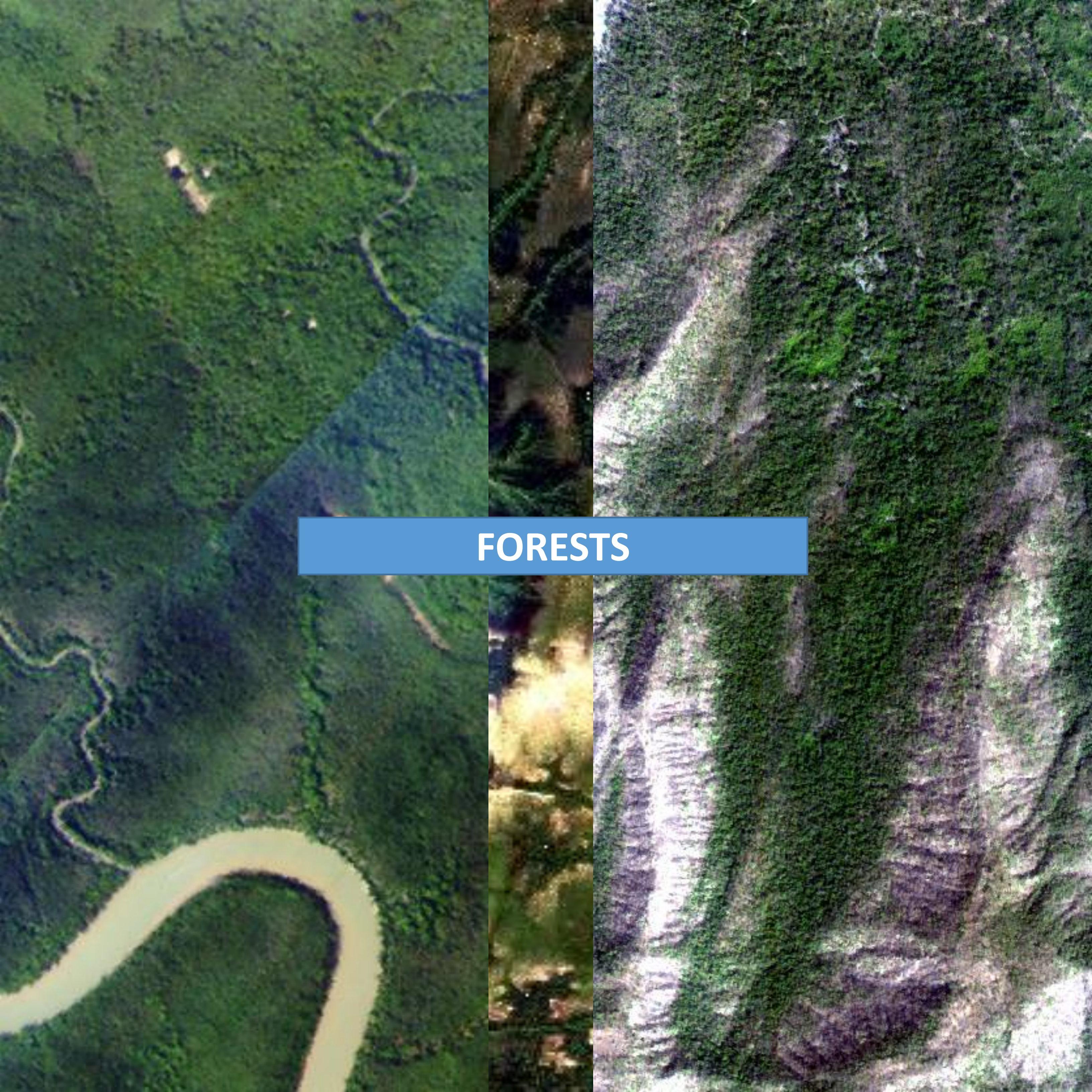
Retrieval of leaf biochemical parameter using hyperspectral remote sensing



Spectral profile over agriculture region from AVIRIS-NG

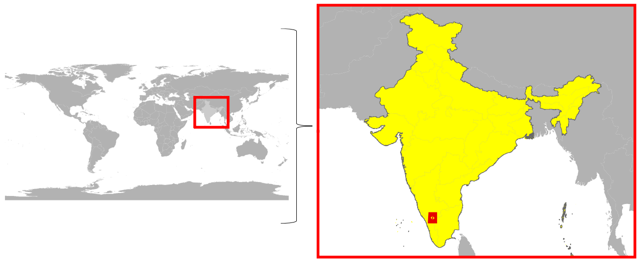


NCC over part of Kota
Detection of crop stress
Site 1
Site 2
Severely Stressed
Moderately Stressed
Healthy


FORESTS

Forest diversity mapping

Jayant Singhal, Rakesh, C. S. Reddy, G. Rajashekar and C. S. Jha



AVIRIS-NG data has been used in forest species and α-diversity mapping at community level. Accurate knowledge of the distribution of species will help the scientific community in better understanding and managing ecosystems and preserving biological diversity. Dominant species in the study area were mapped using AVIRIS data. AVIRIS images for the given area were used to collect the image spectra for the corresponding species/community. Spectral Angle Mapper classification technique was used for species mapping. AVIRIS-NG hyperspectral airborne data was also used to characterize the α-diversity of a forest by estimating Shannon index H’ for the given region. Pixels in a 1 ha cell were classified into spectral species and considering it as population the Shannon index H’ for 1 ha cells were calculated. This 1 ha resolution map will be calibrated with field measurements for Shannon index H.

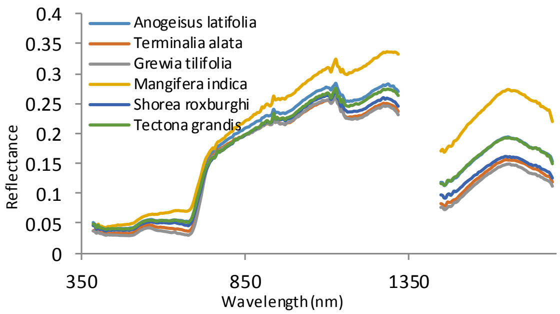
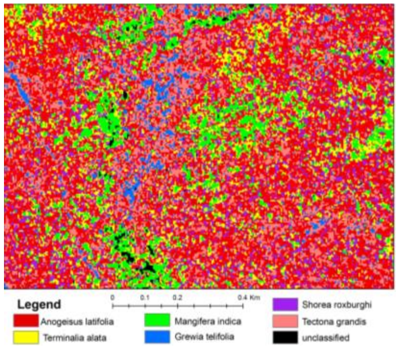
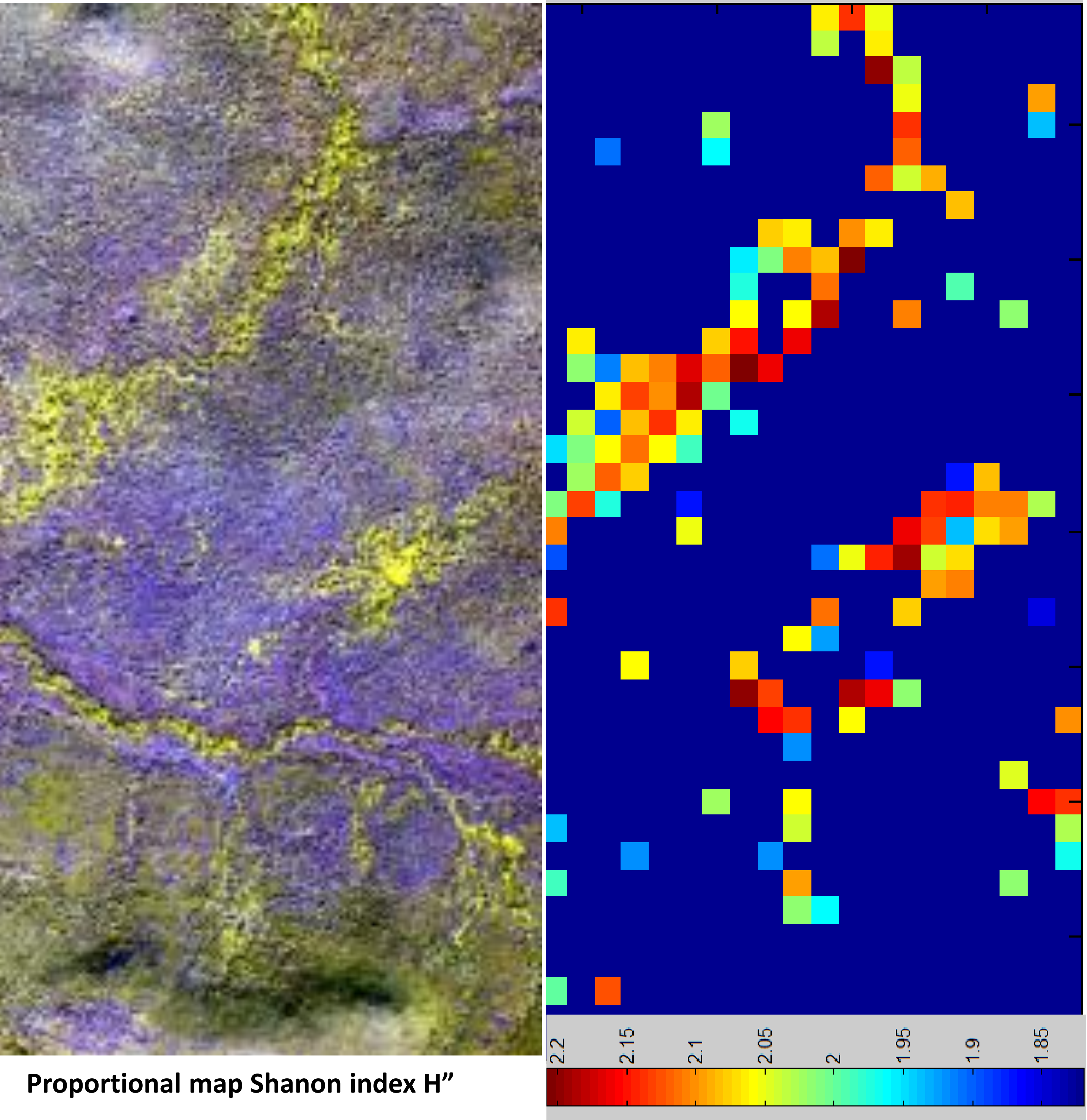


Image Spectra of dominant species



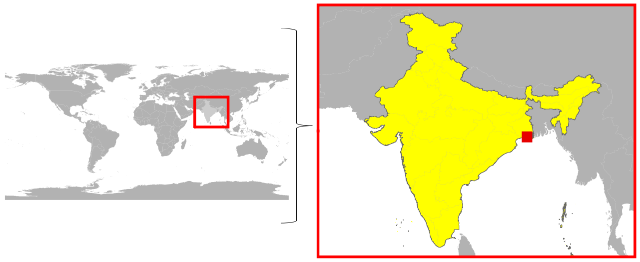
Dominant Species map



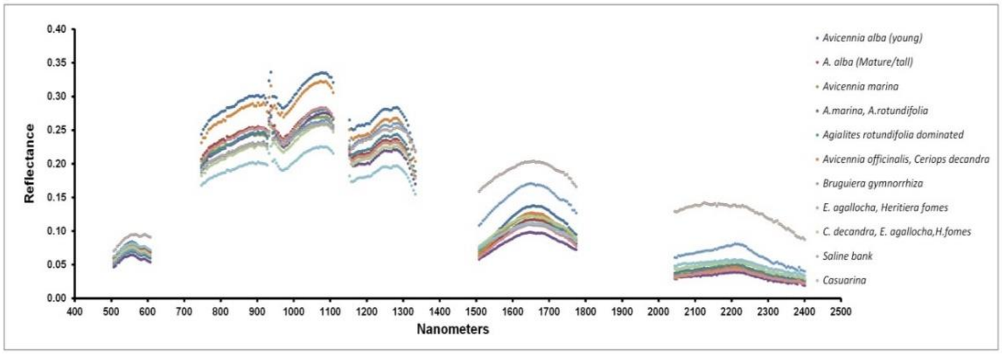
Proportional map Shanon index H"

Mangroves assemblage in Sundarbans

Sudip Manna, Susanto Pal, Nilima Rani Chaube, Arundhati Misra and Sugata Hazra

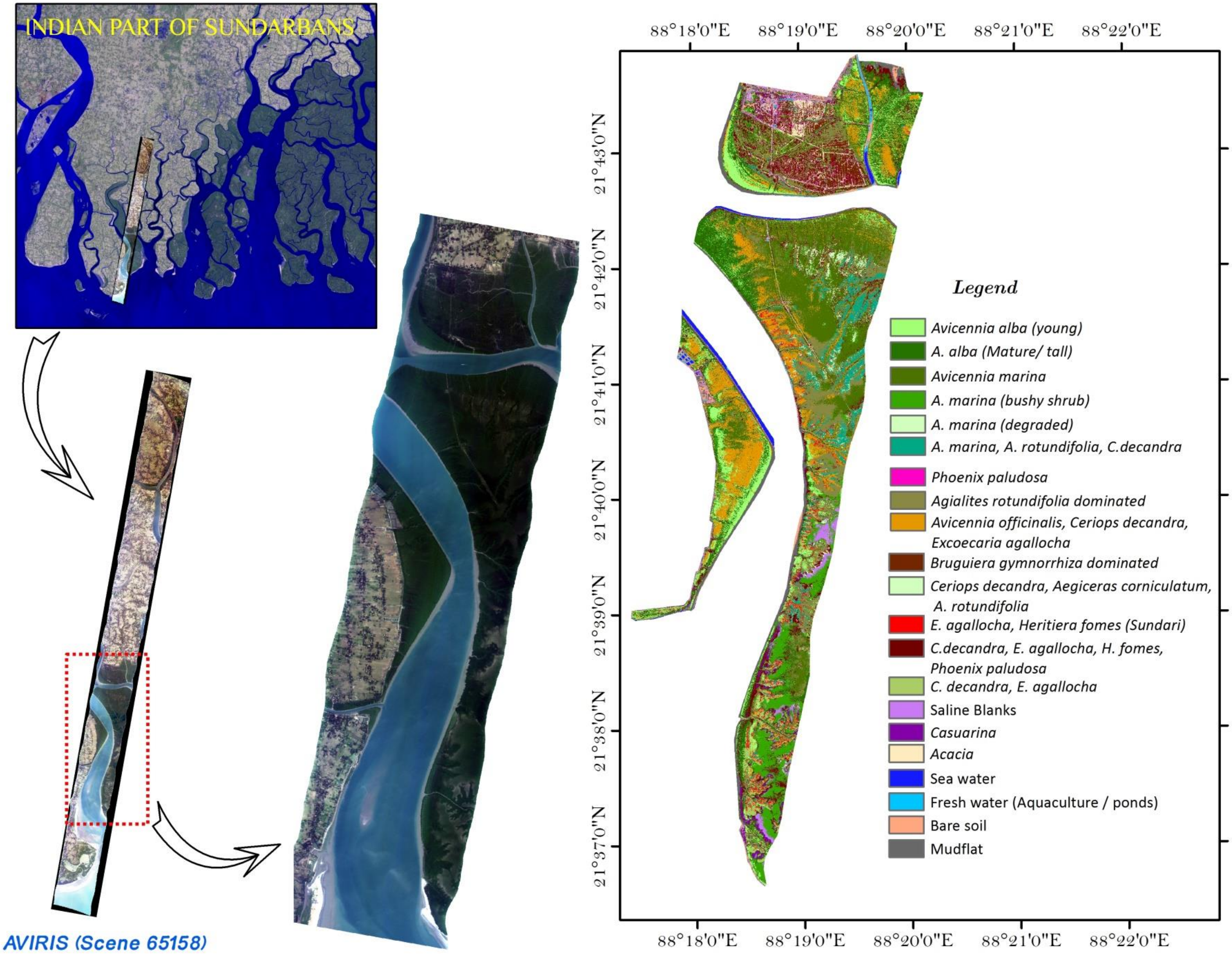


Sundarbans is world's largest contiguous mangrove forest. Mapping different mangroves within this site is essential for any scientific conservation. AVIRIS-NG hyperspectral image enabled discrimination between mangrove species and assemblages of different species. Support vector machine (SVM) has been used for classifying the mangroves. In-situ assessment of soil salinity and nutrient depict a positive relation of mangrove's health with low salinity and lower nutrient availability. Sundari (*Heritiera fomes*), a mesohaline mangrove, now rare in Indian part, has been found to occur at the lowest salinity zones. Edaphic physico-chemical parameters and geomorphological settings are observed to play crucial role in the mangrove's health indicated by varying canopy density and slenderness coefficient of same species occurring at spatial locations with contrasting physicochemical attributes.



Spectral Profiles of mangrove species and associated land-covers

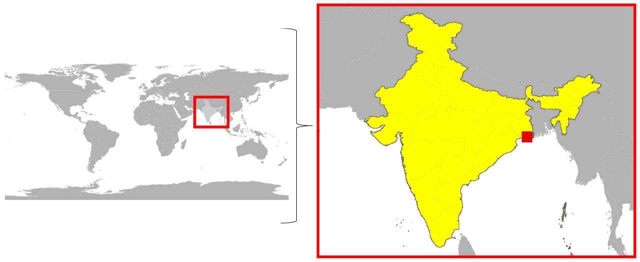
Distribution of Sundari (*Heritiera fomes*)



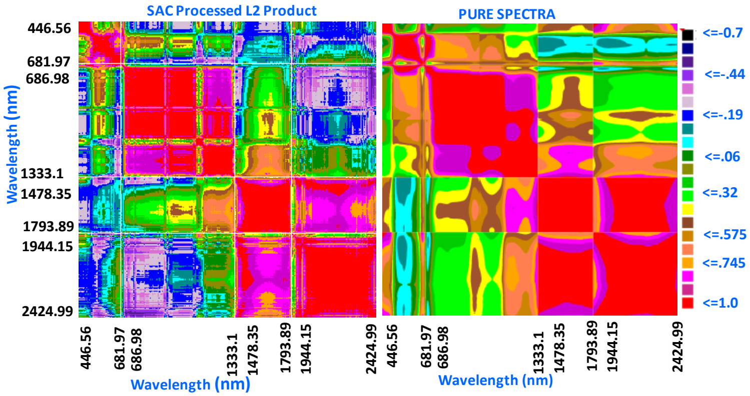
Mangrove species and assemblage map of Lothian, Indian Sundarbans from AVIRIS-NG hyperspectral data.

