Aim of Lesson

To visualize hyperspectral images, to explore image reflectance spectra and to prepare the images for later classification.

Objectives

1. To learn how to explore a hyperspectral image
2. To learn how image reflectance spectra can be explored
3. To investigate the impact of noise removal on hyperspectral images

Background Information

PRACTICAL ISSUES

Hyperspectral images, like most other remotely sensed digital images, often contain noise due to the limited accuracy of the sensor calibration, the inherent sensor design (electron noise, e.g. circuitry), the measurement itself (photon statistics) and the models used to perform the different data pre-processing steps. To compare the different image spectra and subsequently classify the images, noise has to be removed.

SOFTWARE

ENVI ® software is required to carry out the lesson.

Lesson outline

1. Exploring the hyperspectral image and its reflectance spectra

Before you start processing hyperspectral imagery you need to know how to explore the hyperspectral image and the reflectance spectra. You will first learn how to visualize 3 spectral bands in a colour image or show up individual bands in greyscale. Then you will learn to display and investigate the image reflectance spectra.

1. Open hyperspectral images and visualize 3 spectral bands in a colour image.

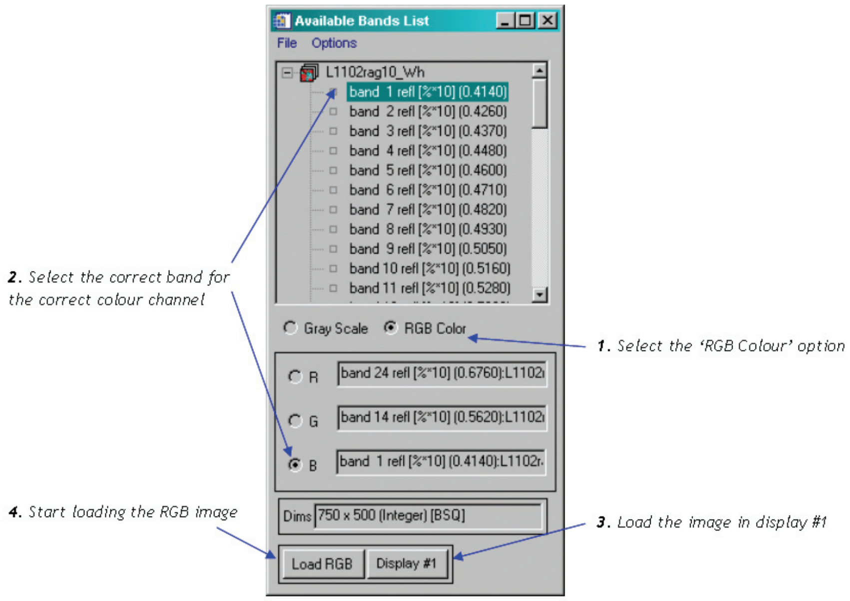
Action : In the 'ENVI' main menu use the 'Open Image File' option to open and display file \Lesson02\Data\L1102rag10_Wh.

Hint: In the ENVI main menu [ENVI] use: <File> <Open Image File>

Action : Use the 'Available Bands List' to load band 1 in the blue (B) channel, band 14 in the green (G) channel and band 24 in the red (R) channel.

Info: The wavelength of band 1 is located in the blue region, the wavelength of band 14 is located in the green region and the wavelength of band 24 Is located in the red region of the electromagnetic spectrum. When assigning these bands to the corresponding Red, Green and Blue channel, an image is obtained, coloured identically as can be seen by the human eye.

Hint: Using the "Available Bands List", bands from the hyperspectral image can be allocated to the Blue, Green and Red channel as shown in Figure2.1.



>> Figure 2.1: The image to be opened appears in the "Available Bands List" window, the bands to be displayed can now be chosen.

