UAV Hyperspectral Data Processing

and Simple Classification in MultiSpec

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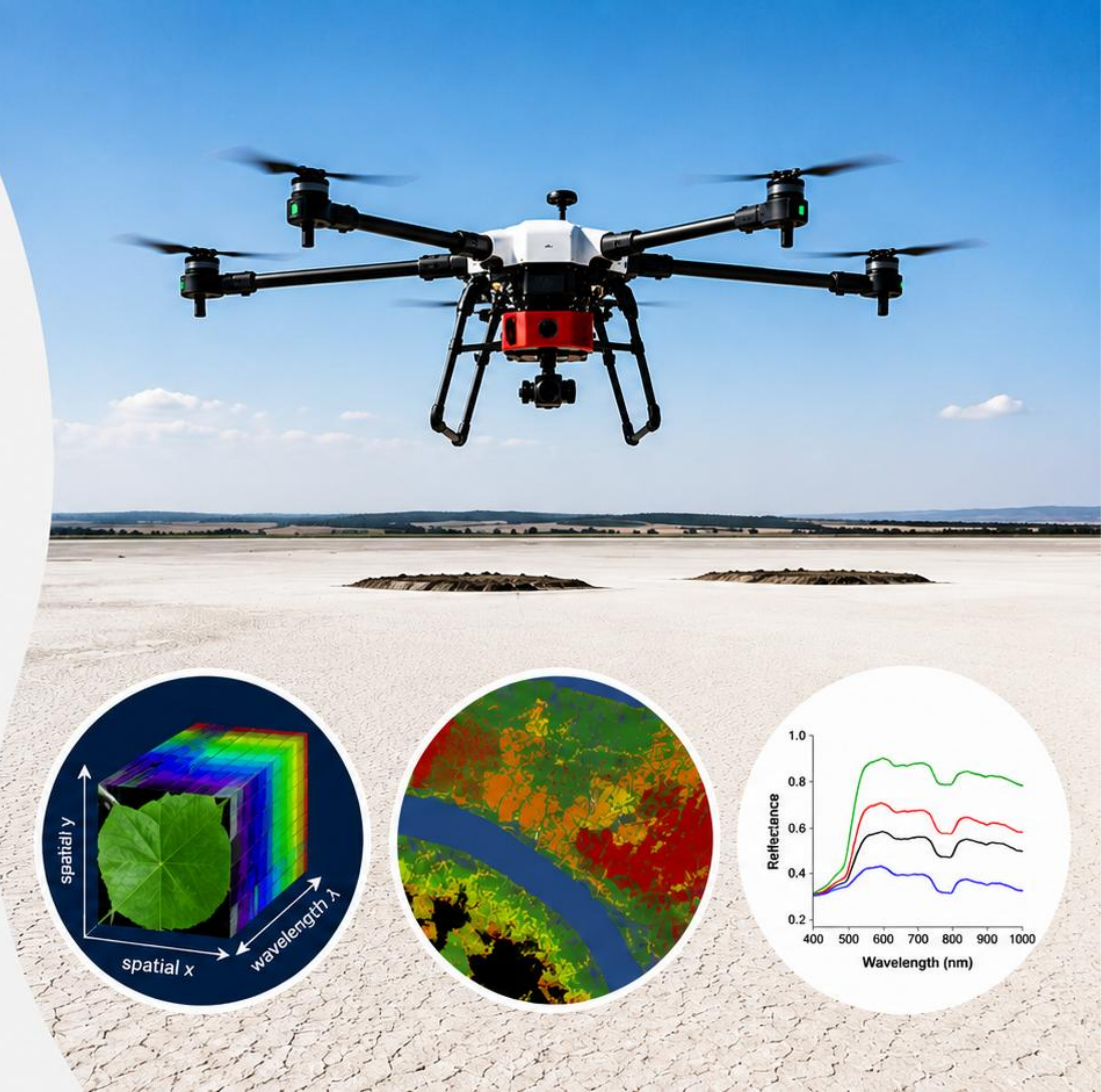