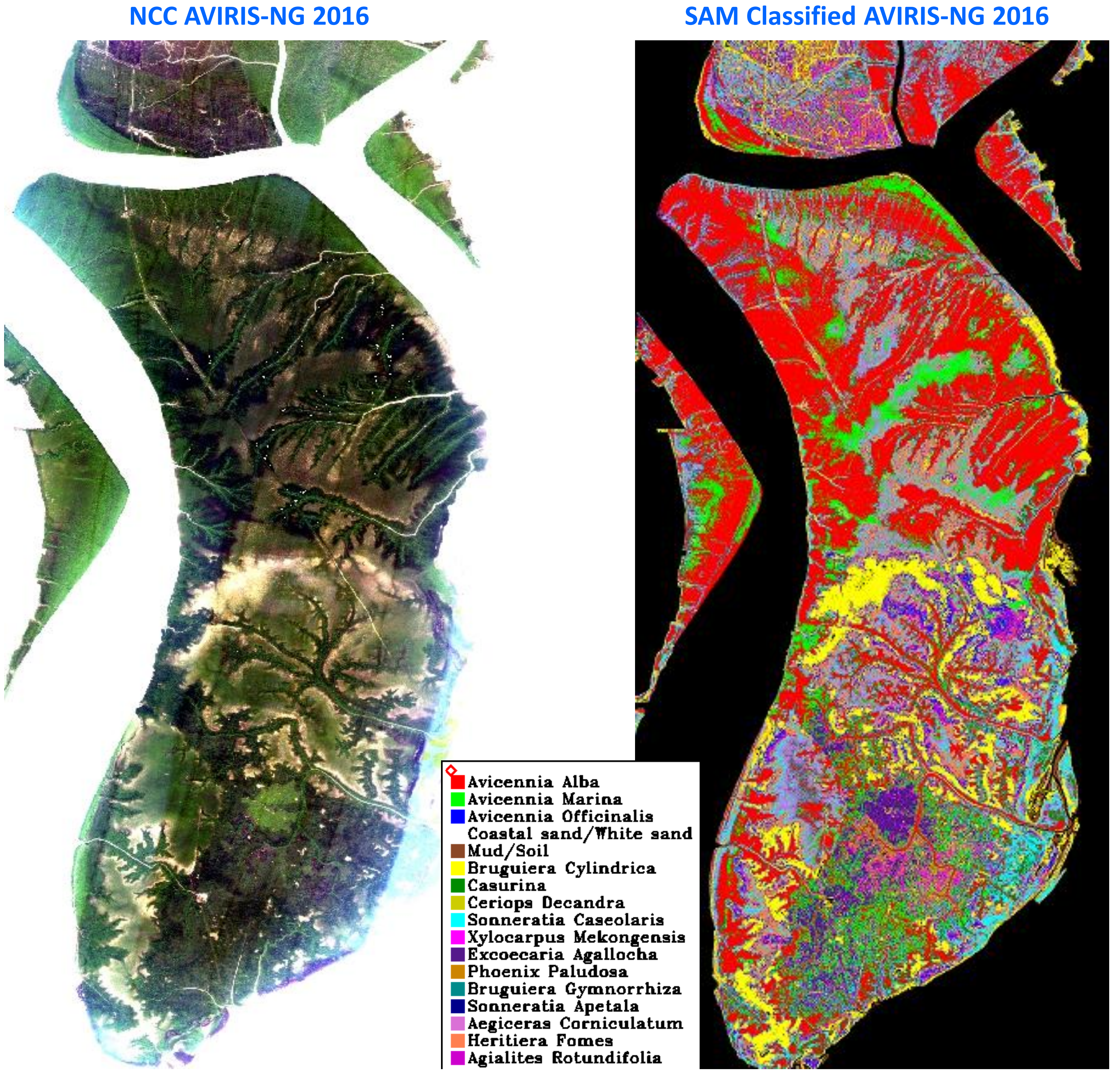
Mangroves species discrimination

Nilima Rani Chaube



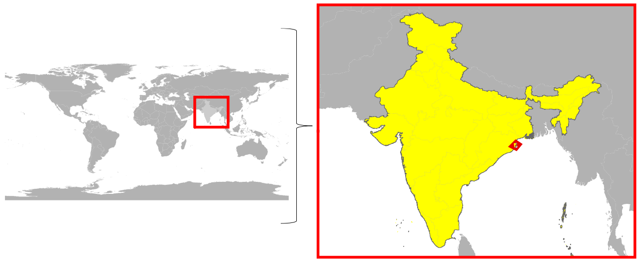
AVIRIS-NG hyperspectral airborne data was acquired over Lothian island, Sunderban on 5 March 2016. Synchronous *in-situ* data was collected using spectro-radiometer for generating mangrove hyperspectral library. Twenty mangrove species were identified during ground truth. Appropriate bands of AVIRIS data are selected by analysing spectro-radiometer data for various species. A comparison of correlation of different wavelengths is depicted between SAC processed L2 product and the pure spectra of a particular species. Fifteen mangrove species out of 20 are discriminated using Spectral Angle Mapper (SAM) classifier. Classification is verified using geotagged mangrove species ground truth data. Natural Colour Composite (NCC) image and SAM classified images are shown, which are generated using AVIRIS-NG data.



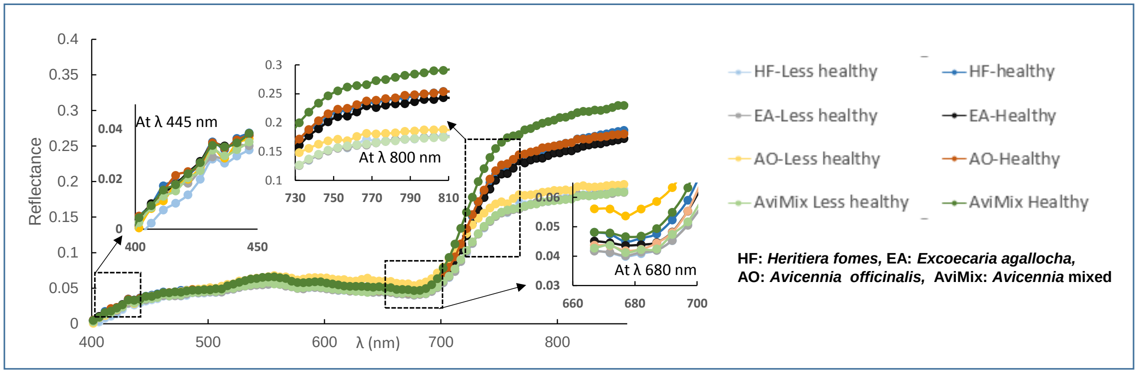

NCC AVIRIS-NG 2016
SAM Classified AVIRIS-NG 2016
Avicennia Alba
Avicennia Marina
Avicennia Officinalis
Coastal sand/White sand
Mud/Soil
Bruguiera Cylindrica
Casurina
Ceriops Decandra
Sonneratia Caseolaris
Xylocarpus Mekongensis
Excoecaria Agallocha
Phoenix Paludosa
Bruguiera Gymnorrhiza
Sonneratia Apetala
Aegiceras Corniculatum
Heritiera Fomes
Agialites Rotundifolia

Mangrove health assessment

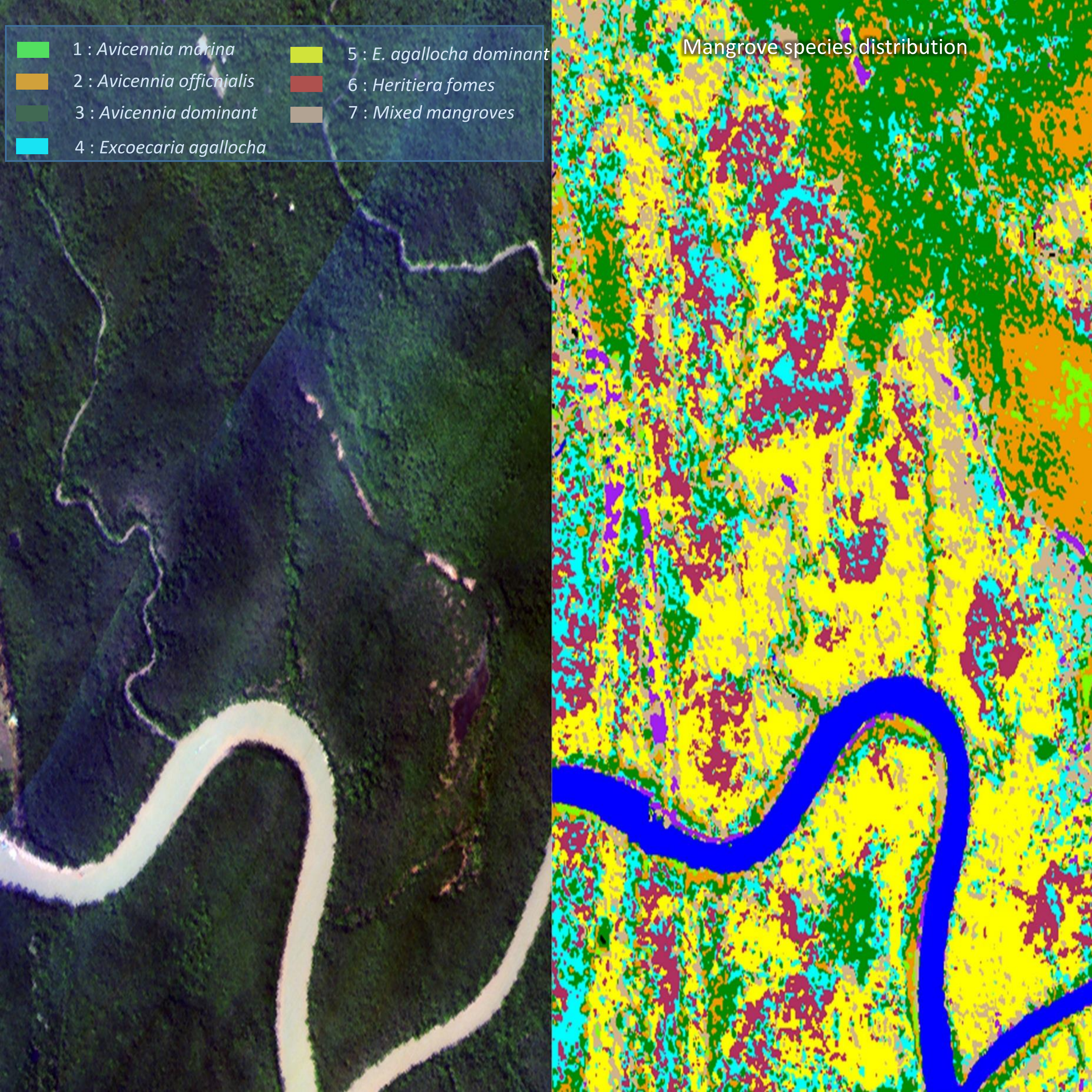
Nikhil Lele and T. V. R. Murthy



Mangroves are typically found in coastal areas where fresh water and salt water co-exist. Owing to accessibility problems and field limitation, lesser is known about species distribution in mangrove areas. AVIRIS-NG airborne data was used to discriminate species in Bhitarkanika mangroves. Dominant and mixed patches of *Exocecaria agallocha, Heritiera fomes and Avicennia* assemblages were discriminated using Spectral Angle Mapper technique. Mangrove health assessment based on greenness and light use efficiency based index was derived using air-borne data and effect of health was studied on vegetation spectra. It was observed that red-edge of chlorophyll absorption and NIR spectra have shown varied spectral response corresponding to their health.

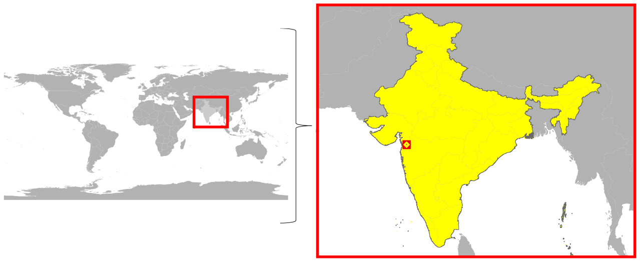


Differences in red-edge region and near infra-red region of healthy and less healthy spectra of same species- as studied in 4 different mangrove species

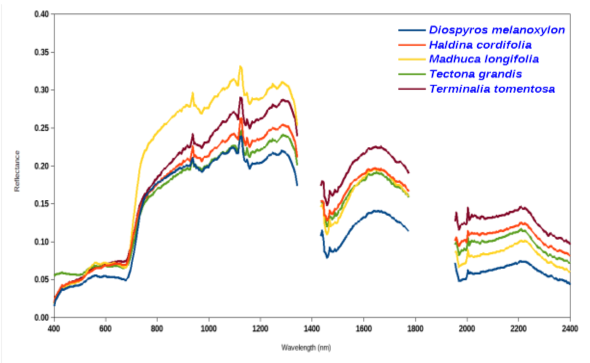

1 : Avicennia marina
2 : Avicennia officnialis
3 : Avicennia dominant
4 : Excoecaria agallocha
5 : E. agallocha dominant
6 : Heritiera fomes
7 : Mixed mangroves
Mangrove species distribution

Deciduous forest species discrimination

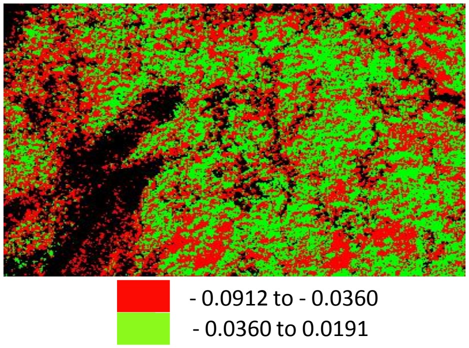
Amrita Chaurasia, Maulik Dave, Reshma Parmar and N. S. R. Krishnayya



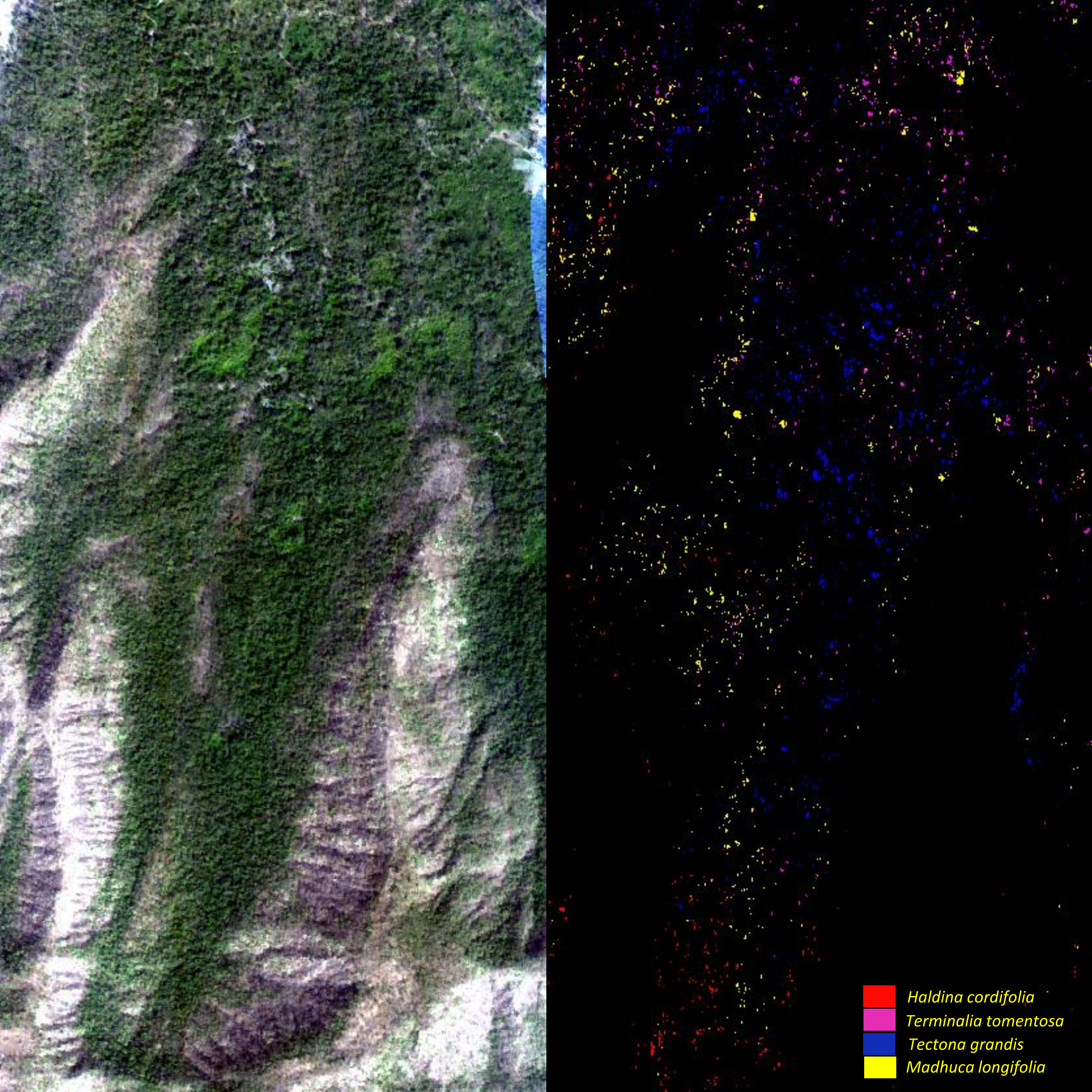
Trees of deciduous forest covers show distinctive phenology. Phenological changes not only get manifested because of tree diversity but also because of their response to local climatic variables such as rainfall. Leaf age variability, seen across canopies of dominant tree species, is reflected in bringing out variations in inter-species spectra. Wider range of Photochemical Reflectance Index (PRI) values is indicative of tree diversity and corresponding phenological dynamics of these deciduous covers. High resolution datasets like AVIRIS – NG, used here, can assist better in retrieving phenology dynamics of highly diverse covers of Indian subcontinent with better precision. This immensely improves phenology linked productivity estimates of deciduous forest covers.



Spectral Profiles of 5 Dominant Species

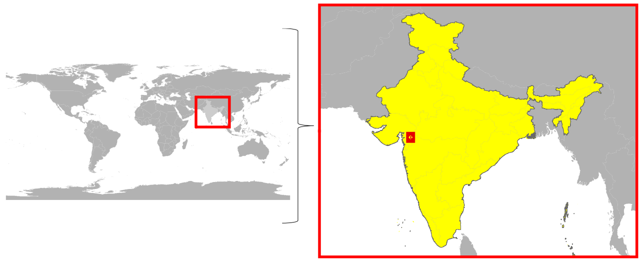


Photochemical Reflectance Index of Deciduous Forest

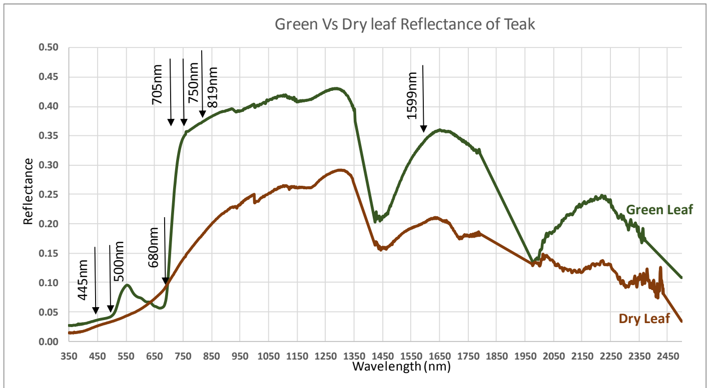

Haldina cordifolia
Terminalia tomentosa
Tectona grandis
Madhuca longifolia

Forest fuel load assessment

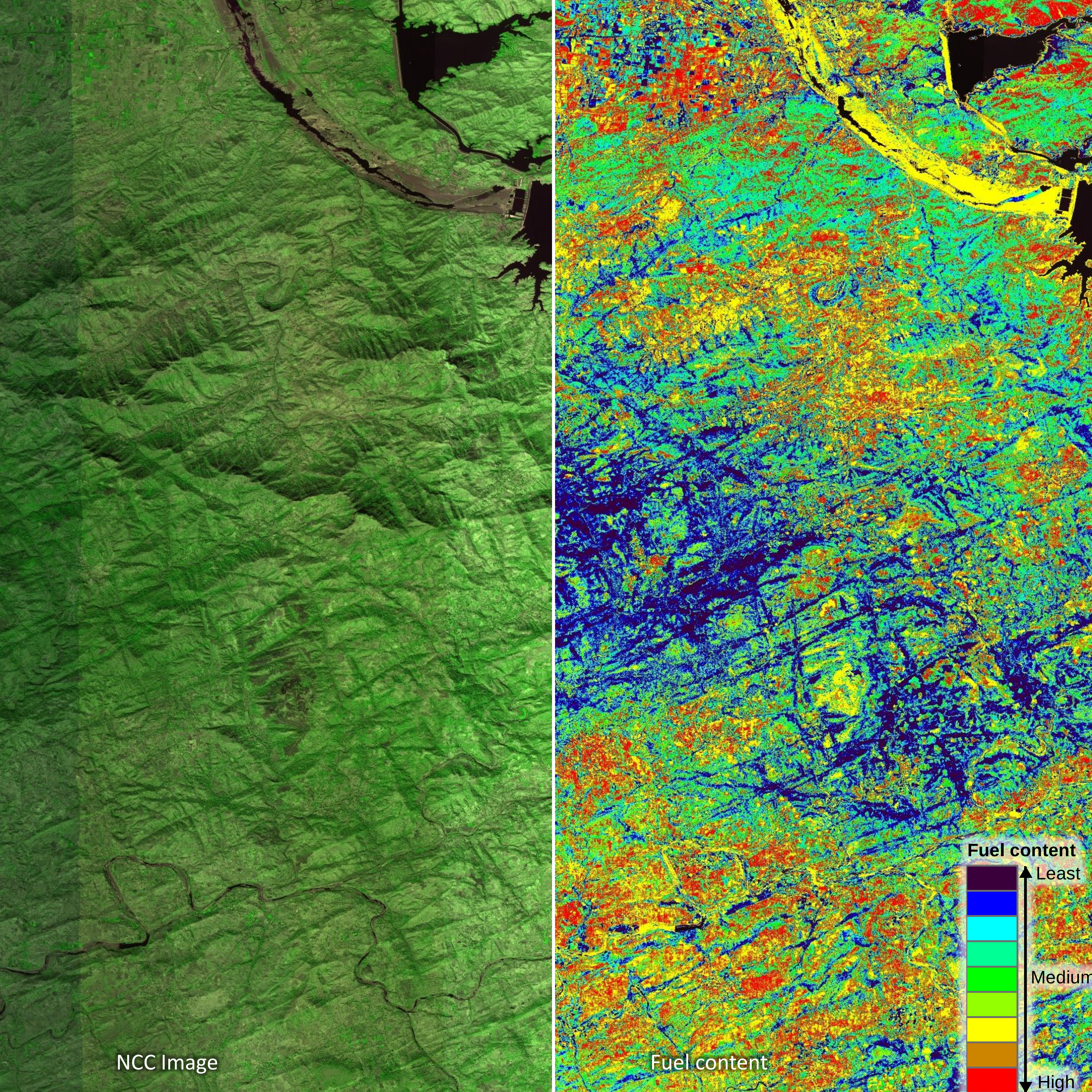
C. P. Singh and Jakesh Mohapatra



Fire fuel analysis is primarily based on indices which can show the bulk amount of green vegetation, the water content and dry or senescent carbon. In Shoolpaneshwar area the AVIRIS-NG data acquisition coincided with the prime senescence period for the deciduous trees of the area. Therefore, the deciduous trees having large amount of leaf litter on the surface were prone to encounter possible fire outbreak due to high presence of fire fuel. The areas having green canopy with good canopy closure is expected to reduce the detection of fire prone dry shrubs beneath the green canopy because dry or senescent indices are only sensitive to the top layer of the vegetation, causing the dry vegetation beneath it to be obscured by the upper layer of green vegetation.