The image now pops up on the screen and you will notice three windows. The 'Scroll' window gives an overview of the complete scene. By shifting the red box around the scene (grab by left mouse button), a more detailed view is obtained in the 'Image' window. Again, the red box in this 'Image' window can be moved around to get an even more detailed view in the 'Zoom' window. You can zoom in and zoom out by clicking the + and – sign in the 'Zoom' window. A cross-hair can be placed in the 'Zoom' window (to indicate the actual pixel) by clicking the empty square, bottom left in the zoom window. This can be useful when you want to investigate individual image reflectance spectra (don't worry we'll explain this later!).

Because the hyperspectral image of 'De Westhoek' is rather small, it is sufficient and more convenient to display the image in only two windows. Therefore click the maximize button on the image window. As a result you will now see the complete hyperspectral image of the dunes, beach and even part of the sea as a whole in the 'Image' window. The 'Zoom' window is still present to explore the image in more detail.

Action: Explore the image by moving around the 'Zoom' window. Zoom in and out on the different parts of the scene to get an idea of the complexity of the hyperspectral image.

Info: You can enlarge the 'Zoom' window by grabbing one of the corners of the 'Zoom' window (left mouse button) and drag it to a larger size.

Question 2.1: You now have visualized three bands (1, 14 and 24) from the available 48 bands. What do you notice in the image? What can be the reason for this?

2. Investigate individual bands in a grey scale image.

Investigating the problem more in depth is possible by visualizing individual bands as grey scale images.

Action: Use the 'Available Bands List' to display band 1 as a 'Gray Scale' image. Load the image in display 2. Load consecutive bands for observation and notice the difference between them.

Hint: To create a new display, click the 'display' button in the 'Available Bands List' dialog and choose 'new display'.

Info: You can load other bands in the actual display by double clicking the required band in the 'Available Bands List'. Make sure that the active window selected, as indicated on the 'display' button, is 'Display #2'.

Action: After you investigated several bands you can now close display #2.

Hint: In the 'Image' window use: <File> <Cancel> or use the window close button at the top right of the image window.

3. Display and investigate image reflectance spectra.

When a large number of bands are to be investigated (which is mostly the case with hyperspectral imagery!), displaying individual bands one by one is very time consuming. The Z profile or spectral profile can be used to get a clear overview of the different spectral band values at pixel level. This Z profile or spectral profile, also called the spectrum, is unique for each material on the Earth's surface and is the basis for hyperspectral image classification.

Action: Explore some pixel spectra. Compare the spectral profile of water pixels with the spectral profile of sand pixels and the spectral profile of vegetation pixels. Notice the difference in spectral profile in relation to the different materials at the Earth's surface.

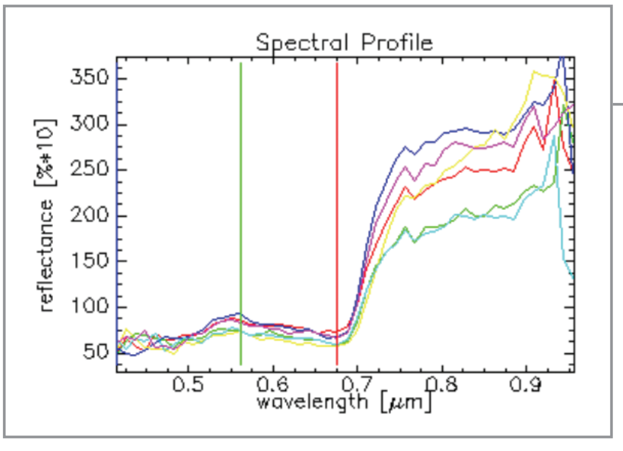
> **Hint**: In the 'Image' window use: <Tools> <Profiles> <Z Profile (Spectrum)…> move the 'Zoom' window around to investigate different pixels.

Question 2.2: How can you distinguish vegetation spectra from non-vegetation spectra? In other words, how does a typical vegetation spectrum looks like?
Often you need to compare different spectra against each other. Therefore an interesting option is to collect different spectra in the same 'Spectral Profile' window.

Action: Move the 'Zoom' window to the bottom right of the image where the blue stripes in the image are located (you still have band 1 on the blue (B) channel, band 14 on the green (G) channel and band 24 on the red (R) channel). Now collect some different spectra in this area by slightly moving the zoom box around.

