Titanium metal identification in southern region of Tamil Nadu using hyperspectral imagery

Vigneshkumar M¹ & Kiran Yarrakula²,*

¹² Centre for Disaster Mitigation and Management, Vellore Institute of Technology, Vellore, India
[E.Mail: kiranyadavphysik@gmail.com]

Received 25 April 2018; revised 24 July 2018

The SEM with EDXS analysis is performed to identify the chemical composition of Titanium metal in soil samples. To estimate the Titanium metal deposit in soil samples using hyperspectral data requires various processing steps such as bad bands removal, destriping, radiance generation, atmospheric correction, data dimensionality reduction, end member identification and classification. The absolute reflectance bands are generated using FLAASH module. The data dimensionality reduction for reflectance bands are carried out such as minimum noise fraction (MNF) and pixel purity index (PPI) respectively. Titanium metal deposit is identified using per pixel based classification depends on the end member spectral signatures.

[Keywords: Hyperion; FLAASH; MNF; PPI; Titanium]

Introduction
Huge amount of spectral information used to mapping the Titanium metal precisely¹,². Hyperspectral images provide rich spectral continuous information and it is to be used to determine more detailed spectral properties of the soil surface and mineralogy. Depending on the material’s spectral response, reflectance spectroscopy is also relatively less expensive and faster than traditional wet chemical measurements³. Titanium is a chemical element with symbol Ti, basic properties such as silver color, low density, and high strength. Titanium is resistant to corrosion in sea water, aqua regia, and chlorine. The availability of Titanium metal in soil samples are identified using the Scanning Electron Microscope (SEM) with Energy Dispersive X-ray Spectroscopy (EDXS)⁴. Visible, Near and Short Wave Infrared Spectroscopy (VNIR-SWIR) in the spectral range of 400 - 2500 nm is used to quantify various soil constituents simultaneously due to the presence of strong spectral features attributable to soil components in this region⁵. The optical properties and chemical properties of titanium metal are performed using ASD Spectroradiometer and SEM instrument⁶.

In the present study Hyperion imagery is used to identify the Titanium metal in soil. Hyperion is a US satellite has 242 spectral bands in the spectral range 0.4 to 2.5 µm at 10nm interval and calibrated in 16 bit radiometric resolution. The spatial resolution is 30m and the temporal resolution is 16 days². The Visible and VNIR region (0.4-1.2 µm) of Hyperion from band 8 to band 57 mainly used for vegetation mapping⁷. The SWIR (1.2-2.5µm) of Hyperion from band 78 to band 220 used to mapping the metals and minerals⁸. Present research work is to estimate the quantity of Titanium metal in soil deposit using hyperspectral remote sensing.

Materials and Methods
The study area contains four blocks such as Thovala, Valliyur, Kalakadu and Agastheeswaram in Tirunelveli and Kanniyakumari districts at southern end part of Tamil Nadu. The study area lies in 080 06'57" to 080 30' 18"N and 770 28' 25" to 770 37' 17" E. The study area has abundant minerals such as Wollastonite, Sillimanite, Kyanite, Dolomite, Barytes, Titanium, Magnesit, Limestone, Gypsum, Garnet, Granite and Zircon⁹.

Figure 1 shows the soil sample collection of Titanium metal and its spectral signature. Figure 2 shows the geographical location of the study area. To establish the Titanium metal from hyperspectral data, various preprocessing steps are to be required. Figure 3 clearly explains the through methodology involved to process the Hyperion data. Those methodology involves field data collection, chemical composition identification, spectral signature characterization, Identify the calibration bands,
vertical strip removal, radiometric correction, atmospheric correction, comparison of image and field spectra, classification and quantity estimation. Soil samples are converted as conductive material by applying the carbon coating. The basic chemical elements of the samples are identified using Scanning Electron Microscope (SEM) with Energy Dispersive X-ray Spectroscopy (EDXS). ASD Spectroradiometer is used to identify the spectral reflectance characteristics of the soil samples in Visible, VNIR and SWIR regions from 400nm to 2500nm. Hyperion imagery contains 242 bands, out of 242 bands, 163 bands are available in calibrating condition. The vertical strip column in Hyperion imagery is removed by adjusting the nearest neighborhood grayscale values. Radiance conversion of imagery carried out in Band Interleaved by Line format at the scale factor of 0.1. In the present study, the FLAASH atmospheric correction module is used to provide absolute reflectance of radiance imageries. FLAASH is a first-principles atmospheric correction corrects wavelengths in the Visible, VNIR and SWIR regions.

Minimum noise fraction (MNF) transformation is performed to generate the reflectance bands in
ascending order depends on the noise level. To identify the spatially pure pixels from the noiseless bands, the pixel purity index (PPI) algorithm is used. The end member identification is performed by the various methods such as SAM, SFF and BE. The SWIR reflectance bands are given as the input to the spectral angle mapper (SAM). SAM classifies the SWIR imagery depends on the end member spectrum. To achieve precise classification accuracy, the trial and error method is performed to fix the angle deviation between spectra.

Results and Discussion

In the study area, soil samples are collected using GPS. The samples are converted to conductive materials by applying the carbon coating. Figure 4 shows the high resolution imagery obtained by apply the electron beam on the soil surface. The chemical compositions in the soil samples are identified using EDS method.

