Hyperspectral remote sensing or Imaging spectroscopy refers to the imaging sensors measuring the spectrum of solar radiation reflected by different materials on the Earth's surface in many continuous wavebands. And the images produced by hyperspectral remote sensing are hyperspectral imageries. Hyperspectral data can be very useful in monitoring minute details on the earth's surface in the field of agriculture, disaster, climate change, etc.

EnMap stands for Environmental Mapping and Analysis Program and is a German hyperspectral satellite mission. The goal is to observe environmental changes in terrestrial and aquatic ecosystems of the Earth on a global scale. It is funded under the German Aerospace Center (DLR) by the Government of Germany.

In this assignment, we will use the EnMap-Box plugin for QGIS to visualize and process remote sensing raster data. This tool was specifically designed to handle imaging spectroscopy data to be expected from the Enmap sensor in the days to come.

Tool: QGIS (any version) with EnMap Box plugin installed
Data: "enmap_berlin.bsq" hyperspectral image and "landcover_berlin point.gpkg" vector layer provided by Enmap plugin

Image statistics

The example image "enmap_berlin.bsq" contained **177 spectral bands**. And the spectral bands ranged from 4**60 nanometers to 2409 nanometers** as shown in image 2 below.

Description	Band	N Valid	N Invalid	Min	Max	
Micrometers)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
band 228 (2.323000 Micrometers)	166	71158	16842	0.0	5031.0	842.1
band 229 (2.331000 Micrometers)	167	71158	16842	0.0	4998.0	819.9
band 230 (2.339000 Micrometers)	168	71158	16842	0.0	4950.0	797.7
band 231 (2.347000 Micrometers)	169	71158	16842	0.0	4992.0	781.1
band 232 (2.355000 Micrometers)	170	71158	16842	0.0	4886.0	766.9
band 233 (2.363000 Micrometers)	171	71158	16842	0.0	4915.0	767.3
band 234 (2.370000 Micrometers)	172	71158	16842	0.0	4783.0	751.8
band 235 (2.378000 Micrometers)	173	71158	16842	0.0	4679.0	742.2
band 236 (2.386000 Micrometers)	174	71158	16842	0.0	4608.0	734.6
band 237 (2.393000 Micrometers)	175	71158	16842	0.0	4768.0	732.4
band 238 (2.401000 Micrometers)	176	71158	16842	0.0	4635.0	718.4
band 239 (2.409000 Micrometers)	177	71158	16842	0.0	4739.0	718.2

Image 1: Screenshot of "enmap_berlin.bsq" statistics

Description	Band
band 8 (0.460000 Micrometers)	1
band 9 (0.465000 Micrometers)	2
band 10 (0.470000 Micrometers)	3
band 11 (0.475000 Micrometers)	4
band 235 (2.378000 Micrometers)	173
band 236 (2.386000 Micrometers)	174
band 237 (2.393000 Micrometers)	175
band 238 (2.401000 Micrometers)	176
band 239 (2.409000 Micrometers)	177

Image 2: Spectral range of the image

Spectral signature

We know that when electromagnetic energy reaches the Earth's surface, the process of reflection, absorption, transmission or combination of these takes place. The reflection phenomena are recorded by the sensors and can be quantified to obtain the **spectral signature** of the surface. Different substances on the surface have different reflection properties and thus different spectral signatures. So, these difference is further studied and are used to identify the surface.

Here, in "enmap_berlin.bsq" hyperspectral image, we look at spectral signatures of different surfaces like highways, water bodies, buildings and trees.

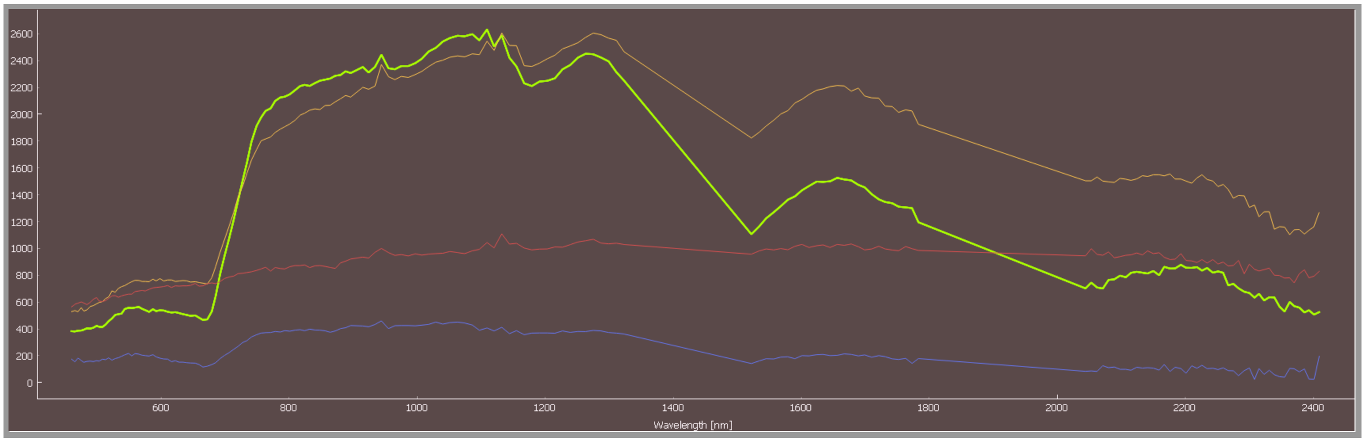

Image 3: Spectral signature curves

Red curve: Highway
Blue curve: Water body (Lake)
Parrot Green curve: Tree
Yellow curve: Building top