> **Hint**: In the 'Spectral Profile' window use: <Options> <Collect Spectra>. The 'Collect Spectra' option can be switched on/off. The option should be marked on.

Depending on the pixels selected, your 'Spectral Profile' window will look like Figure 2.2.



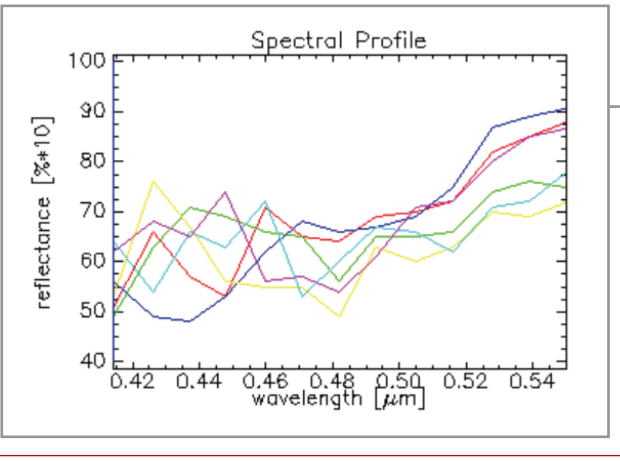
>> Figure 2.2: Spectral profile window showing different spectra collected from the hyperspectral image.

Question 2.3: Observe the collected spectral profiles carefully. What do you notice at wavelengths below 493 nm and above 885 nm? What could be the reason for this?
To view the spectral profile in more detail, the range of the X and Y axis can be changed.

Action: Zoom in on wavelength range 414-550 nm (blue) of the collected spectral profiles.

> **Hint**: In the 'Spectral Profile' window use: <Edit> <Plot Parameters…>. Select 'X-Axis' and change 'Range 0.41400 To 0.55000', then select 'Y-Axis' and change 'Range 40.00000 To 100.00000'. Click <Apply> then <Cancel>.

After zooming in on the blue wavelength range, the 'Spectral Profile' window should look like Figure 2.3 below.



>> Figure 2.3: Spectral profile window showing the detailed part of the collected spectra between 414 nm and 550 nm.

Question 2.4: Now you have a detailed view of the low S/N ratio at the blue wavelength range. Can this problem be solved?

2. Noise removal

In this section you will learn how this noise can be removed from the image. It is not possible to correct the spectra for this noise in the blue region and at the NIR plateau, but we can remove the bands exhibiting noise.

Action: Remove bands 1 to 7 and bands 43 to 48 by creating a new file.

Hint: In the ENVI main menu [ENVI] use: <Save File As> <ENVI Standard>.
In the 'New File Builder' window use: <Import File…>.
In the 'Create New File Input File' window: select the corresponding file (L1102rag10_Wh) and click <Spectral Subset>.
In the 'File Spectral Subset' window: highlight the bands to be saved (select bands 8 till 42, in total 35 bands will be selected) and click <Ok> twice.
Specify the path and filename were to store the new file by <Choose> in the 'New File Builder' window, i.e. use filename L1102rag10_Wh_c.

The newly created file contains less bands and therefore its size will be smaller than the original file (you can check this!). We will now continue using this newly created file which appeared automatically in the 'Available Bands List' after creation.

Action: Load the newly created file in 'Image #1'. Again load band 1 in the blue (B) channel, band 14 in the green (G) channel and band 24 in the red (R) channel.

Question 2.5: Your image will look a bit strange now. What happened? Use the 'Z profile' to explore the spectral profile.
You can reload the visual bands to obtain a naturally looking image. Load band 6 in the green channel and band 17 in the red channel, band 1 stays in the blue channel.