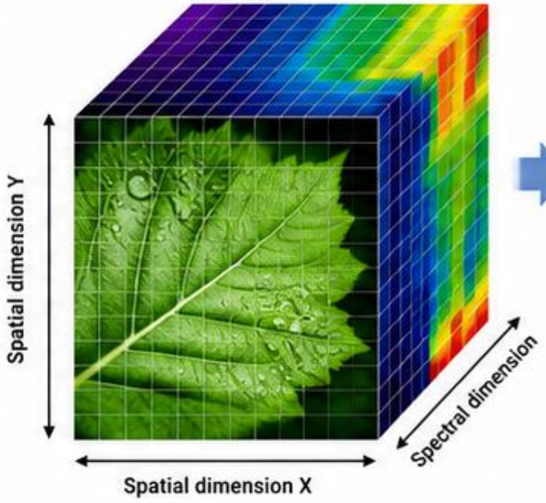
HYPERSPECTRAL CAMERA

- Imaging spectrometer used for **hyperspectral imaging**
- Can measure **thousands** or **hundreds of thousands** of spectra
- The collected spectra are used to form an image of the target, thus we get spectrum and location
- Data that hyperspectral imaging provides is called a **data cube**
  → This is huge amount of accurate information

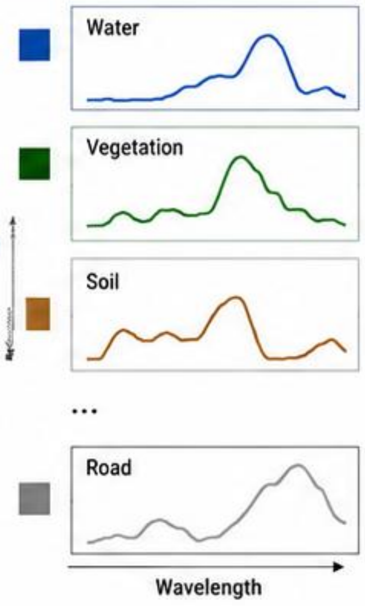
What to do with such a huge amount of information?

How to process the data more effectively and extract the most important information?

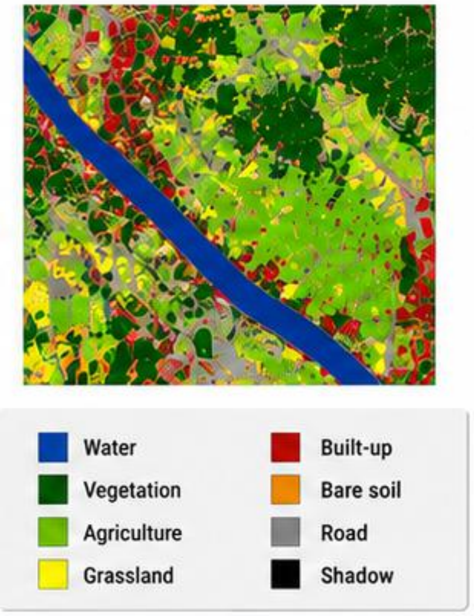
1. HYPERSPECTRAL DATA CUBE



2. SPECTRAL INFORMATION (SIGNATURES)



3. INFORMATION EXTRACTION (CLASSIFICATION)



THE DATA CUBE CONTAINS A VERY LARGE AMOUNT OF INFORMATION.

Dimensionality reduction and efficient data processing (e.g., PCA) help us analyze the data more effectively and extract key patterns.

High-dimensional data cube → Dimensionality reduction (e.g., PCA) → Key information & insights

Next step: We will explore Principal Component Analysis (PCA) as a key method to reduce dimensionality and extract the most important information from hyperspectral data.