Green Vs Dry Leaf Reflectance of Teak and AVIRIS bands used for fire fuel characterisation


NCC Image
Fuel content
Fuel content
Least
Medium
High

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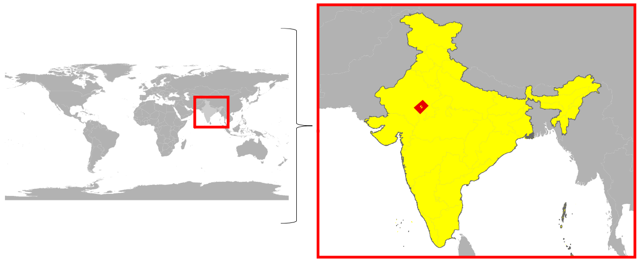
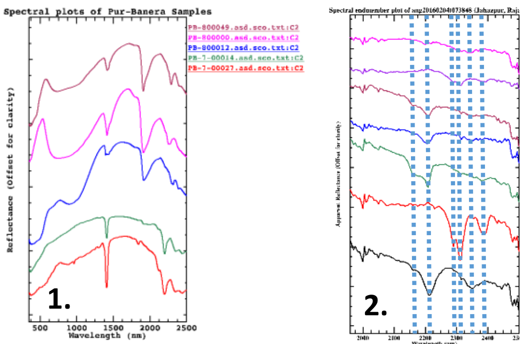
MINERAL EXPLORATION

Mineralogical appraisal

Satadru Bhattacharya, Aditya Dagar and Sumit Pathak

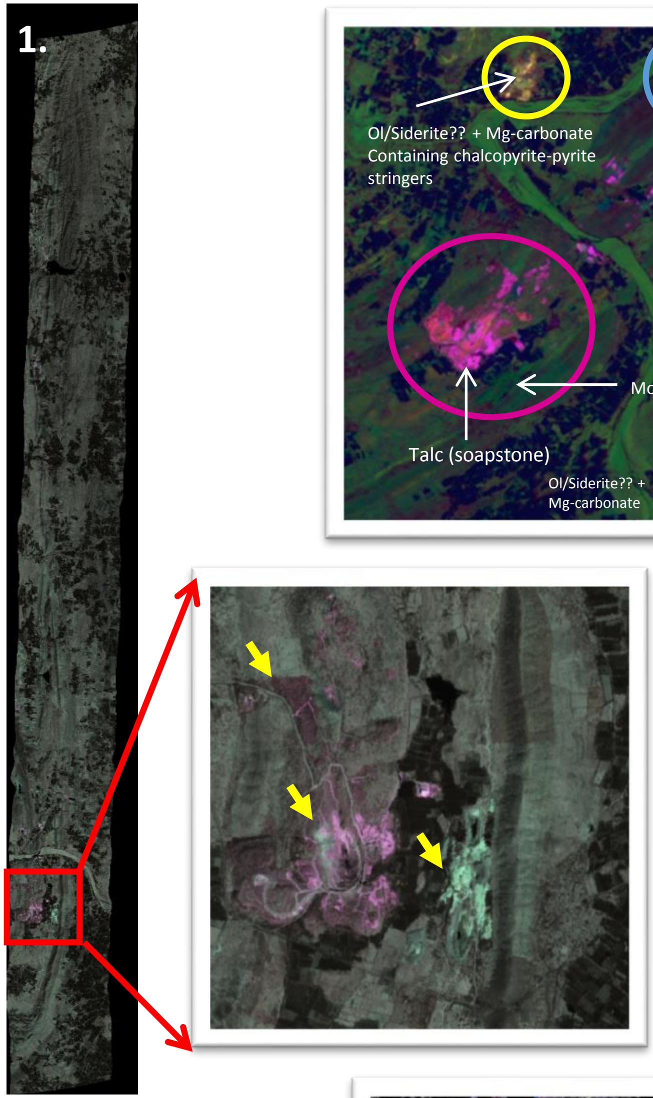


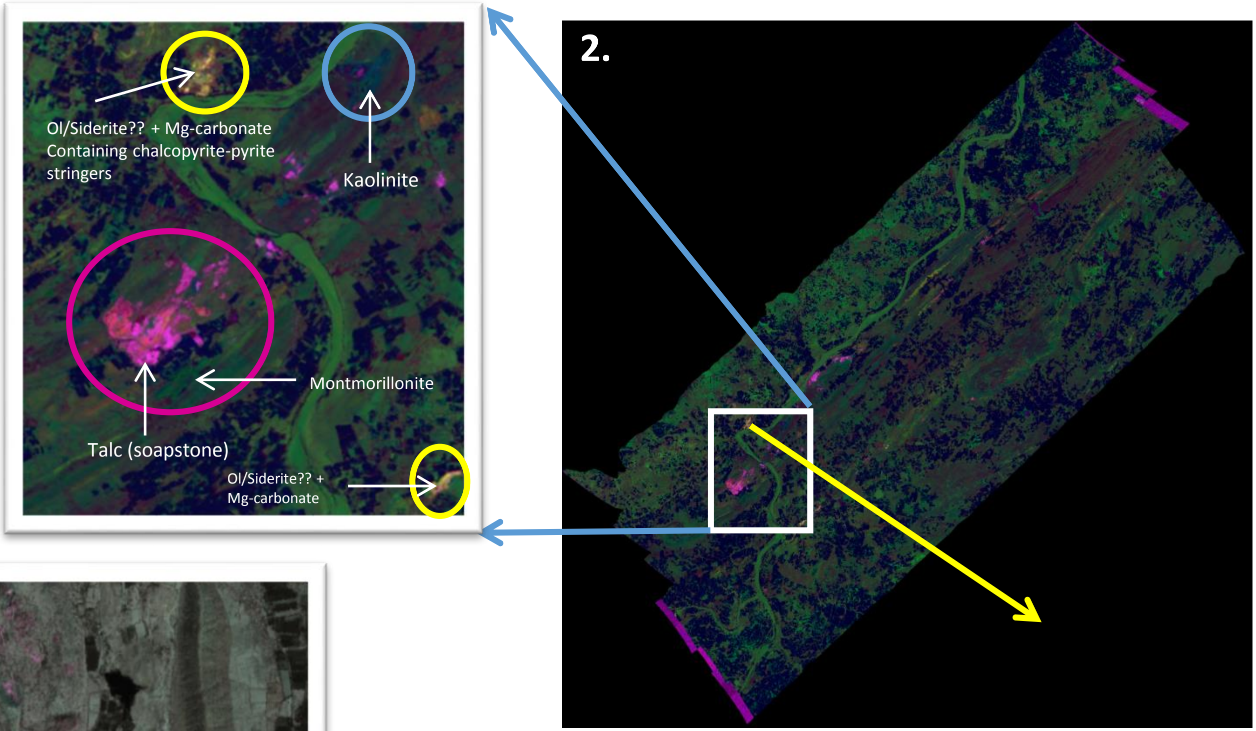
Initial analysis of AVIRIS-NG airborne data over Jahazpur and surrounding mineralized belts of Rajasthan reveals some exciting results in terms of host rock characterization. Geochemical analyses and spectral-compositional analysis have been carried out on the rock and soil samples collected from the field areas. The spectral analyses of these areas suggest that the principle mineralogies are Mg-Carbonates, Talc bearing lithologies and other associated clay minerals, i.e. Montmorillonite and Kaolinite. In the present study, Integrated Band Depth (IBD) parameters have been developed to completely characterize absorption features arising due to electronic transition of Fe^{3+} in the crystal lattice of Fe-oxides and oxyhydroxides and those arising due to combination tones of metal-OH stretching and bending and also due to combination and overtones of $(CO_3)^{2-}$ fundamentals.



Reflectance spectra of Pur-Banera (1) and Jahazpur (2) region using AVIRIS-NG.

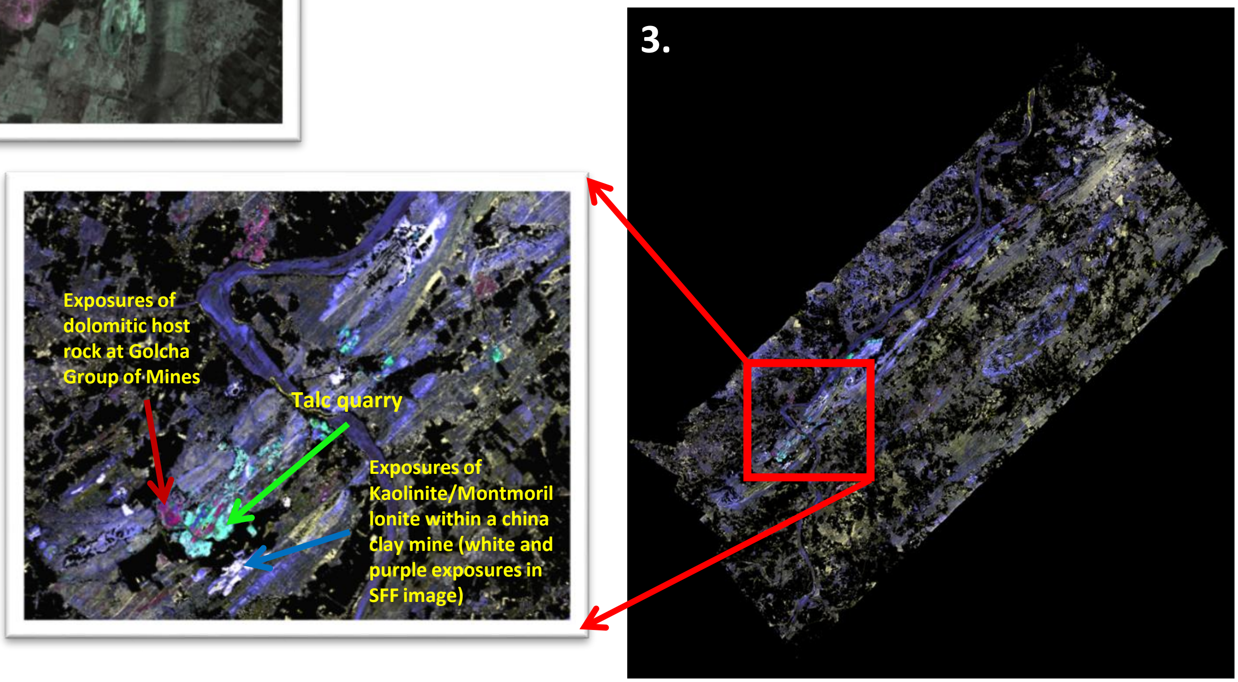
Field photographs





2. False Color Composite (FCC) obtained by assigning Red Channel to 2310-nm Mg-carbonate Band Depth (BD) Parameter; Green to 1030-nm Olivine (Ol) BD and Blue to 2200-nm Clay BD parameter. In this FCC, combined olivine- and carbonate-bearing pixels appear in Yellow, Mg-carbonates in red to Orange to maroon, and soap stones (Talc) in magenta, Kaolinite in bluish green and Montmorillonite in dark green.

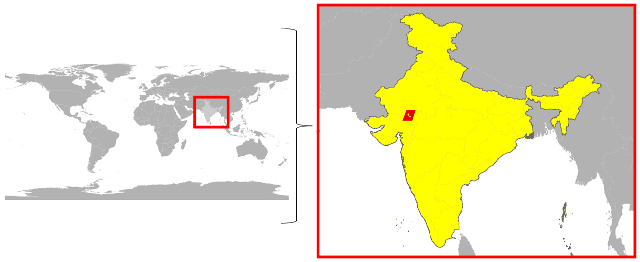
1. RGB FCC of one of the six scenes of ANG covering parts of Jahazpur region obtained by assigning 2345-nm ANG channel to Red; 2209-nm ANG channel to Green; 2389-nm channel to Blue.



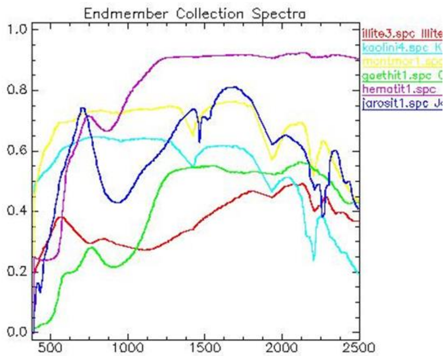
3. SFF-based mineralogical mapping of Mg-carbonate-, talc- and kaolinite-Montmorillonite bearing exposures In the southwestern part of the Western Jahazpur Belt, Rajasthan.

Mineral mapping

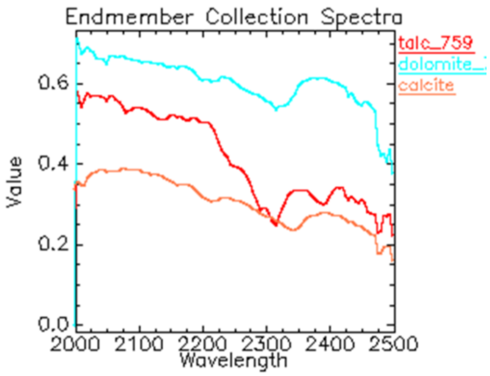
Richa U. Sharma, Vivek Sengar and P. K. Champatiray



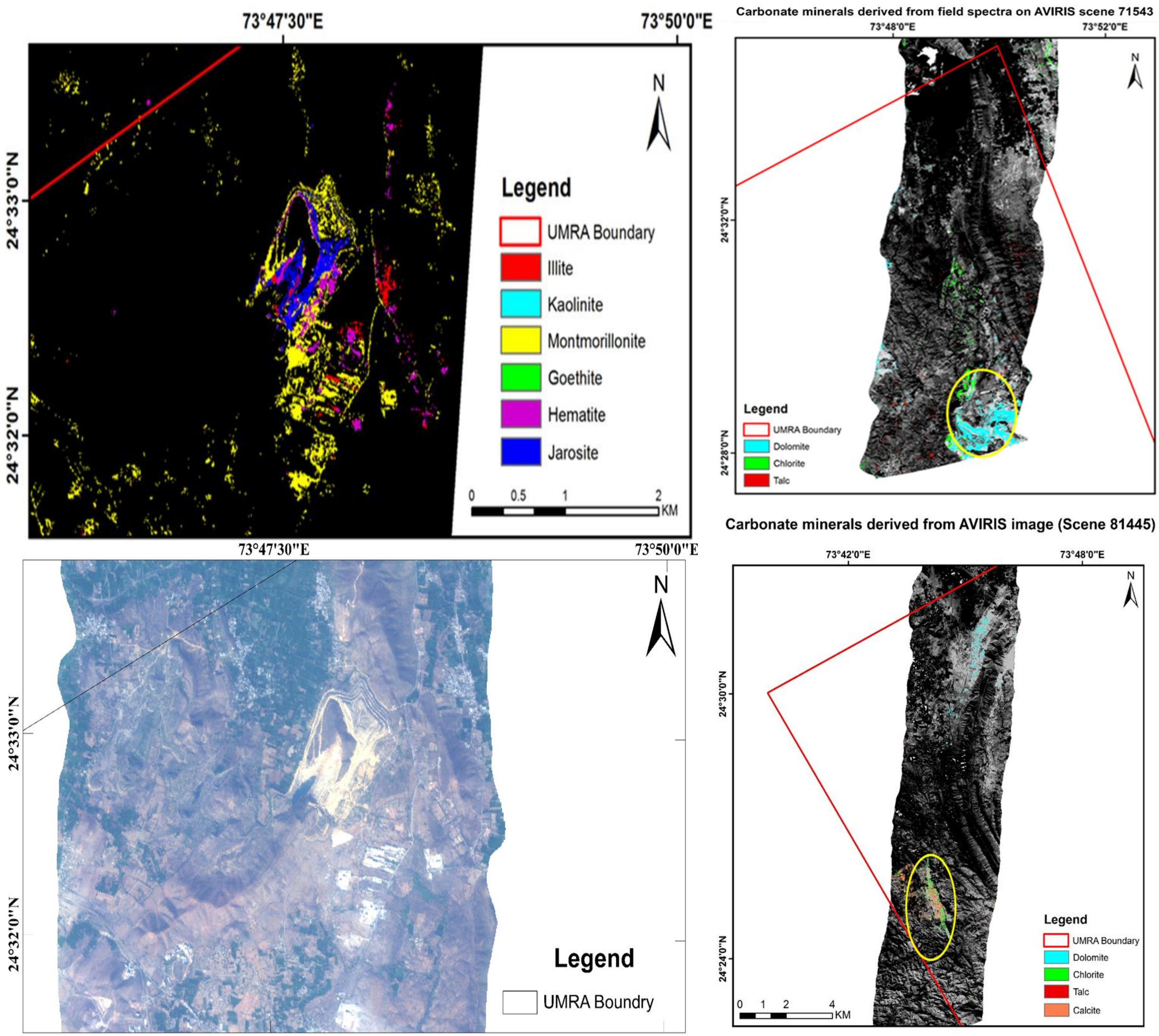
For this study the AVIRIS NG data is used to study the spectral characteristics of minerals present in the area. The image derived endmembers were identified clay and iron minerals and carbonates. Talc is kept in this group because the Talc is associated with the Dolomite in this area, formed via a reaction between Dolomite and Silica, by silica-flooding in contact metamorphic aureoles. The figures below shows spectra of the clay and iron minerals and carbonates. In the scene 71543 the circled part shows dolomite in the Jhamarkotra mines for rock phosphate where the host rock for rock phosphate mineralization is Stromatolitic Dolomite. The scene 81445 shows the mineral Calcite and Chlorite at Babarmal mine (circled) of pink marble.