We can see from the graph, that each feature on the surface reacts to the electromagnetic wave differently. The waterbody has the lowest reflectance over the entire spectrum range. It can also be seen that water doesn't reflect a lot of light compared to roads, buildings and trees in the visible spectrum (~380-700 nm). The tree seems to be healthy and green since the green light is reflected most in the visible spectrum. As soon as we enter the near-infrared spectrum, the reflectance increases drastically for tree and building top and then drops down until ~1500 nm and then increase up to ~1700 nm and then decrease as shown in the graph. The highway on the other hand has more reflectance than water over the entire spectrum and the reflectance is more or less consistent across the entire wavelength. More information can be depicted by looking at the graph in image 3.

Regression based unmixing

Fraction mapping based on unmixing is suitable to describe the composition of surface types in heterogeneous environments. Regression algorithms along with synthetically mixed training data from spectral libraries are used for unmixing urban land cover. *Target classes* are to be selected by the user depending on the requirement. *End member library* with class labels is used to create a synthetically mixed dataset as mentioned above. That dataset is used to train a regression model for each class. And the same regression model is applied to an image to derive fraction maps for each class.

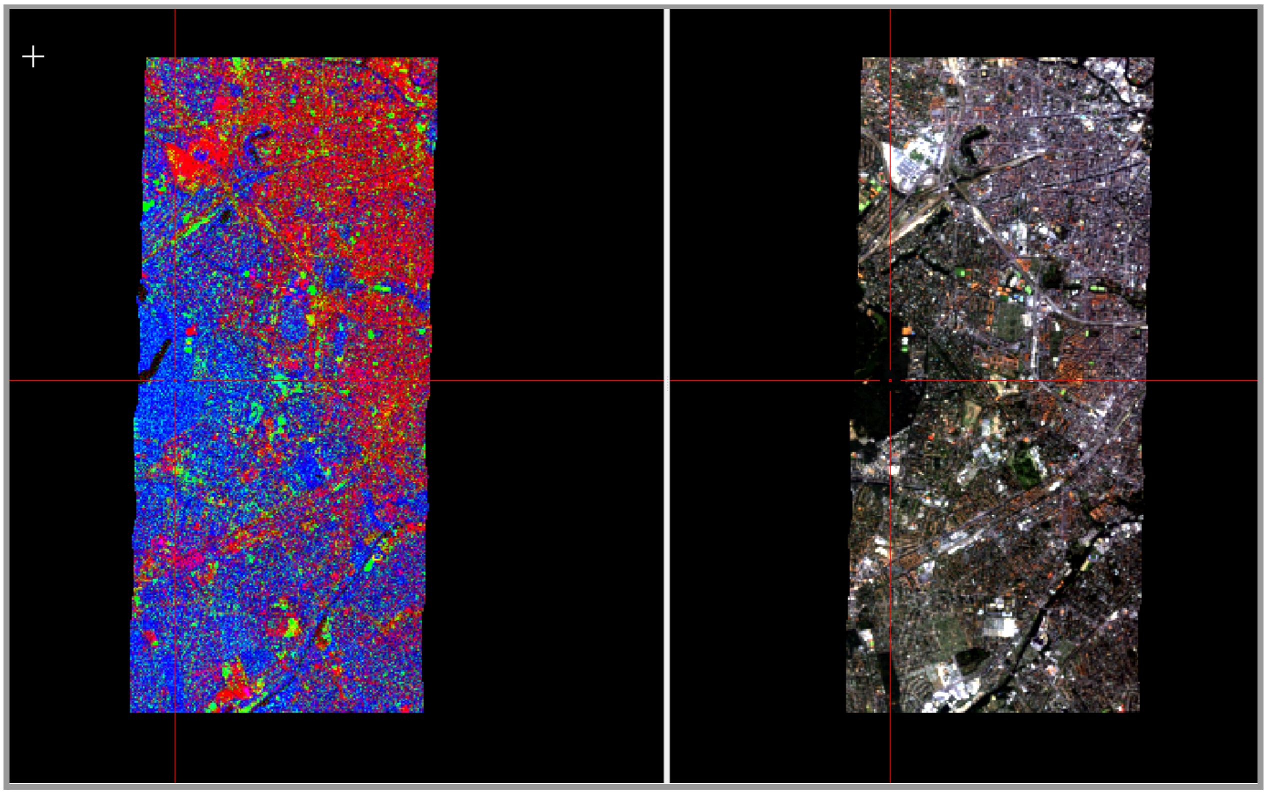

Image 4: Generated fraction map (Left) and original image (Right)

In my case, four target classes were automatically listed: impervious, soil, vegetation and water. The linear regression algorithm was chosen for the area of Berlin and the result on image 4 was generated. The red colour represents impervious features. Soil and vegetation are represented by green and blue respectively in the fraction map. Rooftops and roads were predicted as vegetation class instead of impervious class in some areas of the generated fraction maps. This might be due to the vegetation nearby the impervious features. Along the right top of the map, there is a high density of impervious fractions. We can infer that area as the main city segment in Berlin which can be verified with the original image to the right. The vegetation fraction is more in the mid and bottom left of the map which says that that area has more trees and other vegetation.

We can also validate the generated fraction maps statistically creating other reference fraction maps using significantly higher spatial resolution images.