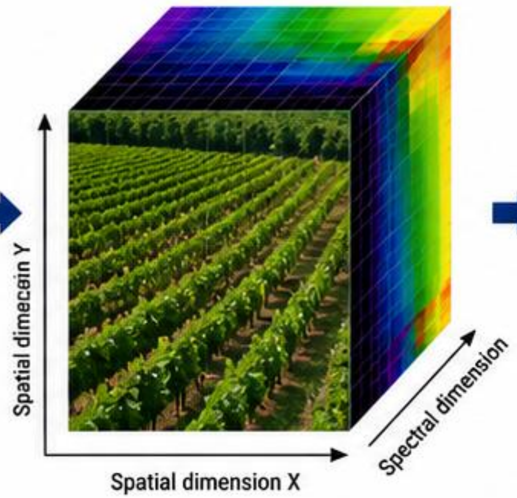
UAV HYPERSPECTRAL REMOTE SENSING

- Hyperspectral imaging combined with UAS enables **efficient data acquisition** over large or difficult-to-access areas
- UAV platforms provide **high spatial resolution** and operational flexibility
- Collects **hundreds to thousands** of spectra for every pixel
- Allows **fast, non-destructive** detection of subtle spectral and spatial variations
- **Great potential** for precision agriculture, environmental monitoring, forestry, and many other applications

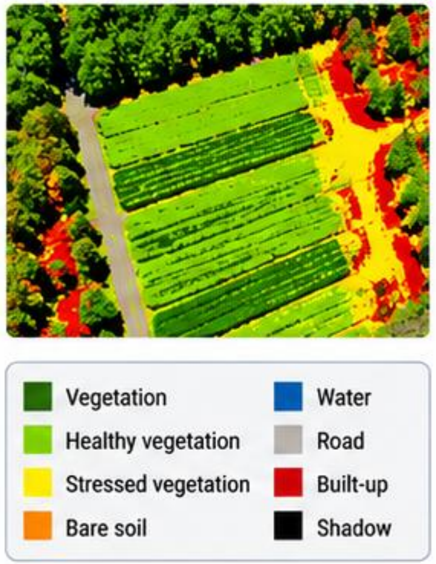
Chance to **develop R&D infrastructure** via the **EU structural funds**

1. DATA ACQUISITION WITH UAV

2. HYPERSPECTRAL DATA CUBE



3. INFORMATION EXTRACTION (CLASSIFICATION / ANALYSIS)



UAV HYPERSPECTRAL REMOTE SENSING MISSION

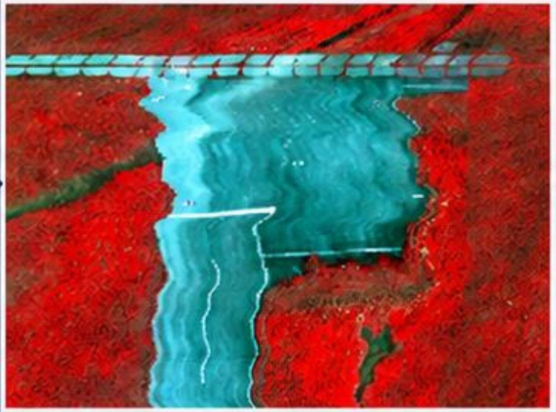
1 PLANNING & FLIGHT MISSION

- Plan flight lines to achieve complete coverage of the area of interest.
- UAV carries the hyperspectral camera and flies over the target area.

2 DATA ACQUISITION

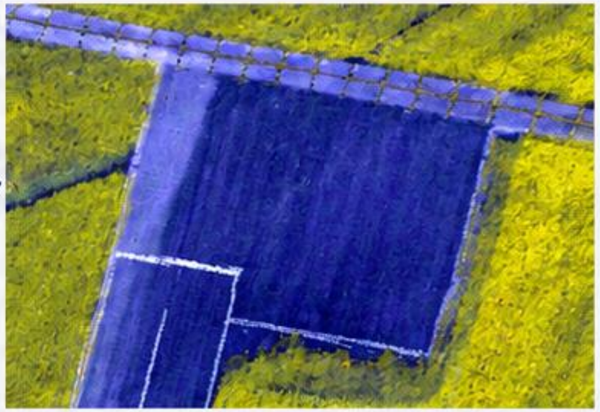
- Push-broom hyperspectral sensor records data line by line while UAV moves forward.
- Each line contains a full spectrum for every pixel.

3 RAW HYPERSPECTRAL DATA



- Each line is captured at a different time instant.
- Perspective geometry varies and line displacement occurs.