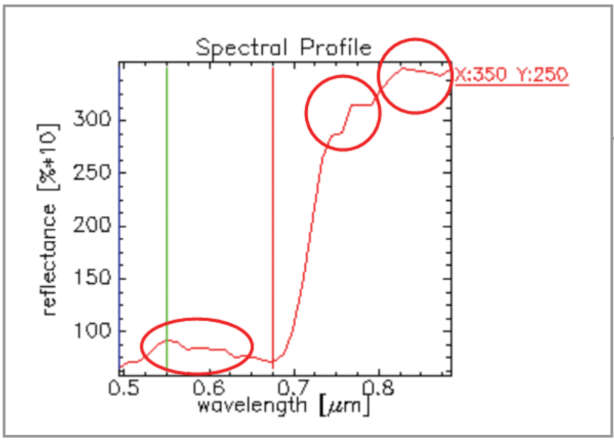
Hint: You can easily load other channels to your image window by using the 'Spectral Profile' window. Grab the corresponding colour bar and drag it to the desired channel or wavelength (use the left mouse button). When all colour bars are on the correct channel, click with the right mouse button in the 'Spectral Profile' window and use <Load New RGB Combination>.

Now that you have reloaded a naturally looking image, you can again explore different spectra in the scene by moving the zoom box around and observing the spectra in the 'Spectral Profile' window.

Action: Observe the spectrum of the pixel located at pixel location: Sample=350, Line=250.

Hint: In the 'Image' window use: <Tools> <Pixel Locator …>. In the 'Pixel Locator' window fill in 'Sample' 350, 'Line' 250 and click <Apply>. In the 'Spectral Profile' window use: <Option> <Plot Key>. You can also use the shorter option by right clicking in the 'Spectral Profile' window and left clicking on <Plot Key>.

Question 2.6: Your 'Spectral Profile' window should now look like Figure 2.4. Do you think this spectrum looks ok now? Especially look at the indicated areas. What might be the reason for this? How can this be solved?



>> **Figure 2.4: Spectral profile window showing a vegetation spectrum containing remarkable spectral features (circumvented in red).**

ENVI also includes a spectral polishing algorithm, but we won't examine this option here. Instead the image \Lesson02\Data\L1102rag10_Wh_cp, which is polished by an external algorithm, is used.

Action: Load image L1102rag10_Wh_cp on display #2. Link this display with display #1 and display the Z profile. Overlay the spectrum of display #2 on the spectrum of display #1. Observe the effect of the external polishing algorithm.

Hint: In the 'Available Bands List' use: <File> <Open Image File…> to open file \Lesson02\Data\L1102rag10_Wh_cp and load the image bands 1, 6 and 17 in display #2 as explained before.
In the '#2 Image' window use: <Tools> <Link> <Link Displays…>.
In the 'Link Displays' window set 'Link Size / Position' to 'Display #1' and click 'Ok'.
Display the Z profile as explained before.
In the 'Spectral Profile' window #2 use: <Edit> <Data Parameters…>.
In the 'Data Parameters' window right click on the red square and change the colour to <Blue>.
Use the 'Plot Key' as explained before, grab the spectrum (use left mouse button) and drag it to the '#1 Spectral Profile' window.

After these actions the 'Spectral Profile' window should look like Figure 2.5 where the polished spectrum (blue) is overlaid on the input spectrum (red). You can clearly see that the noisy input image spectrum has a smoother curvature after polishing. Now the image is ready for classification.

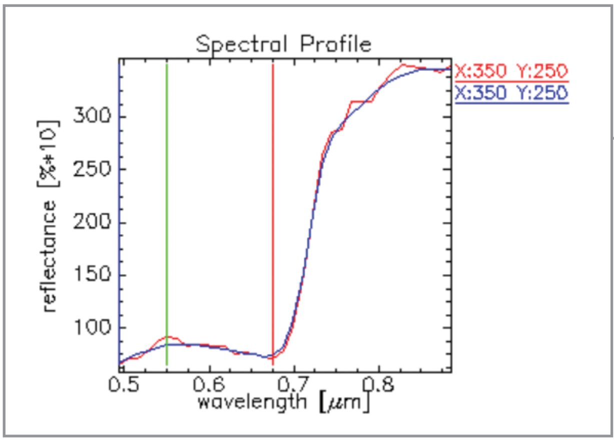
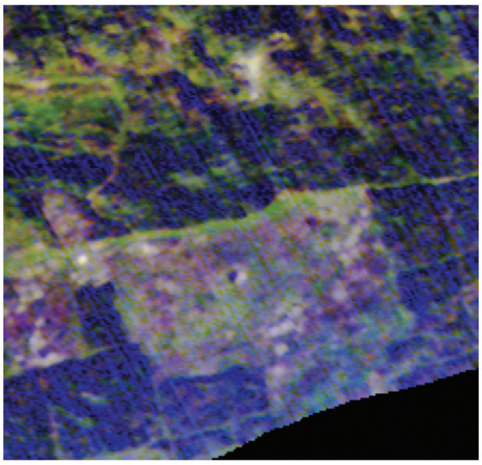