Spectral plot of the clay and iron minerals



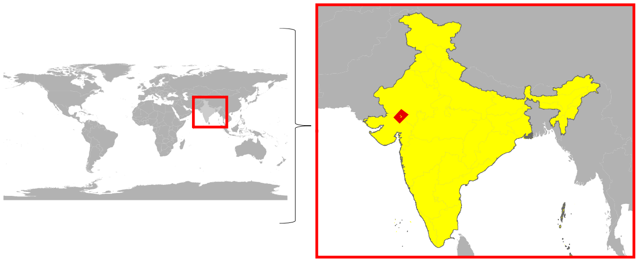
Spectral plot generated by AVIRIS image for Calcite, Dolomite and Talc is in the range of 2—2.5 µm



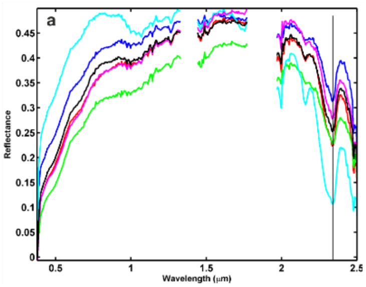
TCC of the AVIRIS image and distribution of the clay and iron minerals (left) and carbonates (right) in the part of Umra area, Rajasthan

Mapping marble deposits

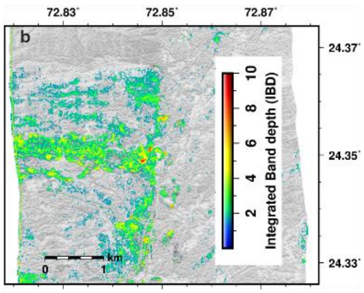
Hrishikesh Kumar and A. S. Rajawat



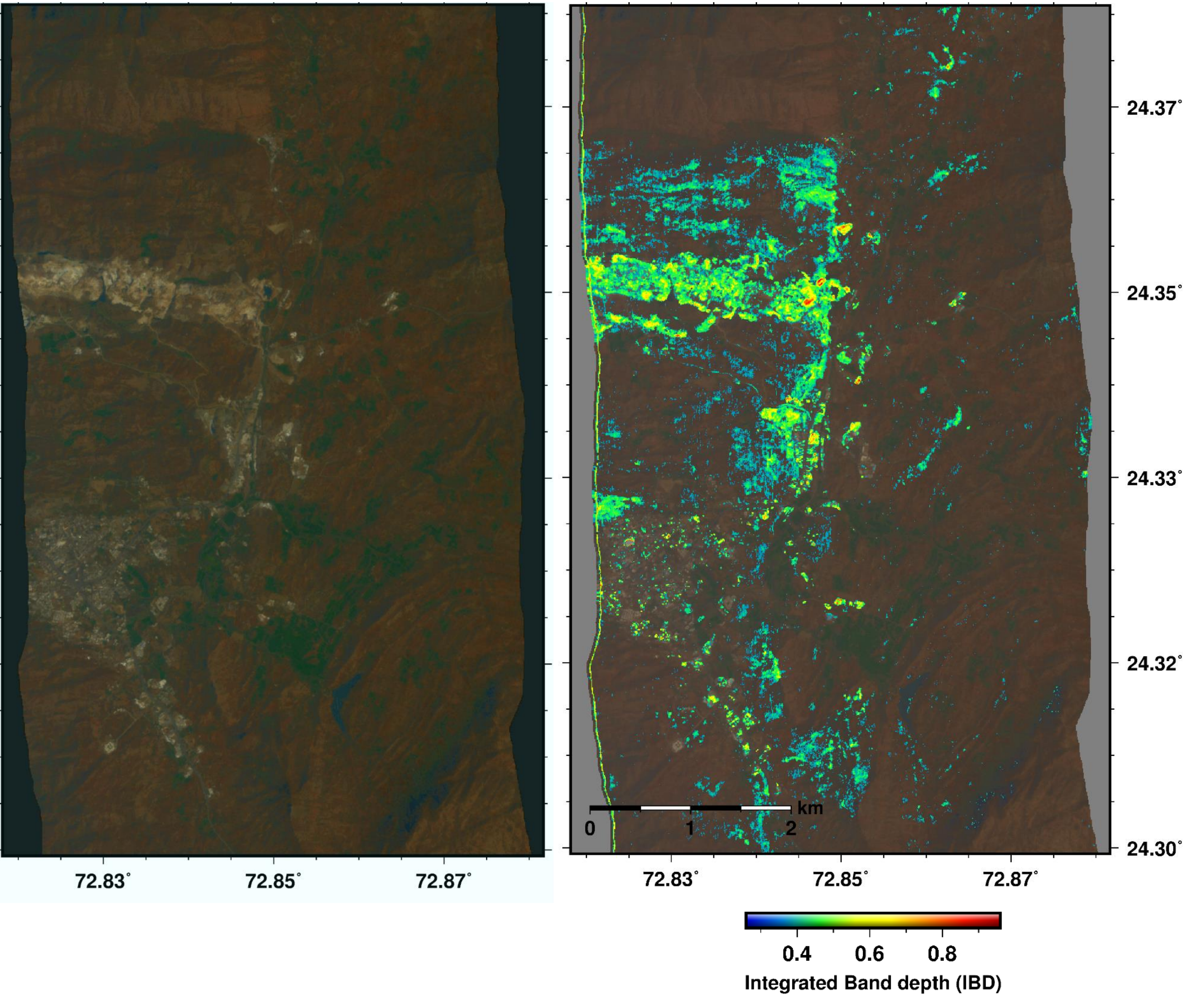
Mineralisation is governed by chemistry of mineralizing fluid, structure and lithology. Various indicators of mineralisation such as alteration zones and gossans exist on the surface are amenable for remote sensing studies. Hyperspectral data sets are used to identify individual species of iron and clay minerals which are key constituents of gossans and alteration zones respectively. Mapping of alteration zones and gossans along with structural information helps in locating favourable zones of precious metals which are generally taken up for detailed field based investigations. An example demonstrating potentials of hyperspectral data acquired by AVIRIS-NG for mapping marbles (carbonates) in parts of Ambaji, Gujarat is shown in figure below along with spectra of marble (calcite). Spatial distribution of marble is mapped using Integrated Band Depth (IBD) approach. Higher value the value of integrated band depth, more is the abundance of marble at that pixel.



Reflectance Spectra of marble from AVIRIS-NG over Ambaji



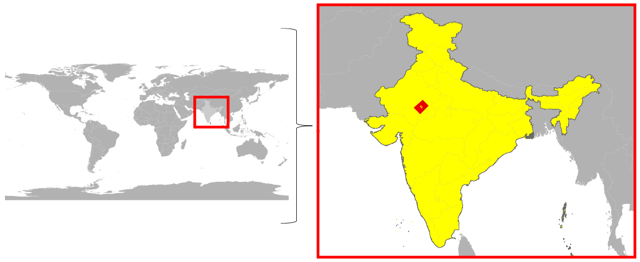
Map showing distribution of marbles



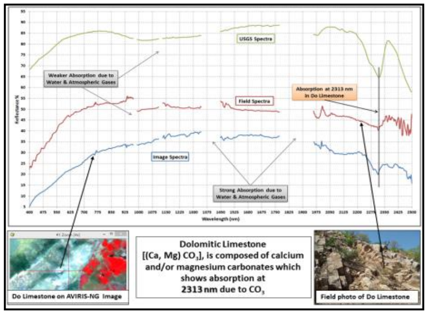
Natural Colour Composite (NCC) image and distribution of marble rich region mapped using IBD technique and overlaid on NCC image

Inventory of base metal deposits

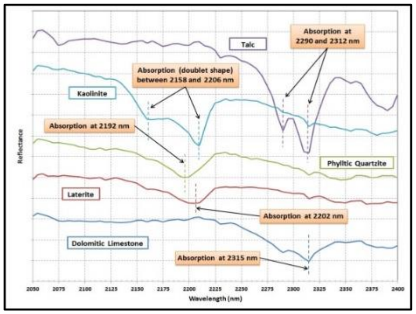
B. K. Bhadra, Suparn Pathak and Ankit Gupta



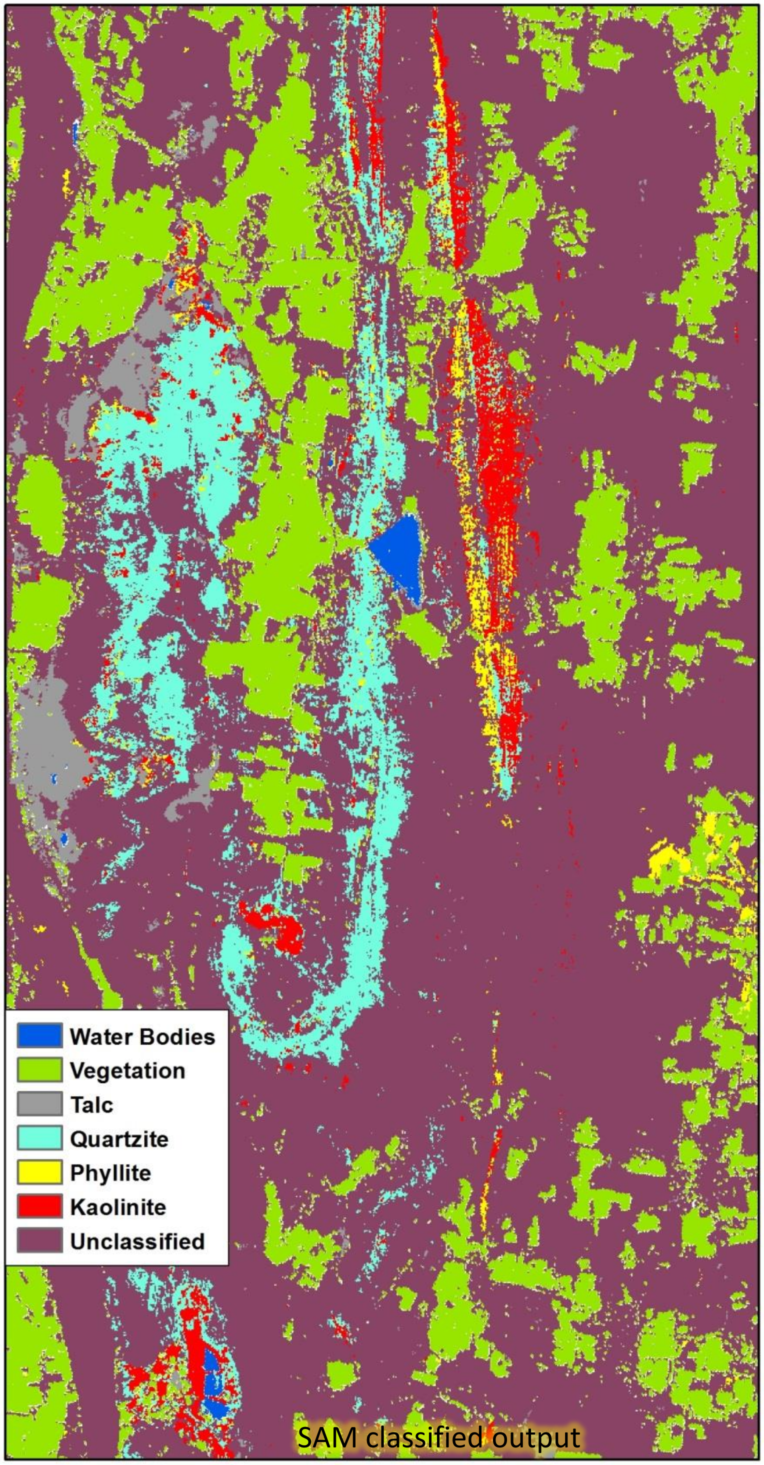
Airborne hyperspectral data (AVIRIS-NG) has the potential to identify base metal deposits due to it's better spectral and spatial resolution. Specific bands in SWIR region are very useful in detection of hydrothermally altered hydroxyl bearing minerals. The present study highlights the efficacy of AVIRIS-NG data along with the field spectroradiometer observations in Jahazpur belt of Bhilwara district of Rajasthan. The study area is comprised of quartzite, dolomite, phyllite and tuff which act as host rocks for Pb, Zn and Cu minerals. Processed image data is integrated with the ground information like geology, field spectra and geochemical analysis of rocks/minerals/soil samples. It has been observed that Dolomitic limestone is characterised by an absorption dip at 2313 nm due to CO_3 absorption. Strong absorption features for Laterite is found at 2201 nm and Carbonaceous Phyllite at 2192 nm.



Spectral Profiles of Do Limestone



Spectral Profiles of rocks/minerals


Water Bodies
Vegetation
Talc
Quartzite
Phyllite
Kaolinite
Unclassified
SAM classified output

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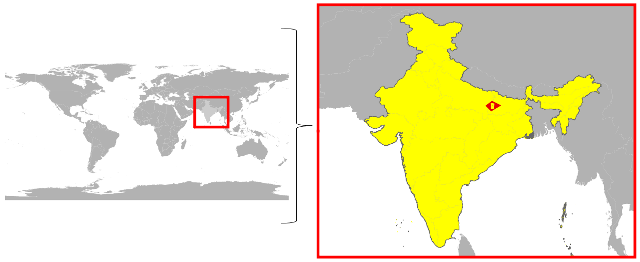
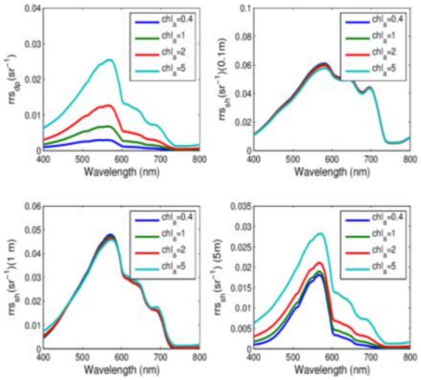
WATER QUALITY AND ECOSYSTEM
(RIVER, COASTAL & OCEAN)

River water quality assessment

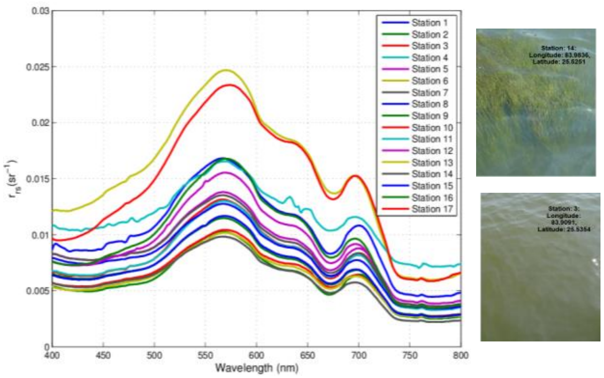
Shard Chander and Ashwin Gujrati



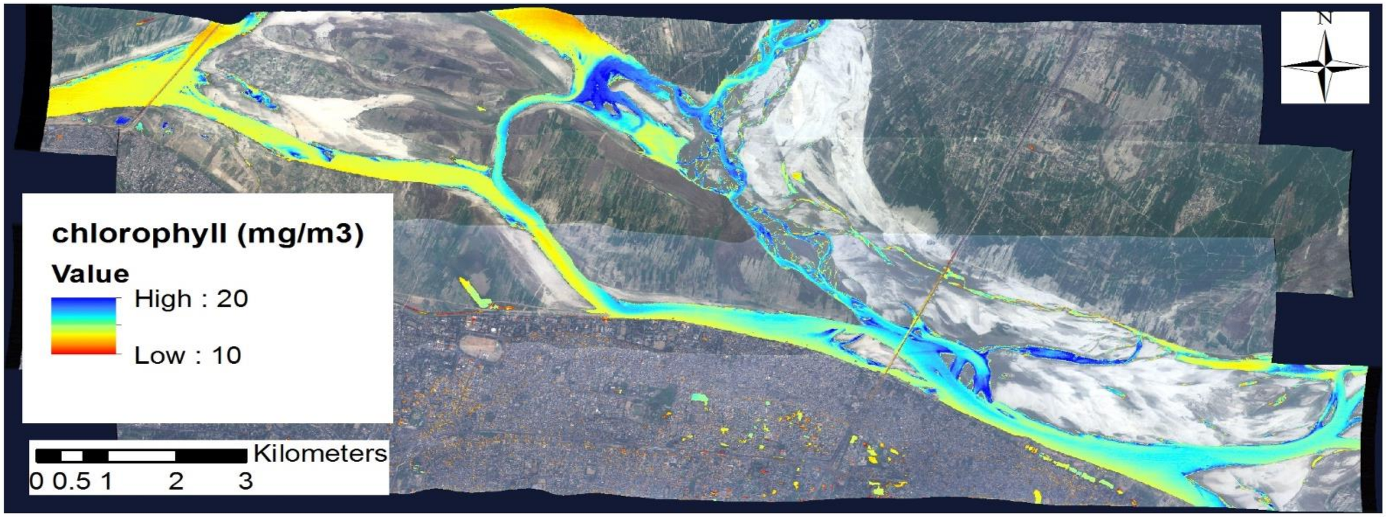
The aim of this study was to utilized high spectral and spatial resolution AVIRIS-NG dataset to measure Water Quality parameters over complex inland systems. We have investigated both empirical and radiative-transfer driven methods to map suspended sediment concentration (SSC), chlorophyll, and colored dissolved organic matter (CDOM) concentration from the water column over Ganga river. The remote sensing reflectance was simulated using forward simulations for various optical properties of water and for different water depth. The AVIRIS and field ASD measured reflectance was inverted to obtain the inherent optical properties of water to retrieve the main constituent's concentration. One of the key deliverables is the water quality maps of inland water bodies.



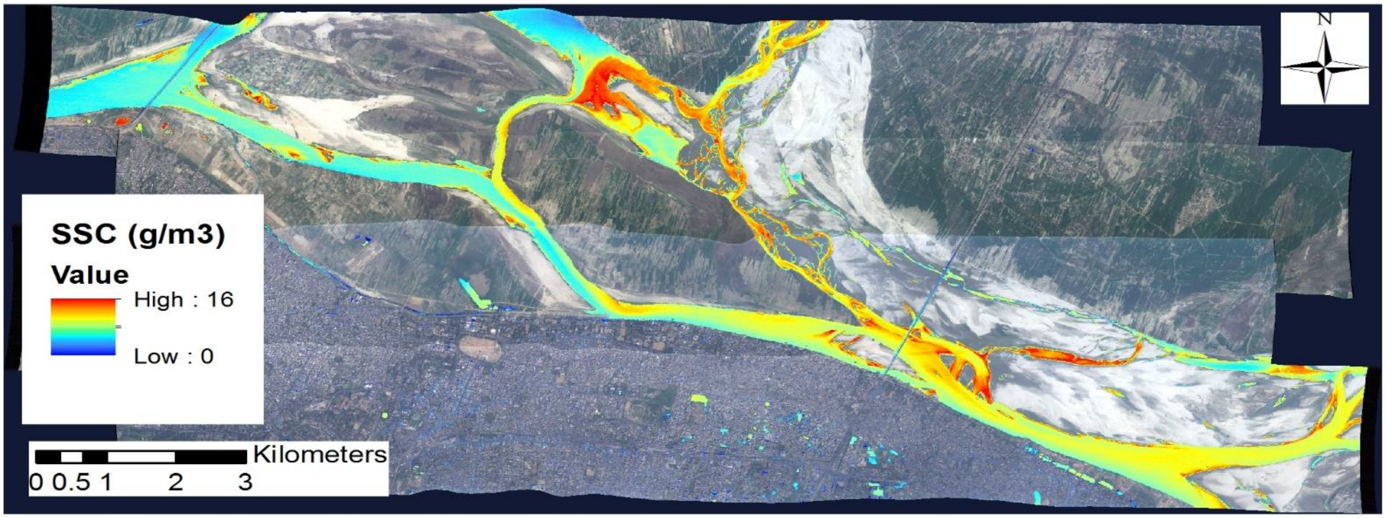
Simulations of Remote Sensing Reflectance's with Depth and varying water quality properties



Field measured reflectance over Ganga River, Buxar during AVIRIS-NG flight Campaign

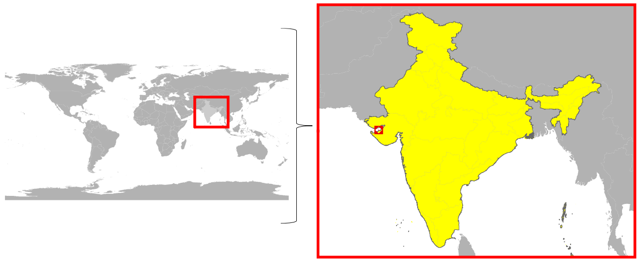

chlorophyll (mg/m3)
Value
High : 20
Low : 10
Kilometers
0 0.5 1 2 3
N


Ganga River, Patna, Bihar,
AVIRIS reflectance image (4 m)
23 February 2016
Kilometers
0 0.5 1 2 3
N