The EDS elemental identification and quantitative compositional information are showed in Figure 4. The chemical components of soil samples contain C(34.79%), O(42.14%), Na(0.5%), Mg(0.85%), Al(1.12%), Si(3.26%), Cl(0.39%), K(0.61%), Ca(2.17%), Ti(7.09%), Fe(7.08%) respectively. From Figure 4, it is clearly identified that, the Soil samples contain heavy metal Iron, Titanium, Copper and Calcium Carbonate.

In the present research work, ASD Spectroradiometer is used to characterize the reflectance of samples in Visible, VNIR and SWIR regions. Depends on the physical and chemical properties, it provides the reflectance in various regions. The ASD Spectroradiometer (400nm-2500nm) shows more reflectance in VNIR and SWIR regions due to their Iron and Titanium metal respectively. Figure 5 shows the reflectance curve of soil samples characterized using ASD Spectroradiometer.

Hyperion data has a total of 242 bands, out of 242, 163 bands are in calibrating condition, other bands are affected by noise, non-illuminated and water vapor. Table 1 shows the list of unused and bad bands in the Hyperion sensor.

![Fig. 4 — Microstructure of soil sample and its quantitative chemical composition](image)

![Fig. 5 — Spectral signatures of Titanium metal](image)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Bad bands</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-7</td>
<td>Zero bands, Non-illuminated</td>
</tr>
<tr>
<td>2</td>
<td>58-76</td>
<td>Zero bands, Overlap region between VNIR-SWIR region</td>
</tr>
<tr>
<td>3</td>
<td>121-132</td>
<td>Water vapor region has lot of Noise</td>
</tr>
<tr>
<td>5</td>
<td>165-181</td>
<td>Water vapor region has lot of Noise</td>
</tr>
<tr>
<td>6</td>
<td>221-224</td>
<td>Water vapor region has lot of Noise</td>
</tr>
<tr>
<td>7</td>
<td>225-242</td>
<td>Zero bands, Non-illuminated</td>
</tr>
</tbody>
</table>
Hyperion follows the push broom scanning method and the column gray level values are dropped, it provides the vertical lines in imagery and its affect the precision mapping\textsuperscript{17}. vertical strips present in the Hyperion data are removed using local destriping algorithm. It modifies striped column gray values by averaging the nearest neighborhood pixel value and improves the mapping accuracy.

The radiometric calibration modifies the radiance value of the earth surface from the DN value of Hyperion data. Radiometric calibration converts the Hyperion CCD digital numbers to radiance value at the scale factor 0.1. Atmospheric correction module of Hyperion imagery is performed using FLAASH module to get the absolute reflectance bands\textsuperscript{18}. FLAASH uses the advanced techniques to knob particularly stressing atmospheric conditions, such as the presence of clouds and providing the smoothness reflectance compare to others.

Figure 6 shows the Hyperion imagery and its spectral profile plot with respect to raw image, radiance and reflectance characteristics. The reflectance bands of Hyperion imagery contain more noise (Band 20). Minimum noise fraction (MNF) is executed to identify the pure spectral information. Pixel purity index (PPI) is executed to locate the pure spatial information. MNF arranges the reflectance bands in the ascending order depends on the noise level\textsuperscript{19}. Figures 7a, 7b clearly show sorting of noiseless reflectance bands. The noiseless bands are given as input for PPI. PPI implements the MNF bands in the threshold value from 2.5 to 10000 iterations. Black and white pixels in the PPI indicate the impure and pure pixels respectively. Figure 7(c) shows the spatially pure pixels like as white pixels and black pixels show impure pixels.

Titanium reflectance spectrum is characterized using ASD Spectroradiometer\textsuperscript{20}. The spectral analyst tool compares the sample spectra to image spectra and provides probability using the techniques such as SAM, SFF, BE. Figure 8 shows spectral signature for Titanium metal at SWIR region.

Titanium metal classification using Spectral Angle Mapper (SAM) method

SAM compares the image spectra and Titanium metal sample spectra. Angle difference between the image spectra and Titanium spectra executed using trial and error method\textsuperscript{21}. SAM results show the red pixels demonstrate the Titanium metal appropriation in the earth terrain. Figure 9 illustrates the Titanium metal classification using SAM.

The red pixels designate the Titanium metal and the black pixels designate the other earth surface
In the region 23.87% i.e. 78.93km² Titanium is identified using hyperspectral imagery. The other 76.13% area accomplished as other earth terrain surfaces such as vegetation, soil, rock, urban features and etc.

**Conclusion**

The spectral signature of Titanium metal is characterized using ASD Spectroradiometer. Titanium metal deposited in the soil is around 23.87% of the total area. Availability of dense vegetation affects the spectra and limits the Titanium metal classification. In future, the high spatial and spectral resolution imagery such as AVIRIS provides the higher precision in mineral or metal identification.

**Acknowledgement**

Authors are grateful to the Centre for Disaster Mitigation and Management (CDMM), Vellore Institute of Technology, Vellore for their support and guidance provided for the completion of the manuscript.

**References**