Figure 2.5: Spectral profile window showing a polished vegetation spectrum (blue) overlaid on the same non-polished vegetation spectrum.

Answers to questions

Answer 2.1: You now have visualized three bands (1, 14 and 24) from the available 48 bands. What do you notice in the image? What can be the reason for this?

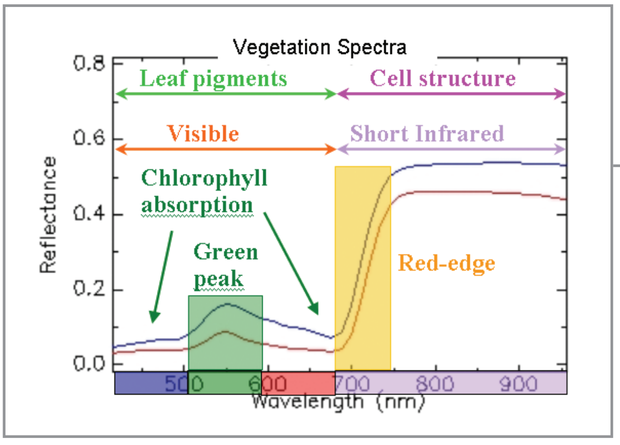
As can be seen in the detailed view below (Figure 2.6) some striping is present in the scene. This striping is parallel to the scan direction of the hyperspectral sensor and is due to noise in some of the bands. This noise is the result of the limited calibration accuracy of the sensor, the low irradiance at the shorter wavelengths and the limited accuracy of the different models for radiometric and atmospheric correction.



>> Figure 2.6: Hyperspectral image showing band 1 in the 'Blue' channel, band 14 in the 'Green' channel and band 24 in the 'Red' channel.

Answer 2.2: How can you distinguish vegetation spectra from non-vegetation spectra? In other words, how does a typical vegetation spectrum looks like?

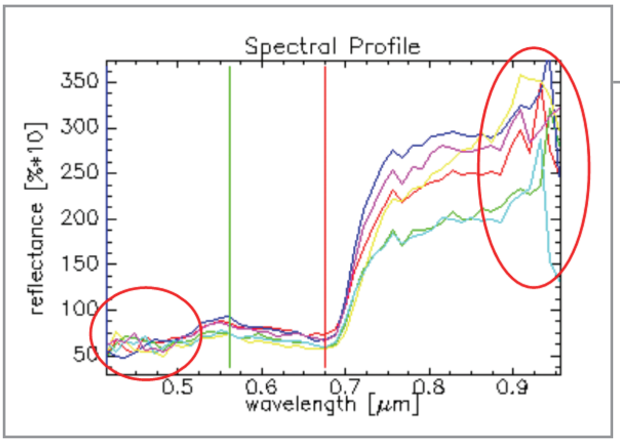
Vegetation spectra can easily be distinguished from non-vegetation spectra by some characteristic features. Absorption by green plants is strongest in the blue and red part of the visible spectrum. The green part of the solar spectrum is less absorbed and this is the reason why plants look green to the human eye. This increased reflection in the green area around 550 nm is called the green peak and is one of the two characteristic spectral features for vegetation.
The energy contents of the non-visible short infrared is insufficient for photochemical reactions and therefore it is not absorbed by the chlorophyll and the other leaf pigments. This results in a strong increase of reflection around 690 nm called the 'Red-edge' this is typical for vegetation and is the second characteristic spectral features for vegetation. These typical features are illustrated in Figure 2.7.