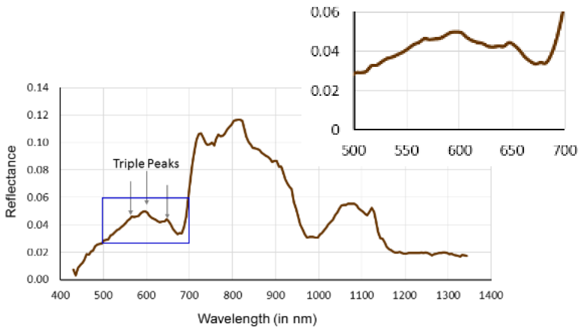

SSC (g/m3)
Value
High : 16
Low : 0
Kilometers
0 0.5 1 2 3
N

Coral reef macro-algae discrimination

Nandini Ray Chaudhury, Mohit Arora and Ashwin Gujrati

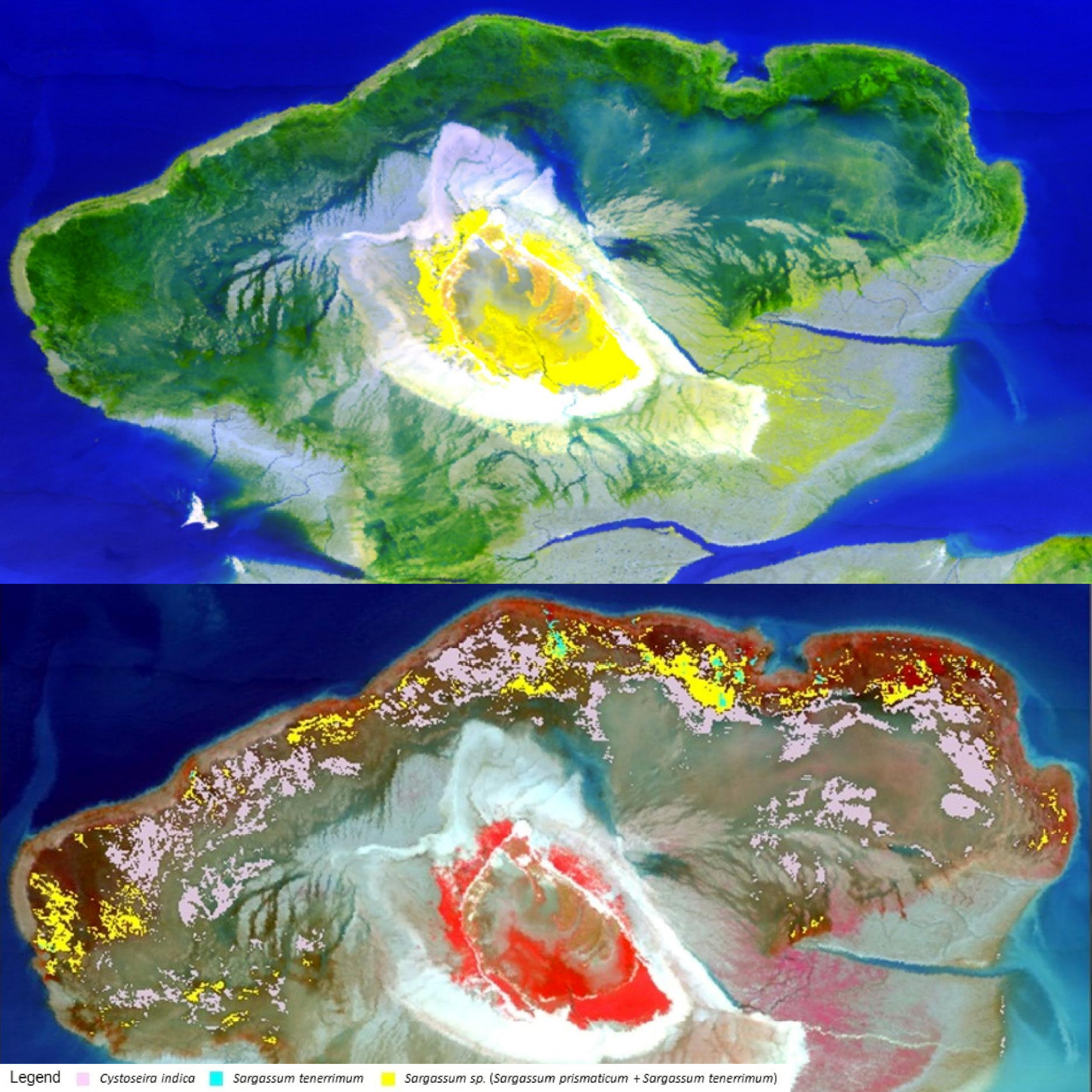


Marine macroalgae are primary producers in coral reef ecosystems and are important to human life as source of food, fodder, fertilizers, medicines and raw materials for cosmetic industries. Brown macroalgae species of Sargassum have been detected and mapped using AVIRIS-NG hyperspectral airborne data for Pirotan reef in Gulf of Kachchh based on their characteristic triple-peaked reflectance pattern in the green and red region (575, 600 and 650 nm) of the spectrum. Spectral Angle Mapper (SAM) classification has been used for creating species level distribution map of three Sargassum species: *Sargassum tenerrimum*, *Sargassum prismaticum* and *Cystoseira indica*. Sargassum species are important for alginate and liquid seaweed fertilizer production in India.



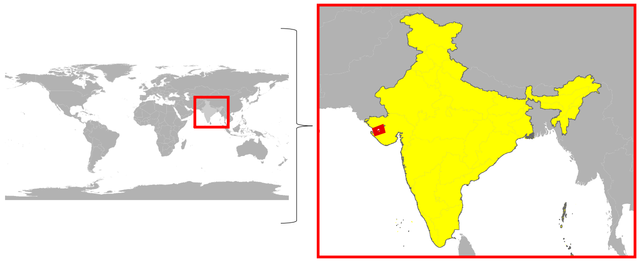
Characteristic spectra of Sargassaceae

Species level Map of Sargassaceae

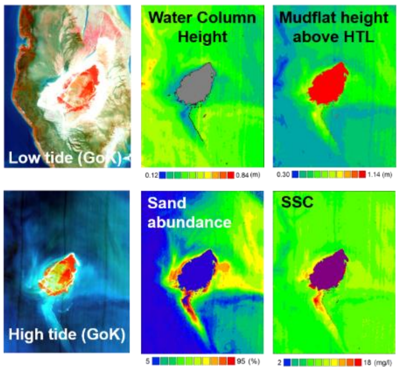

Legend
Cystoseira indica
Sargassum tenerrimum
Sargassum sp. (Sargassum prismaticum + Sargassum tenerrimum)

Coastal zone assessment

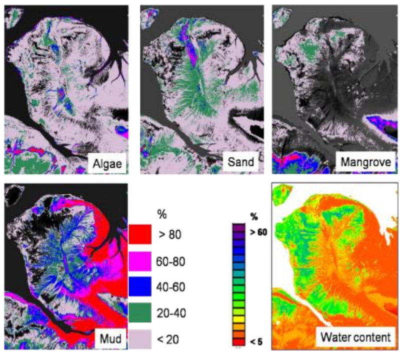
Ratheesh R., Preeti Rajput, Arunkumar S. V. V. and A. S. Rajawat



AVIRIS-NG data was collected in parts of Marine National Park, Gulf of Kachchh (GoK) to understand spectral characteristics of different coastal features. Bio-optical model, which make use of optimization techniques to assess water quality and bottom properties through inversion of the remote sensed data are used to estimate water column depth of tidal mudflats, estimate suspended sediment concentration and map the abundance of submerged features of the tidal mudflat. Linear spectral unmixing technique is used to determine relative abundance of algae, sand, mangroves and mud within the tidal mudflats to establish a methodology towards estimating stability index of mudflats. The specific absorption band at 0.97 µm is used to estimate the water content using band depth analysis.



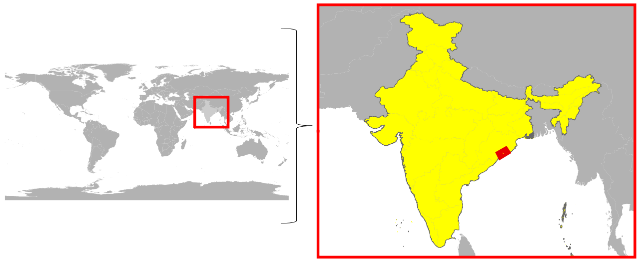
Water Column height estimation, abundance map of sand and SSC estimation using spectral inversion



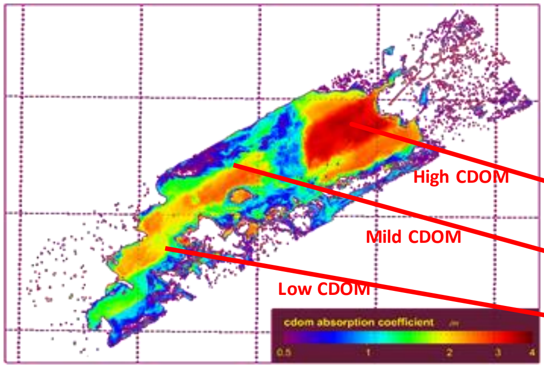
Abundance map of different coastal features and moisture content at Gulf of Kachchh

Coloured Dissolved Organic Matter (CDOM) in Chilika lagoon

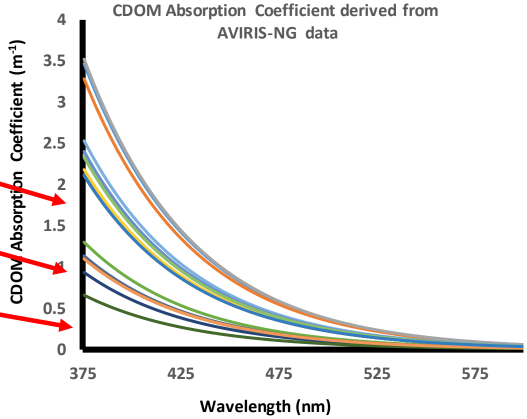
Arvind Sahay, Gunjan Motwani, Anurag Gupta, Syed Moosa Ali, Mini Raman et al.

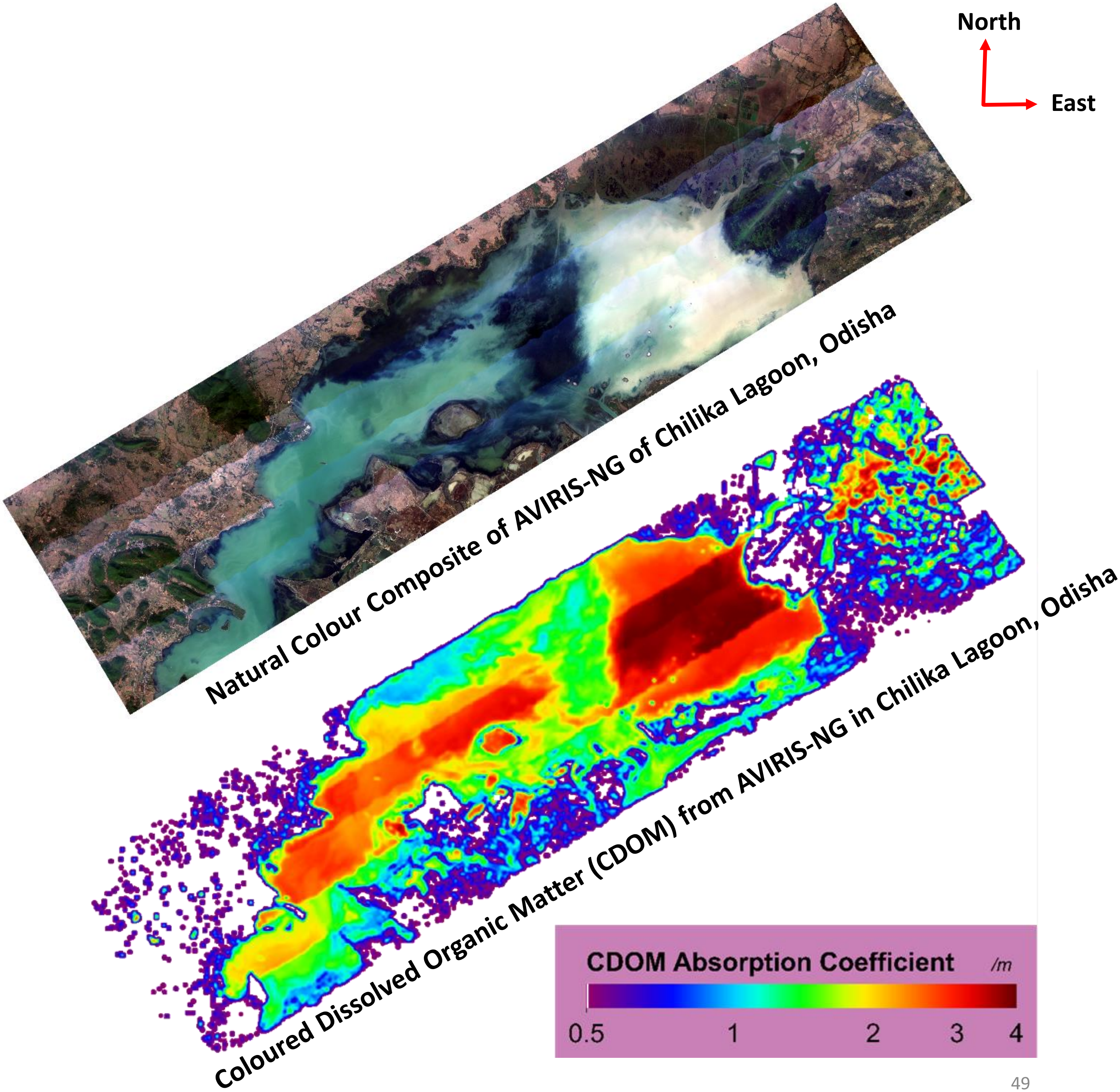


CDOM forms a significant fraction of the total Dissolved Organic Matter (DOM) in water bodies. It absorbs light strongly in the ultraviolet and blue domains, thereby playing essential roles in the light-induced biogeochemical processes and carbon cycling. CDOM absorption coefficient is retrieved from AVIRIS-NG L-2 data (SAC developed atmospheric correction scheme) in complex lagoon environment of Chilika lake. The variability shows that in northern side of the Chilika CDOM absorption is quite high in the range of 2.5-3.0 m^{-1} whereas in southern and middle sector it is varying up to 2-2.5 m^{-1} . High CDOM in North of Chilika is observed is due to the terrestrial organic matter mixing by many river tributaries and estuaries.



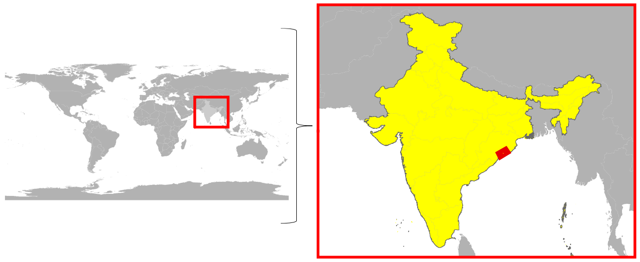
Map of CDOM absorption coefficient from AVIRIS-NG over Chilika Lagoon, Odisha, 27 December-2015



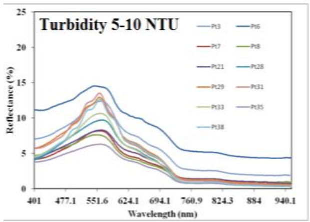

North
East
Natural Colour Composite of AVIRIS-NG of Chilika Lagoon, Odisha
Coloured Dissolved Organic Matter (CDOM) from AVIRIS-NG in Chilika Lagoon, Odisha
CDOM Absorption Coefficient /m
0.5
1
2
3
4

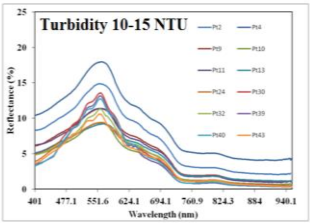
Water Quality Mapping in Chilika lake

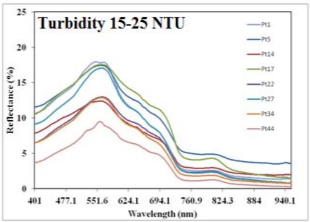
Vaibhav Garg, Vinay Kumar, Pankaj Dhote, S.P. Aggarwal, A. Senthil Kumar

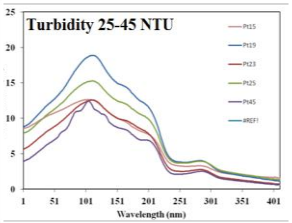


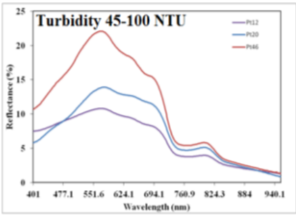
The water quality of Chilika lake with regard to turbidity concentration has been studied. A geotagged spectral library, specific to Chilika lake water quality parameters, has been generated using field spectro-radiometer and turbidity meter. The field spectra has been resampled to AVIRIS NG bandwidth and used for spectral similarity analysis adopting most widely used Spectral Angle Mapper (SAM) approach. A very high similarity between the image spectrum and field spectrum was found. At the selected locations, the SAM similarity score was higher than 0.9. As, the field spectra were classified into 7 classes of turbidity concentration as < 5, 5-10, 10-15, 15-25, 25-45, 45-100 and >100 NTU, SAM classified image resulted in these 7 classes of turbidity in the selected region of the lake.

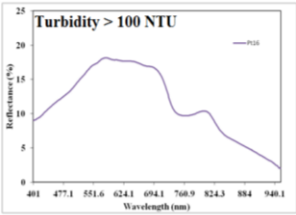






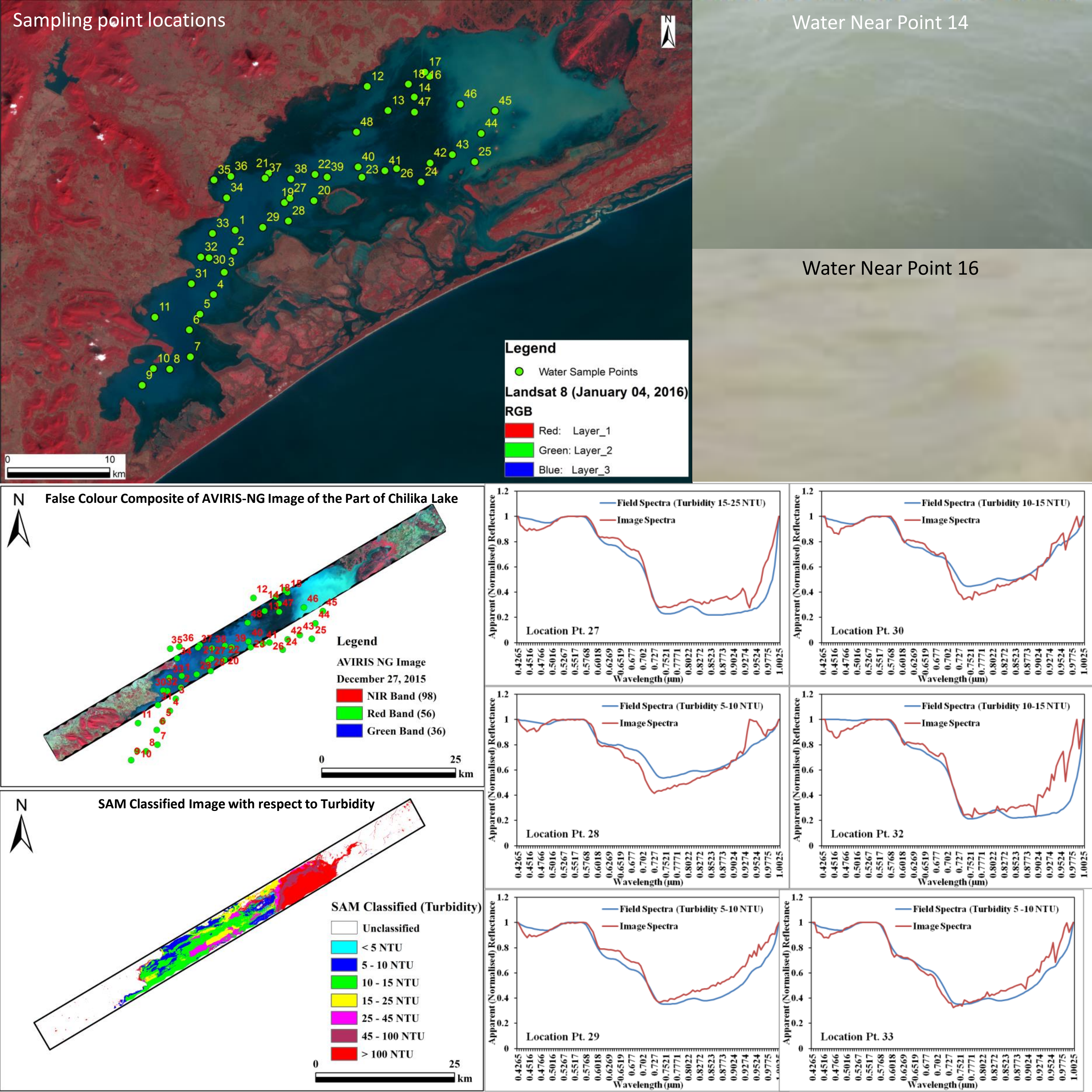






Field Spectro-radiometer

Turbidity meter

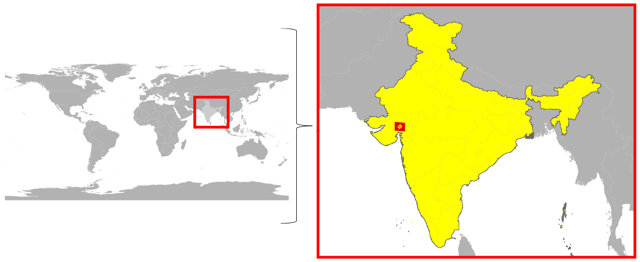


Sampling point locations
Legend
Water Sample Points
Landsat 8 (January 04, 2016)
RGB
Red: Layer_1
Green: Layer_2
Blue: Layer_3
0 10 km
Water Near Point 14
Water Near Point 16
False Colour Composite of AVIRIS-NG Image of the Part of Chilika Lake
Legend
AVIRIS NG Image
December 27, 2015
NIR Band (98)
Red Band (56)
Green Band (36)
0 25 km
SAM Classified Image with respect to Turbidity
SAM Classified (Turbidity)
Unclassified
< 5 NTU
5 - 10 NTU
10 - 15 NTU
15 - 25 NTU
25 - 45 NTU
45 - 100 NTU
> 100 NTU
0 25 km
Field Spectra (Turbidity 15-25 NTU)
Image Spectra
Location Pt. 27
Field Spectra (Turbidity 10-15 NTU)
Image Spectra
Location Pt. 30
Field Spectra (Turbidity 5-10 NTU)
Image Spectra
Location Pt. 28
Field Spectra (Turbidity 10-15 NTU)
Image Spectra
Location Pt. 32
Field Spectra (Turbidity 5-10 NTU)
Image Spectra
Location Pt. 29
Field Spectra (Turbidity 5 -10 NTU)
Image Spectra
Location Pt. 33
Apparent (Normalised) Reflectance
Wavelength (µm)

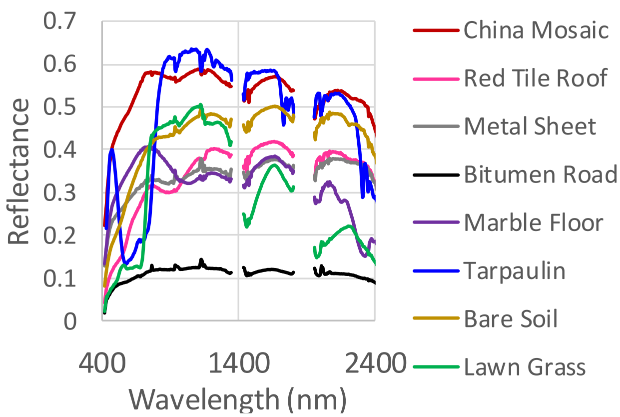

URBAN

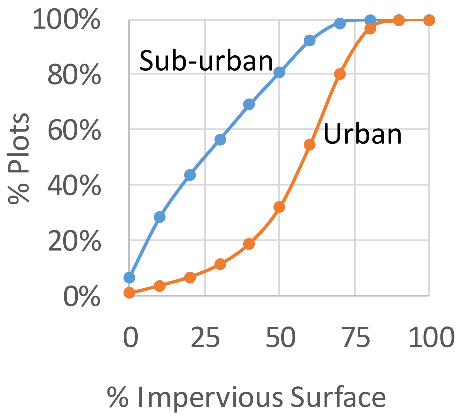
Urban and peri-urban area characterization

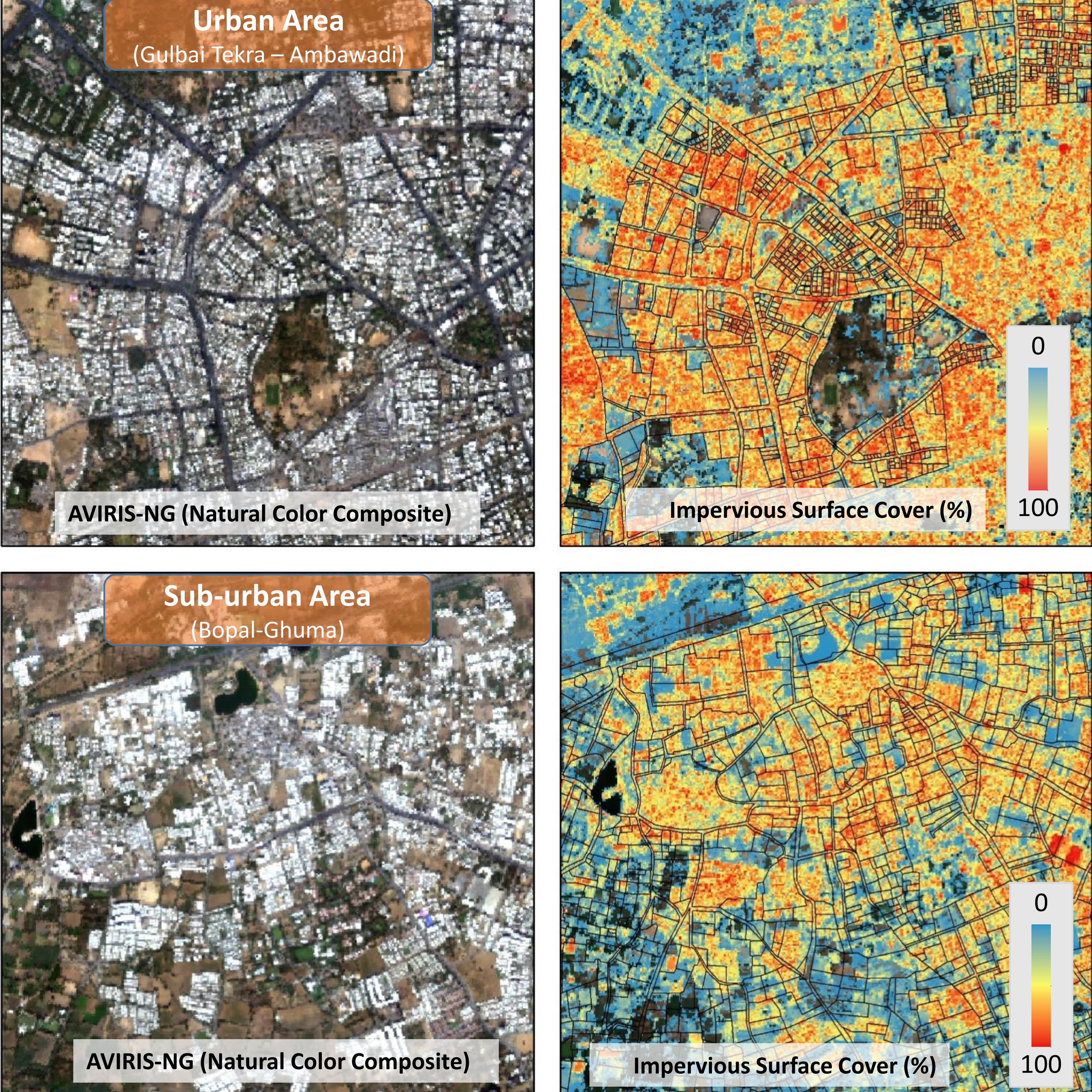
Gaurav V. Jain and Shashikant Sharma



Impervious surface refers to the land covered by impermeable materials such as concrete, bitumen, bricks etc, which significantly reduces the infiltration capacity of the soil. Urban land cover is characterized by heterogeneous mix of both anthropogenic and naturally occurring materials, which hinders estimation of impervious surfaces using multispectral data. The narrow-band hyper-spectral data acquired by AVIRIS-NG enables separation of several such urban materials. In this study Linear Spectral Mixture Analysis was used to estimate the fraction of various pervious and impervious surface materials in urban (Ambawadi and Gulbai Tekra Wards) and peri-urban (Bopal and Ghuma Villages) areas of Ahmedabad city.

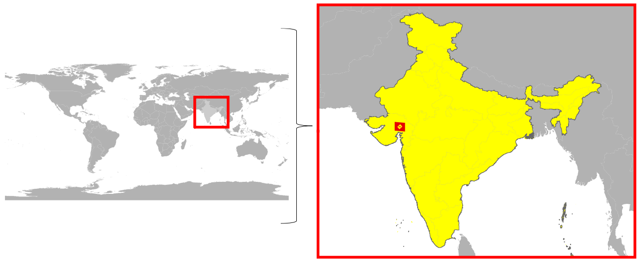




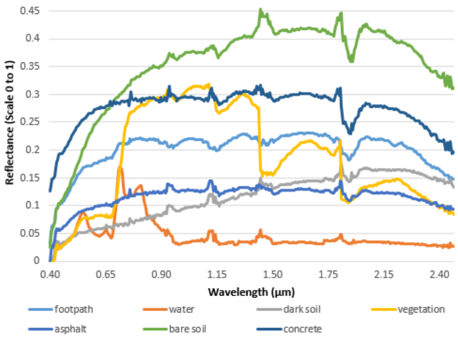

Urban Area
(Gulbai Tekra – Ambawadi)
AVIRIS-NG (Natural Color Composite)
Impervious Surface Cover (%)
0
100
Sub-urban Area
(Bopal-Ghuma)
AVIRIS-NG (Natural Color Composite)
Impervious Surface Cover (%)
0
100

Urban area mapping

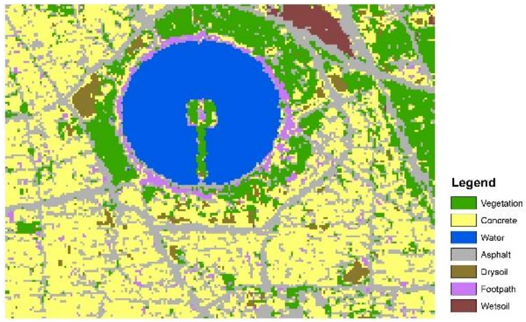
Asfa Siddiqui, Vinay Kumar, Pramod Kumar and A. Senthil Kumar



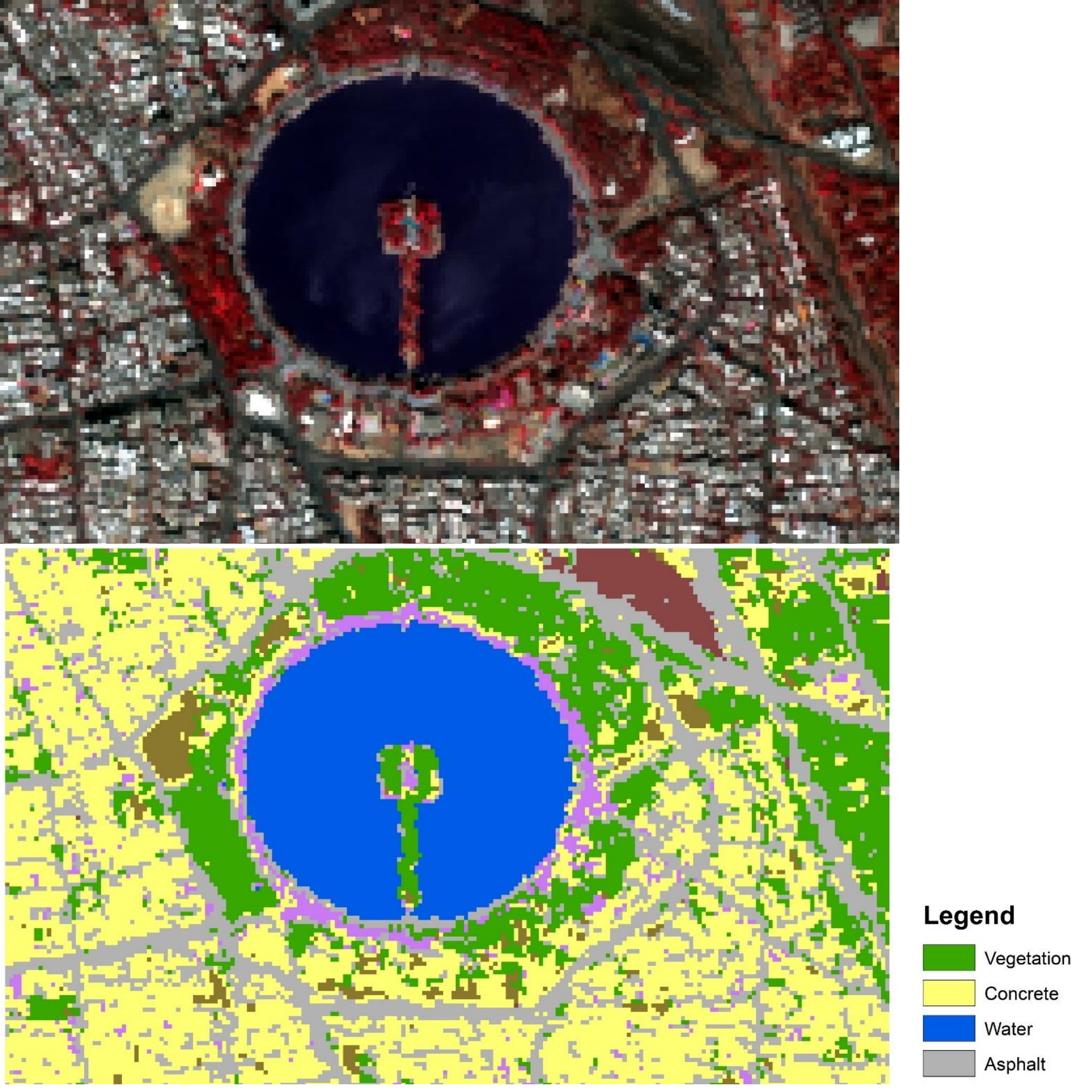
Urban areas are characterizes by spectrally distinct surface materials (natural and man-made) possessing different chemical properties. This complex ensemble within the cities due to immense heterogeneity called for a need for high resolution hyperspectral imagery available through AVIRIS-NG mission. The extraction of pervious and impervious layers shall help in understanding the urban growth phenomenon, condition of infrastructure (road), roof types and its impact towards urban energy balance and local climate in the urban boundary layer, etc. The research focused on building precise spectral library (using SAM, CBD and SDS methods) and using the spectral signatures for identifying land cover materials. The analysis was done using Support Vector Machine (SVM) Classification algorithm and tested on AVIRIS dataset.



Spectral Profiles of Urban Materials



Urban Land Cover Classification using SVM


Legend
Vegetation
Concrete
Water
Asphalt

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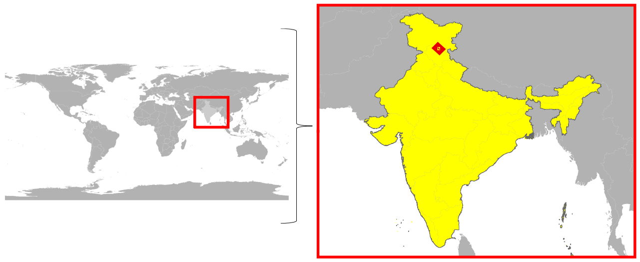
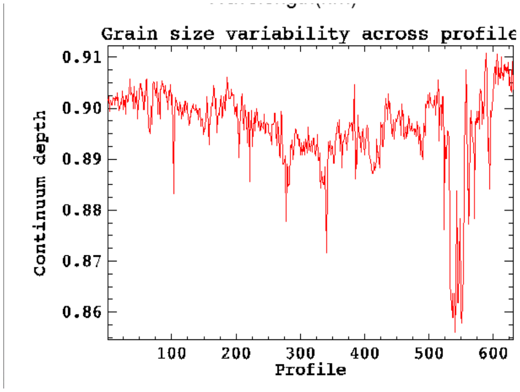
SNOW

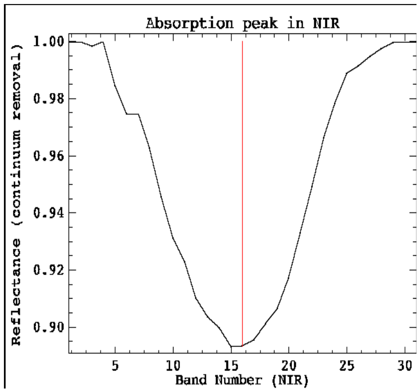
Snowpack characterization

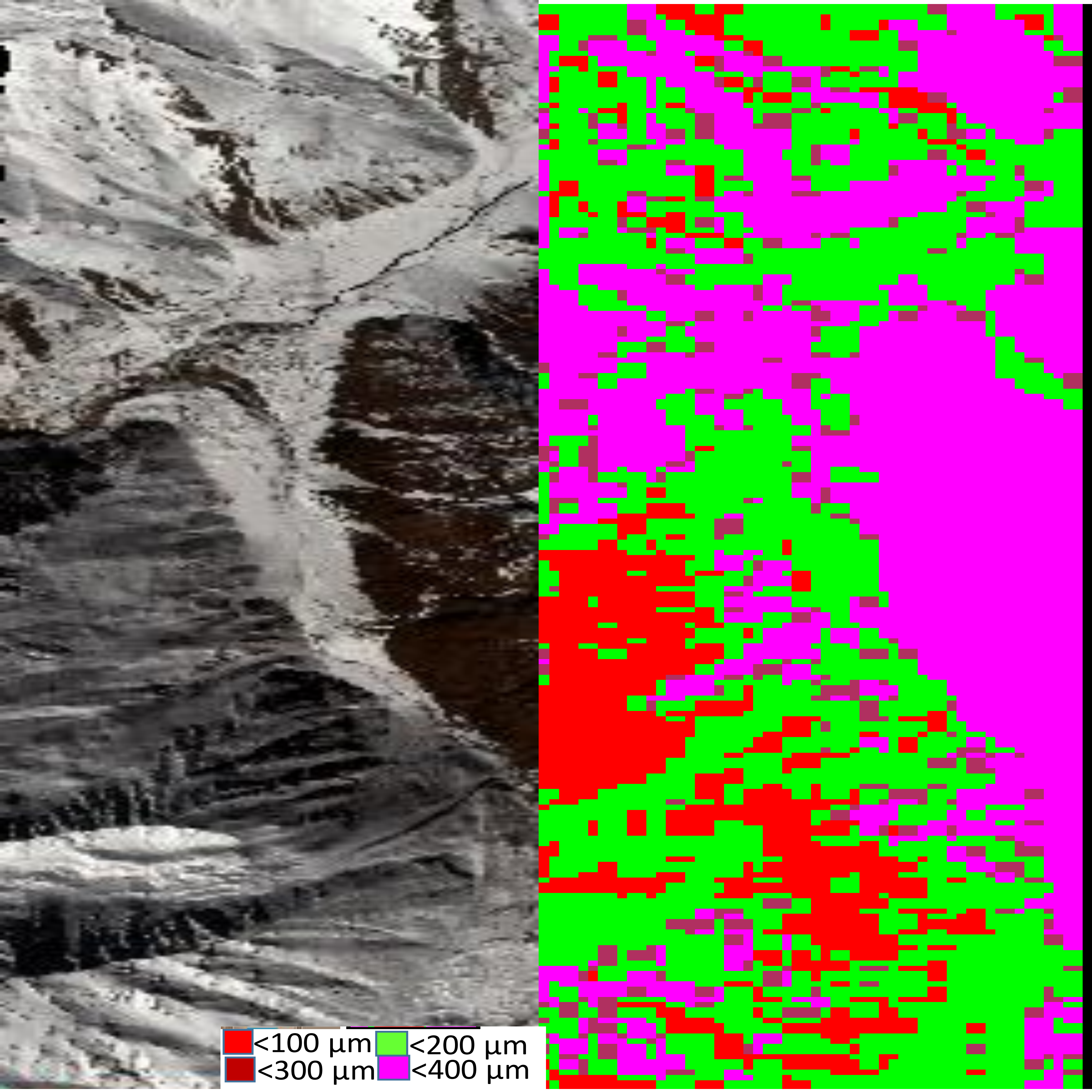
S. K. Singh, B. P. Rathore, Snehmani and I. M. Bahuguna



AVIRIS-NG hyperspectral airborne data was collected in parts of Himalaya to understand the variability in reflectance with respect to varying snow physical properties. Synchronous in-situ data was collected using spectroradiometer and collateral instruments for measuring radiometric and physical properties of snow. Variation in snow grain size affects the absorption peak centered at 1025 nm. Radiative transfer model was used to understand the grain size variability and its effect on absorption peak. Continuum removal was performed of absorption peak and band depth was estimated for ground observations and airborne data. Normalized difference snow index was estimated using visible and SWIR band and a threshold of 0.70 was used to identify pure snow pixels.