>> Figure 2.7: Vegetation reflectance spectrum showing some typical vegetation spectral features, i.e. the chlorophyll absorption features, the green peak and the red-edge.

Answer 2.3: Observe the collected spectral profiles carefully. What do you notice at wavelengths below 493 nm and above 885 nm? What do you think is the reason for this?

The two areas which look a bit suspicious are indicated by the two circles in Figure 2.8. The reason for this strange behaviour in the blue region (shortest wavelengths) was explained in answer 2.1. On the Near Infra Red (NIR) plateau there is an additional problem caused by water vapour absorption. Both phenomena result in a poor Signal to Noise ratio (S/N ratio) at these wavelengths.



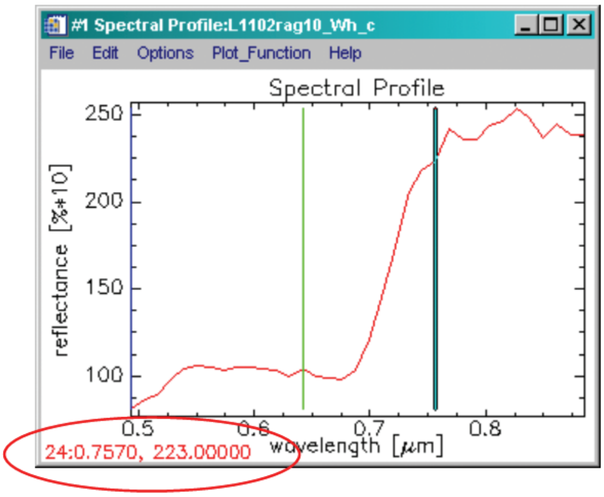
>> Figure 2.8: Spectral profile window showing noisy vegetation spectra.

Answer 2.4: Now you have a detailed view of the low S/N ratio at the blue wavelength range. Can this problem be solved?

Smoothing or polishing algorithms can't be used when the S/N ratio is too bad. So the only way you can solve this problem is by removing the bands with poor S/N ratios. This process is called "bad band removal".

Answer 2.5: Your image will look a bit strange now. What do you think happened? Use the 'Z profile' to explore the spectral profile.

Because the first 7 bands where removed you now loaded the same band numbers on the same colour channels but these band numbers now are allocated to longer wavelengths. In fact, by removing the first 7 bands, you're displaying the original bands 8, 21 and 31, which are allocated to wavelengths 493 nm, 642 nm and 757 nm respectively. You can check the wavelength by clicking on the blue, green or red bar in the 'Spectral Profile' window (use left mouse button). The corresponding channel number, wavelength and pixel value will appear at the bottom of the window. See Figure 2.9 where channel 24, allocated to wavelength 757 nm and with pixel (reflectance) value 223 is shown.



>> Figure 2.9: The spectral profile window can be used to find out the reflectance value of a certain band at a particular wavelength. Here band 24 at 757 nm has a reflectance value of 0.223.

Because you have assigned a NIR wavelength (channel 31 at 757 nm) to the red channel, the image displayed is in fact a false colour infrared. Because vegetation strongly reflects the NIR wavelengths (remember the red-edge!), it looks red now. Because the reflectance at the NIR plateau is determined by the water contents and the internal structure of the leaf, different plant types can be distinguished by the different shades of red. You can check this by carefully looking at the image, using the zoom window. We will explore this in more detail in lesson 9 (The colour of leaves).

Answer 2.6: Your 'Spectral Profile' window should now look like the one in Figure 2.4. Do you think this spectrum looks ok now? Especially look at the indicated areas. What might be the reason for this? How can this be solved?

These kinks aren't usual vegetation features. Again, as explained in answer 2.1, to solve this problem different smoothing and polishing algorithms exist but we're not going into depth in this lesson.