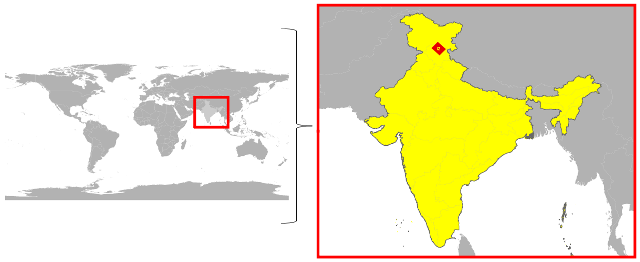




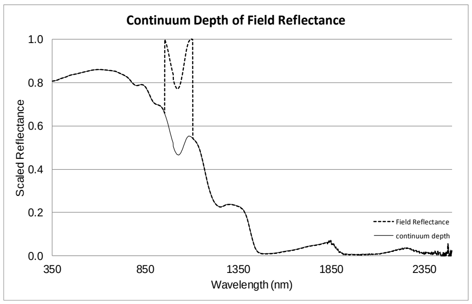
<100 µm
<200 µm
<300 µm
<400 µm

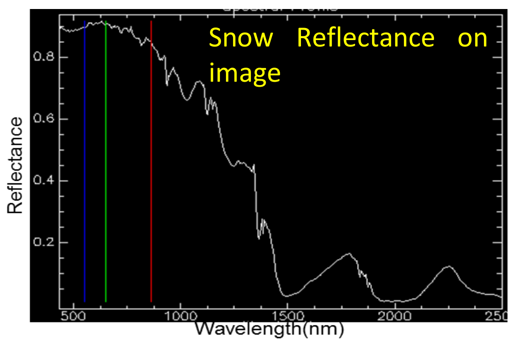
Snow grain size assessment

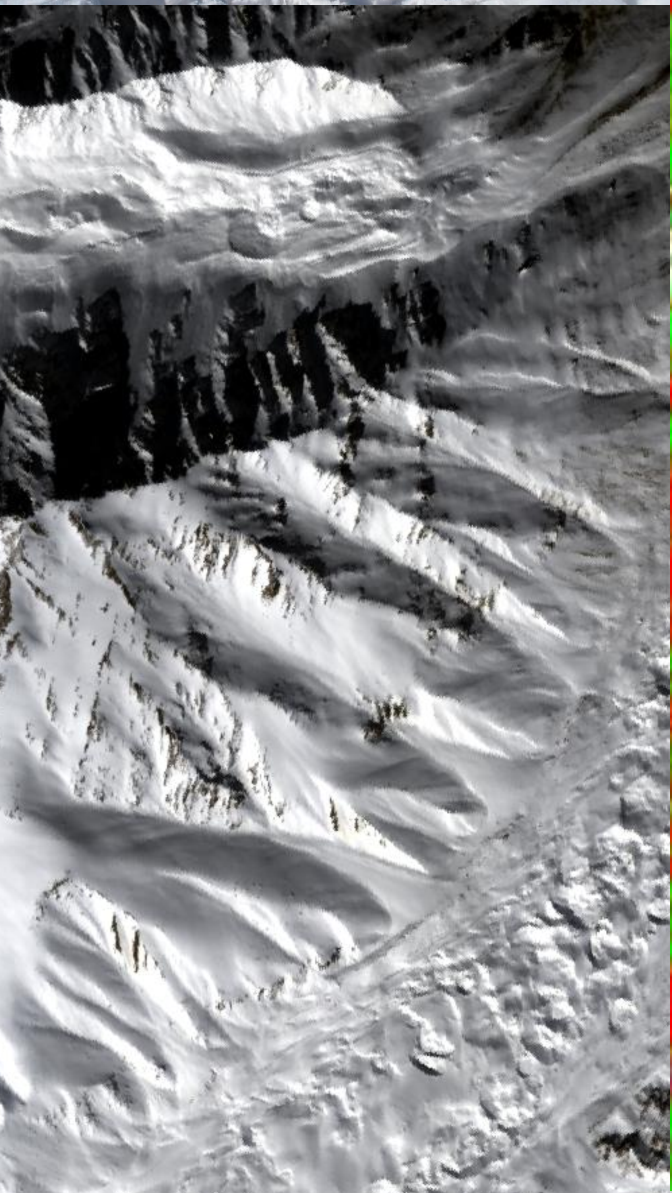
S. K. Singh, B. P. Rathore, Snehmani and I. M. Bahuguna

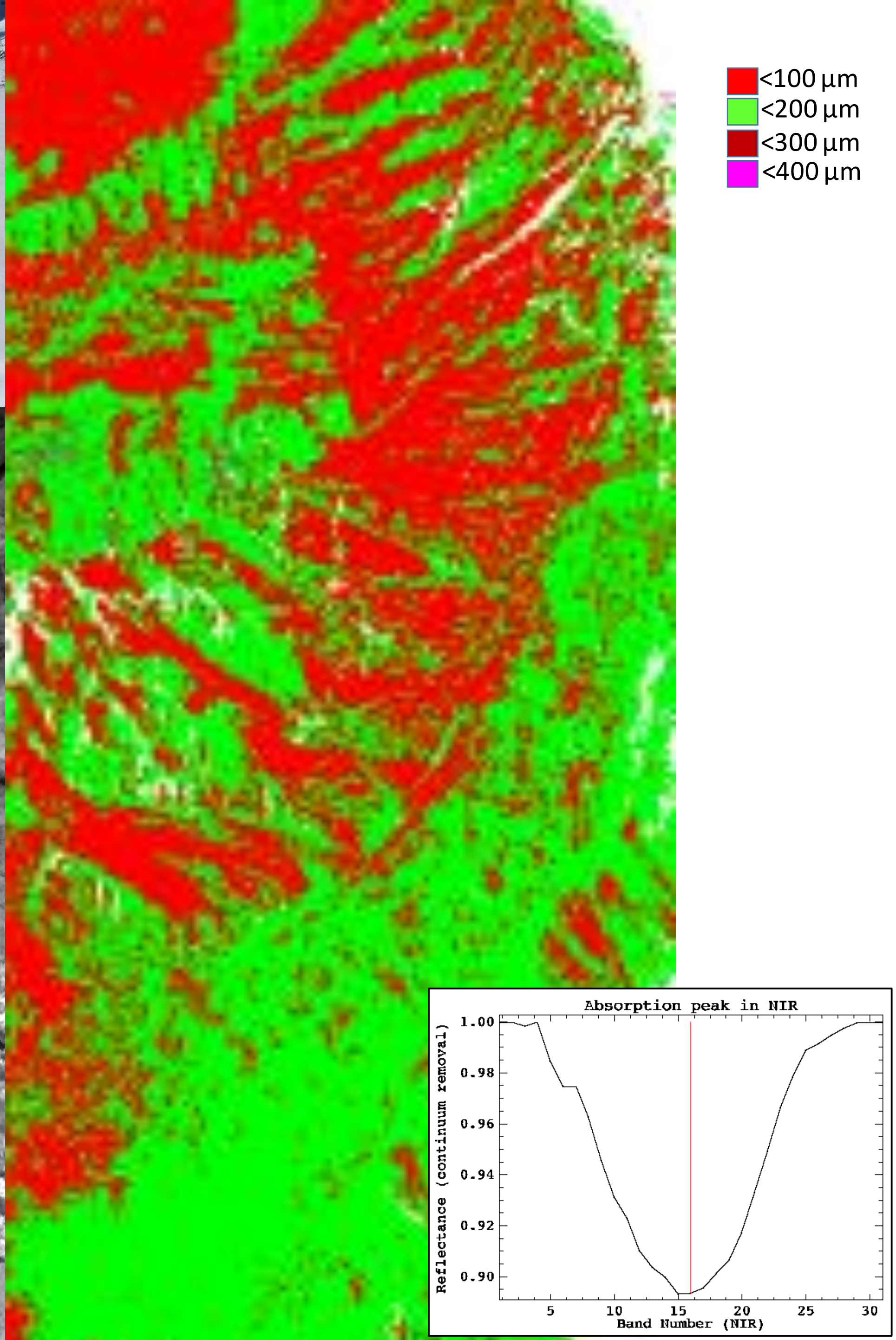


About 10% of the earth's surface is covered by water in solid form (the Cryosphere). Snow grain size is an important parameter for understanding the variability in albedo and snow melt runoff studies. Snow looks white homogeneous and very bright object due to its high reflectivity on the Earth surface whereas it absorbs in SWIR region, and this distinct spectral behavior has been used to map snow pixel operationally from space. Contamination, grain size growth, liquid water content, aging, depth etc affects the reflectance of snow in different parts of EM spectrum. AVIRIS-NG airborne hyperspectral data was flown over snow covered region with synchronous radiometric field observations to retrieve snow physical property. Airborne Hyperspectral data, ground based observations and radiative transfer model based observation were used to retrieve grain size of snow based on continuum removal of absorption peak at 1025 nm, mainly influenced by grain size variation.









Continuum removed absorption depth of image pixel

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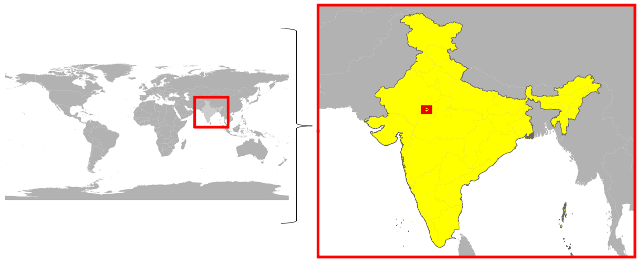
ATMOSPHERE

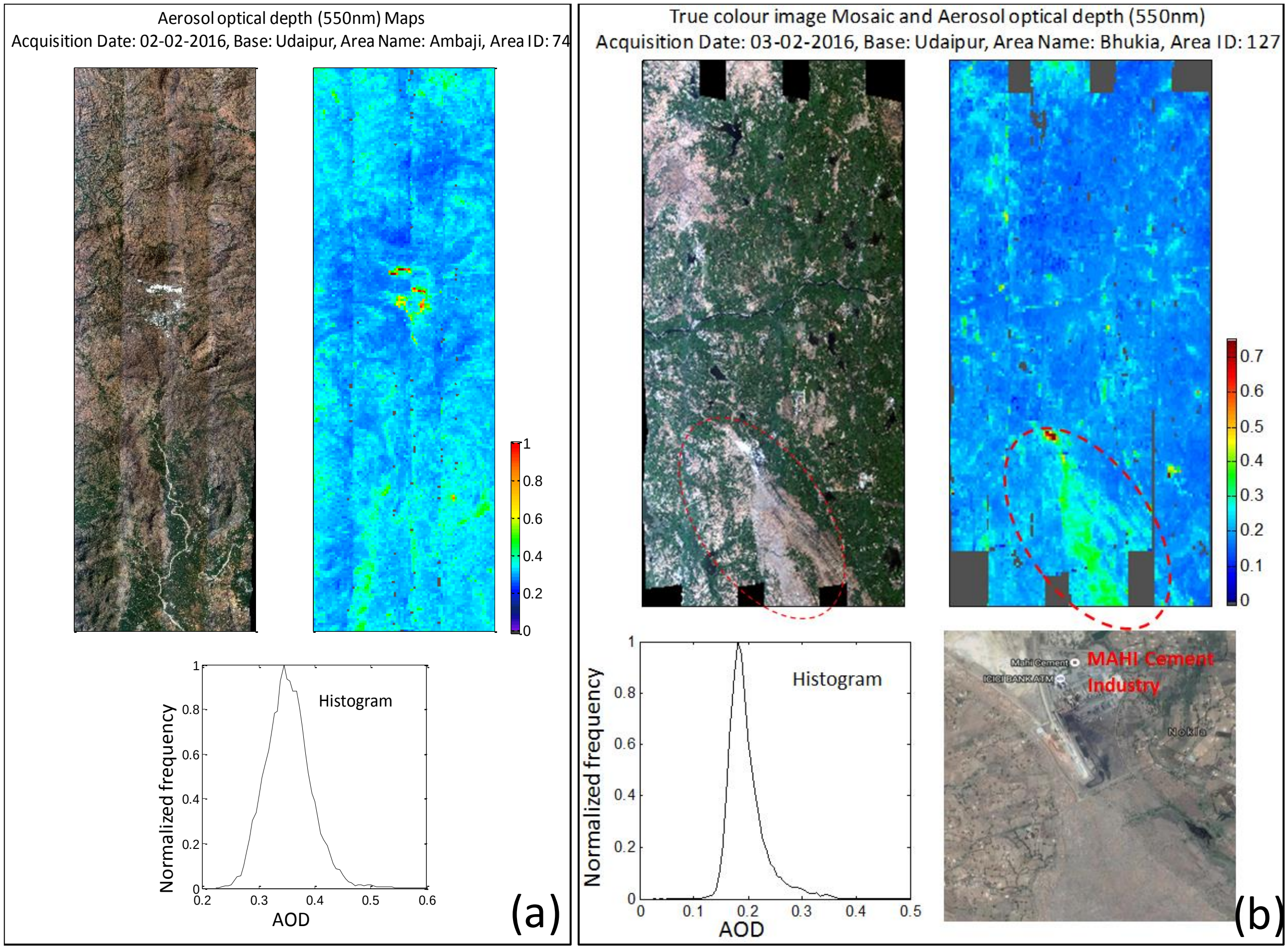
Aerosol and water vapour retrieval

Manoj K Mishra and Arundhati Misra

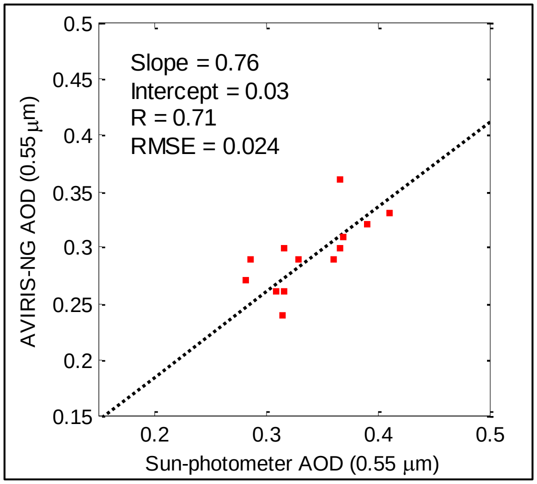


Applications of high resolution AVIRIS-NG data requires a thorough compensation for atmospheric absorption and scattering. A method for retrieving critically important atmospheric parameters namely, “water vapour (WV) and aerosol optical depth (AOD)” is developed. These parameters have been operationally used to generate AVIRIS-NG L2 data products. Aerosols are most difficult retrievable parameter due to their high heterogeneity in time and space. In this method first the aerosol insensitive SWIR measurements are used for characterization of visible channel surface reflectance and secondly radiative transfer modelling is used for deriving AOD. Estimation of integrated WV is carried out using continuum interpolated band ratio (CIBR) method. The retrieved AOD is compared with in-situ values, while retrieved water vapour is compared with JPL water vapour product.

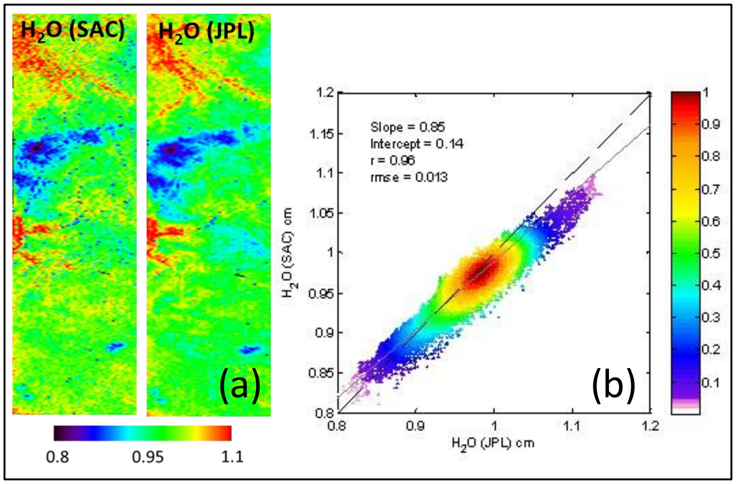
Showing AVIRIS-NG observation over Kota, Rajasthan. The low contrast and haziness in RGB, Blue, Green and NIR channels is due to radiative scattering effect of aerosol. Due to insensitivity of SWIR to aerosol the SWIR image shows higher contrast. It shows the utility of SWIR channel for removing surface contribution from sensor measurement.



True colour image, AOD map and histogram for Ambaji (a) and Bhukia (b), region. Figure (b) shows high AOD plume which is due to the suspension of aerosol particles in to the atmosphere in adjoining regions of MAHI cement industry.



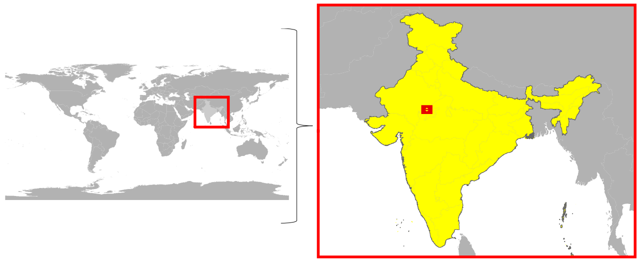
Comparison of retrieved and in-situ AOD.



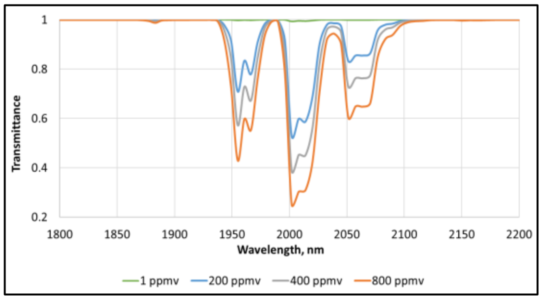
Water vapour map derived from AVIRIS-NG data acquired on 02-02-2016 in Amabaji region using SAC and JPL algorithm (a). Comparison between SAC and JPL derived water vapour values (b).

Atmospheric CO_2 retrieval

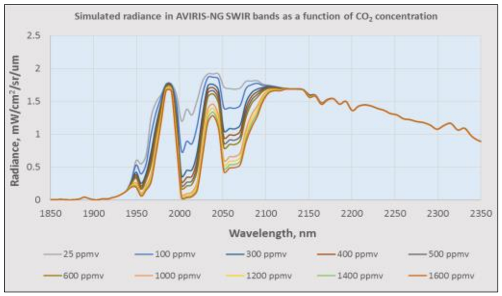
Abha Chhabra, Mehul Pandya and Prakash Chauhan



This study demonstrated the application of hyperspectral airborne AVIRIS-NG data for detection and quantification of CO_2, a major Greenhouse gas. Synchronous in-situ data of various air pollutants, Aerosol Optical Depth, Water vapour and surface reluctance of various targets were collected at two Indian sites of Kota, Rajasthan and Ahmedabad, Gujarat. A method has been developed for retrieval of atmospheric CO_2 concentration using a Radiative Transfer model. Site-specific model coefficients were generated and a Continuum Interpolated Band Ratio (CIBR) algorithm was used for CO_2 retrieval. CO_2 plumes density and dispersal from Coal-fed Kota Super Thermal Power Station (KSTPS) could be mapped using AVIRIS-NG data. CO_2 distribution map for Ahmedabad was also generated using AVIRIS-NG CO_2 retrievals and validated with in-situ observations.

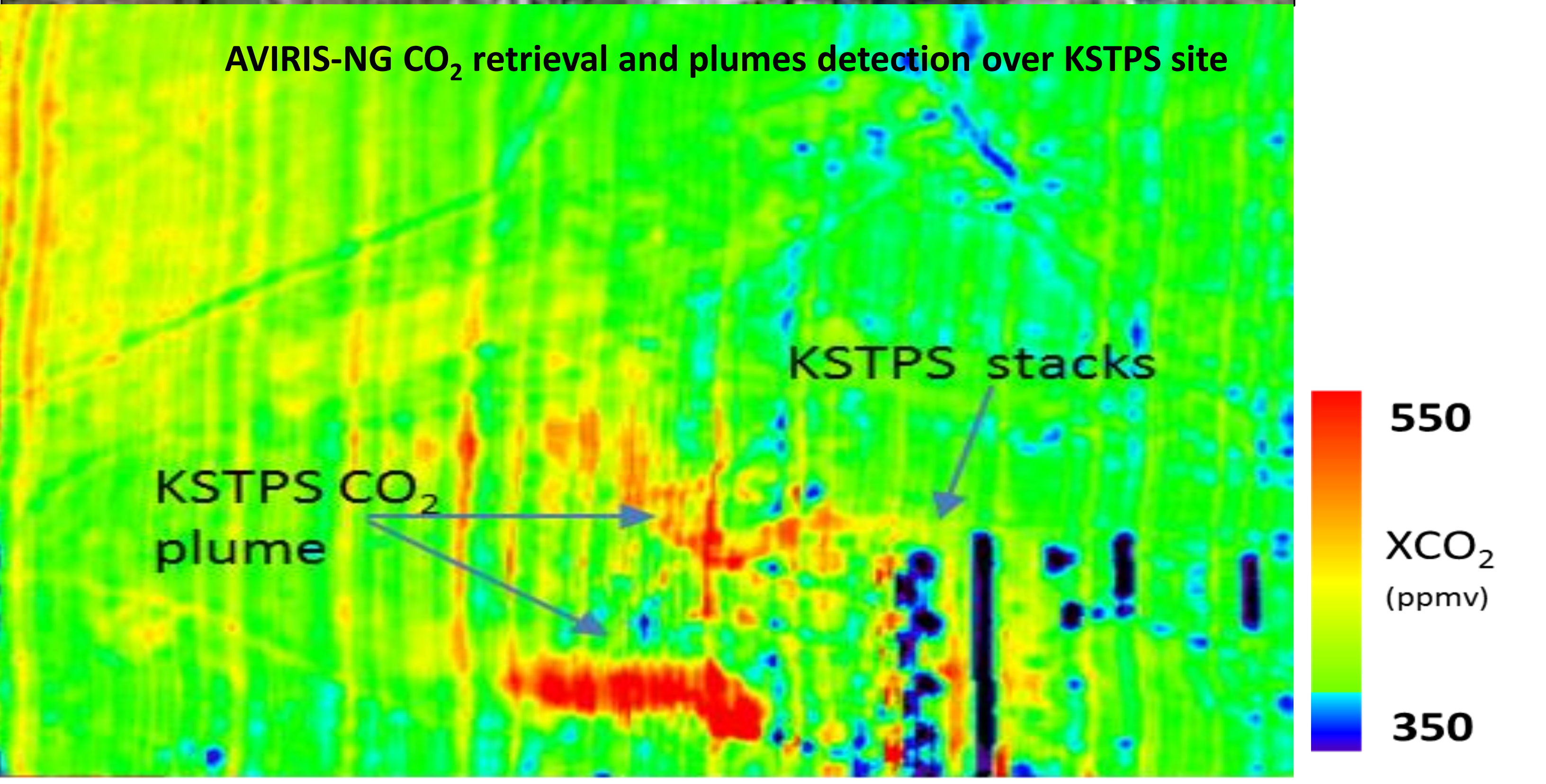


Modelled CO_2 transmittance in SWIR spectral range



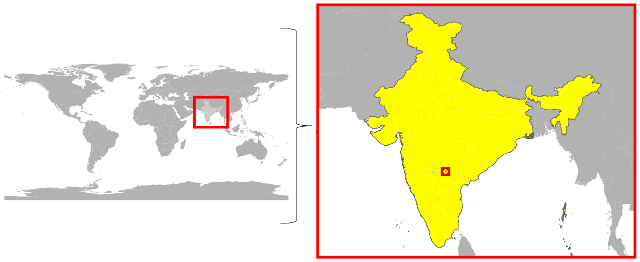
AVIRIS-NG simulated radiance as a function of CO_2 concentration


Power Plant

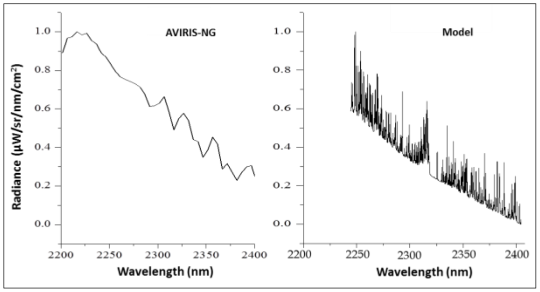

AVIRIS-NG CO_2 retrieval and plumes detection over KSTPS site
KSTPS stacks
KSTPS CO_2 plume
550
XCO_2
(ppmv)
350

Atmospheric methane estimation

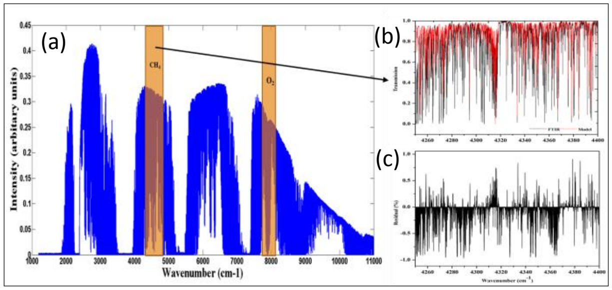
Mahesh P., B. Gharai, Rao P. V. N., Sreenivas G., Mallikarjun K., S. Jose et al.



An attempt has been made to retrieve column averaged concentration of methane (XCH_4) over a sub urban site, Shadnager near Hyderabad from the spectral radiance measured by AVIRIS-NG data, acquired on 19 December, 2015. XCH_4 is derived following MODIS water vapor retrieval algorithm technique, wherein ratio of the measured radiance in absorbing to the non-absorbing bands is used to retrieve atmospheric transmittance spectrum. In the present study, we utilized airborne imaging radiance data in CH_4 absorbing channel at 2.29±0.0059µm and non-absorbing channels at 2.20±0.0059µm & 2.35±0.006µm. Using line-by-line RT algorithm, CH_4 concentration is estimated from the AVIRIS-NG radiance data and compared with ground based FTIR retrieved XCH_4 .

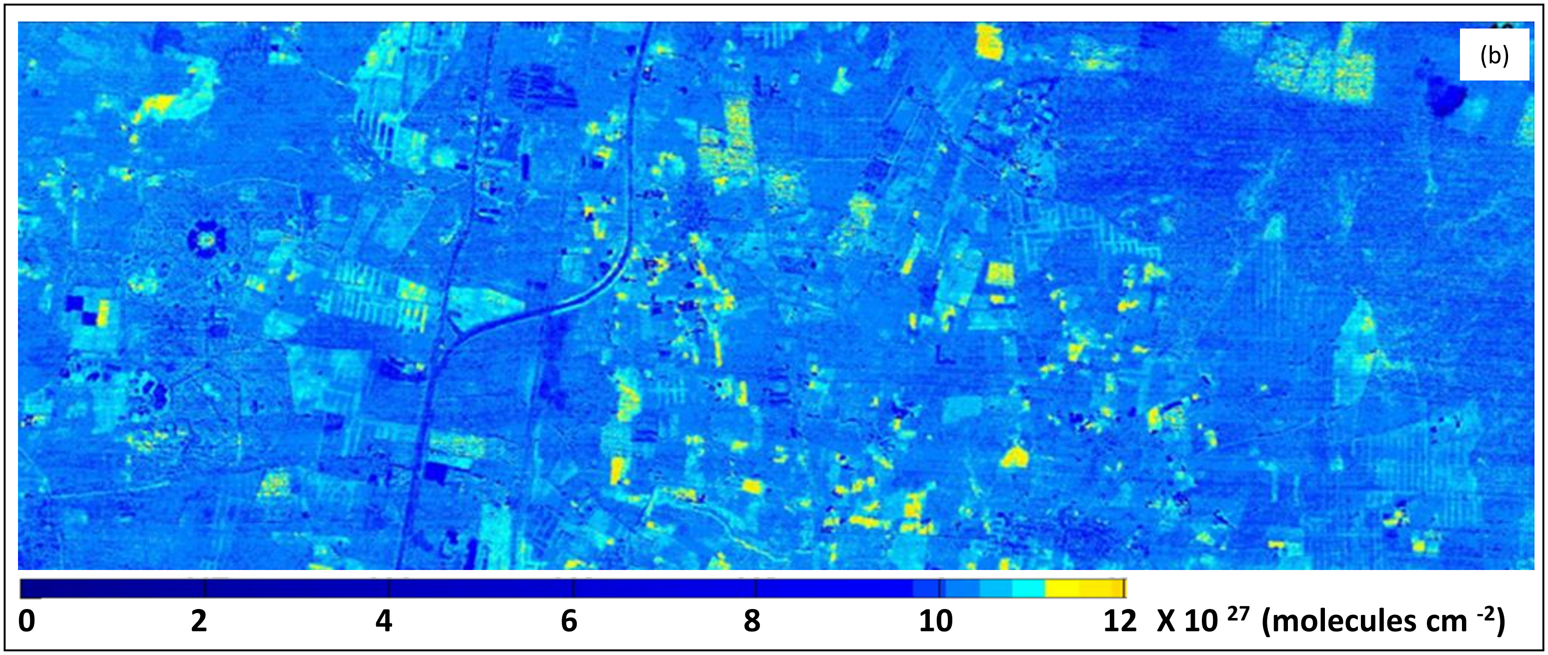


Comparative analysis of radiance measured by AVIRIS-NG against simulated radiance



(a) Solar spectrum measured using ground based FTIR
(b) Black lines indicate measured transmittance,
red lines represent fitted transmittance for CH_4 and (c) residual error (%)
for CH_4 between measured and model derived.

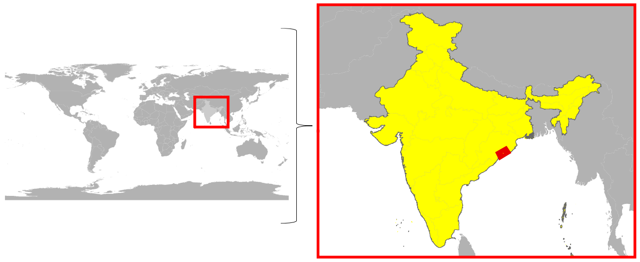
(a) Natural colour composite of Shadnagar region as acquired by AVIRIS-NG on 19 December, 2015



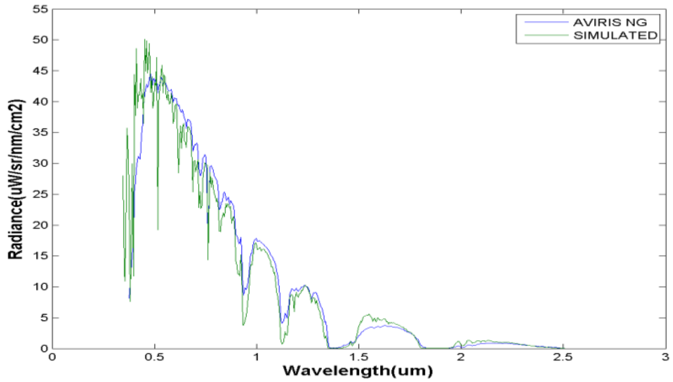
(b) Retrieved molecular density of Methane (XCH_4) using AVIRIS-NG over Shadnagar region

Cloud microphysical properties

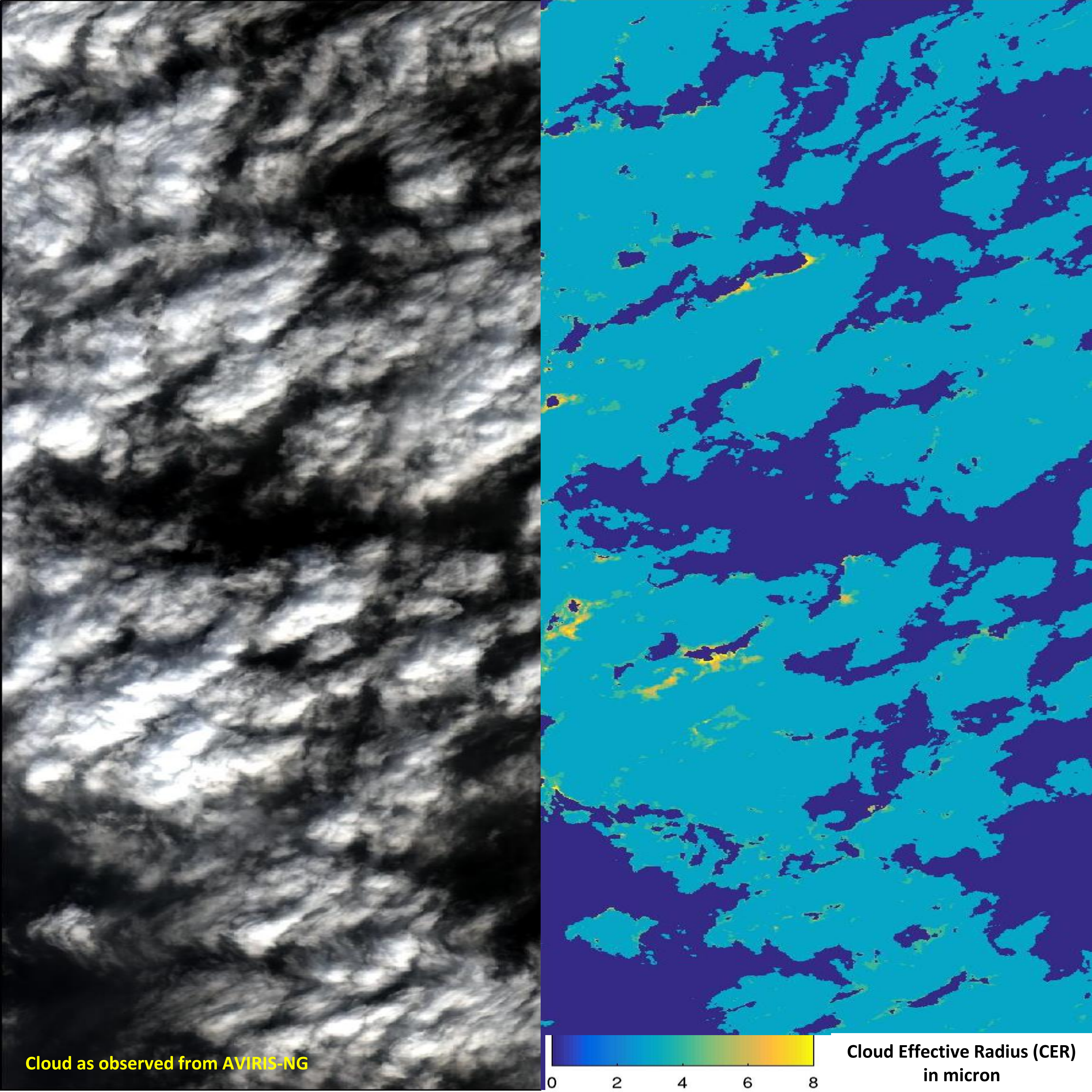
Bipasha Paul Shukla and Jinya John



Clouds are modulators of Earth's climate. Understanding of cloud growth and precipitation mechanisms is essential for climate and hydrological studies, extreme rainfall events etc. Cloud microphysical parameters (CMP) include particle size distribution, effective radius, liquid water path, cloud optical thickness etc. Among them, cloud optical depth (COT) and cloud effective radius (CER) distribution describe almost completely the radiative properties of a cloud. In this study, a simulated hyperspectral library for different cloud types was constructed using high resolution RT model. Further, high resolution CMP map was derived using AVIRIS-NG observations. Cloud base was also derived using the cloud shadow technique.



Best match obtained for Low Clouds with medium opacity (Cloud Optical Thickness ~3.6 Cloud Effective radius ~ 4 micron)


Cloud as observed from AVIRIS-NG
0
2
4
6
8
Cloud Effective Radius (CER)
in micron

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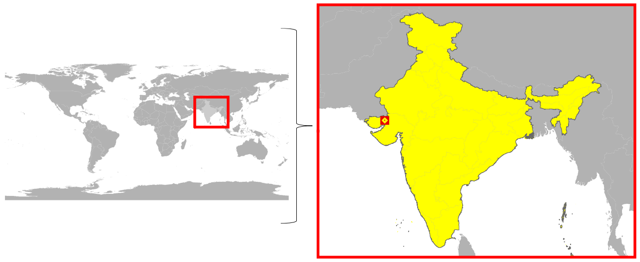
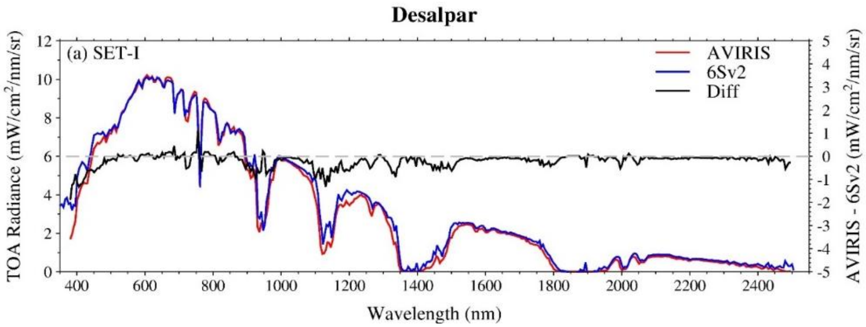
CALIBRATION & VALIDATION

Calibration of AVIRIS-NG imager over natural targets

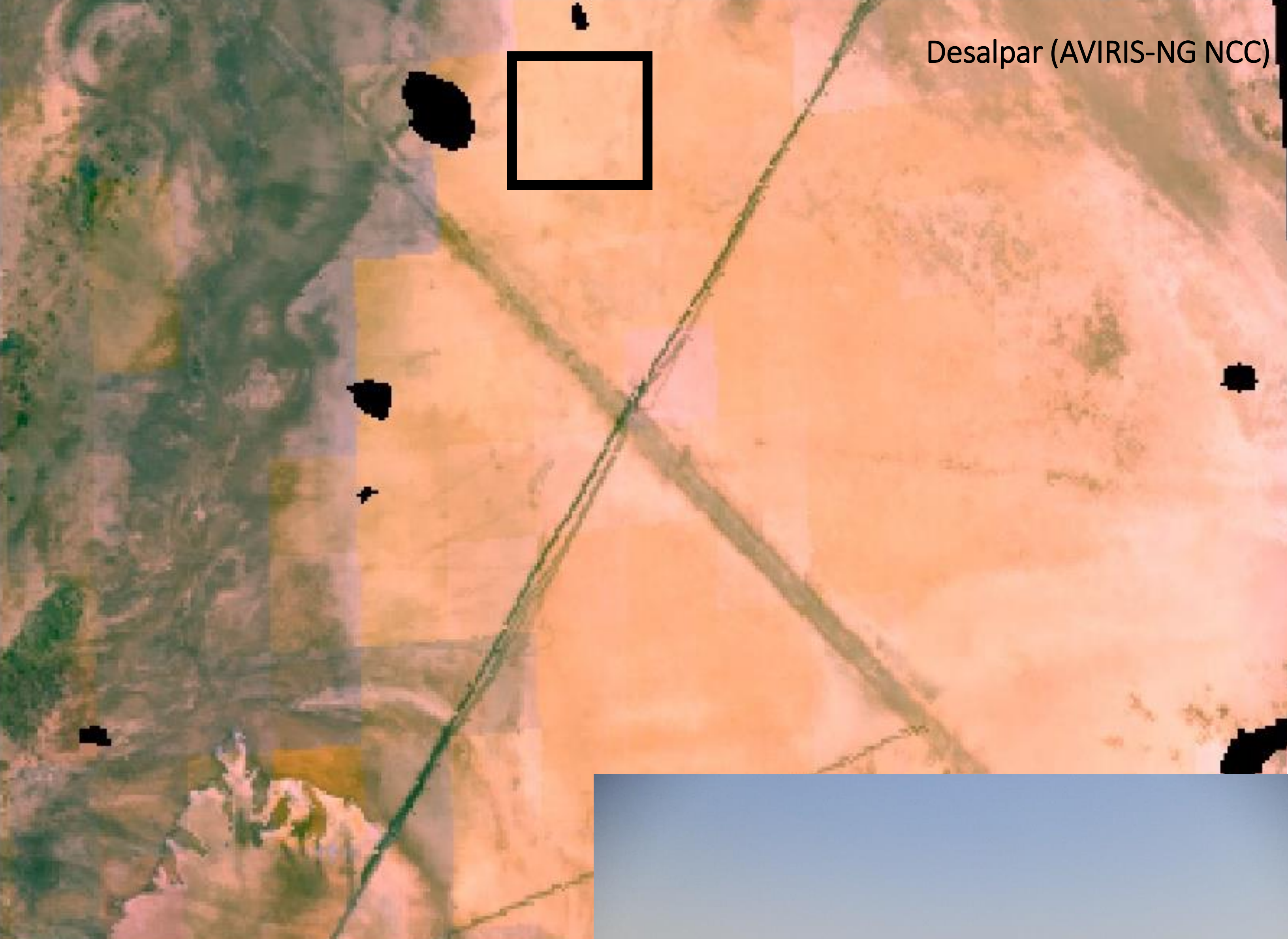
K. N. Babu, R. P. Prajapati, P. N. Patel, and A. K. Mathur



Sensor radiometric calibration, the most fundamental part of the calibration-validation process, is a broad and complex field that imposes the greatest limitations on quantitative applications of remote sensing, especially to improve the quality of all the derived products. Therefore, it impacts the quality of each geophysical products and in turn the interpretation of spectral signature of AVIRIS-NG measurements. The objective here is to report the calibration performance assessed during the calibration campaign of AVIRIS-NG aerial mission over Desalpar site. The improved 6Sv2 radiative transfer model used to perform in-situ calibration of AVIRIS-NG using ground reflectance measurements along with atmospheric parameters (aerosol optical thickness, total ozone and water vapor content). The spectral in-situ calibration gains are within 5% with respect to model simulation with 3-4% total RMSE error.



Spectral AVIRIS-NG, 6Sv2 RT model simulated radiance and their difference over Desalpar site



Desalpar (Rann of Kuchchh) field photograph

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