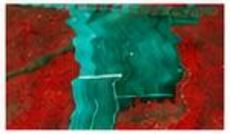
4 RECTIFIED HYPERSPECTRAL RESULT



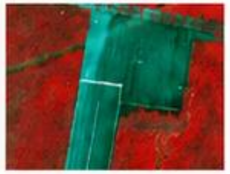
- After rectification and calibration, data are aligned to a common geometry.
- Ready for information extraction, classification and analysis.

PRE-PROCESSING: RECTIFICATION & CALIBRATION

Before rectification



After rectification

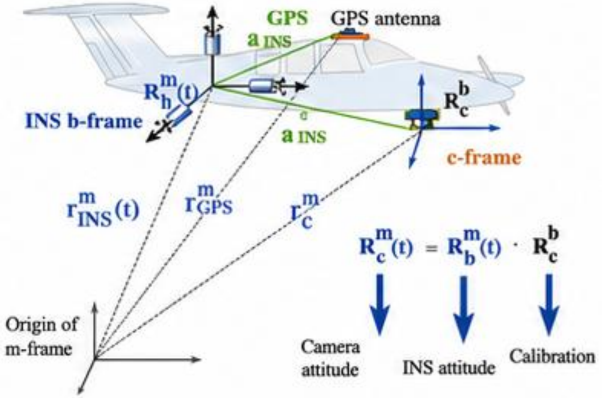


RECTIFICATION (geometric correction)

- Each line of push-broom images is collected at different time instants.
- Perspective geometry varies with each line and causes geometric distortions.
- Rectification is needed to align all image lines to a common geometry.

CALIBRATION (boresight calibration)

- Requires measuring position and attitude of the sensor using the IMU/GNSS unit on board the UAV.
- Accurate alignment of overlapping data strips requires compensating for geometric distortions caused by boresight misalignment.
- Ensures accurate georeferencing and high-quality hyperspectral data.



Hyperspectral data exercise:

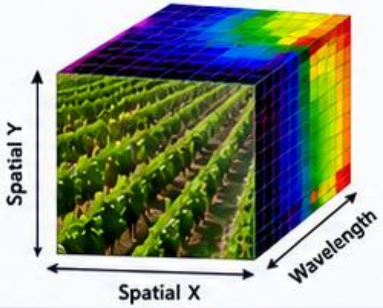
UAV hyperspectral data processing and simple classification in MultiSpec

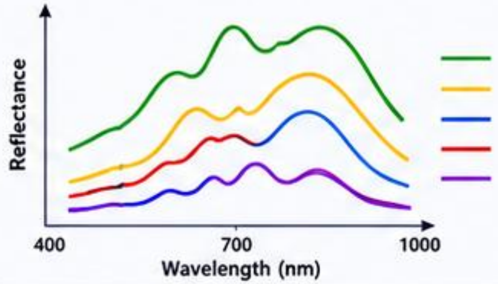
CONTENT OF THIS PRACTICAL

1

Spectral signatures (HS data)

- Explore and visualize spectral signatures from UAV hyperspectral data
- Analyze reflectance curves of different land cover / vegetation types
- Identify key spectral features and differences

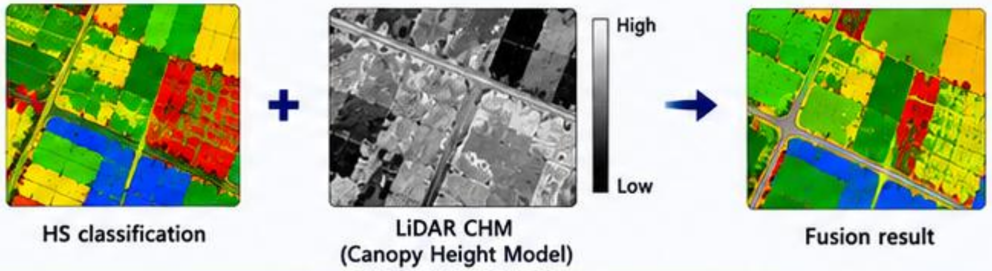




2

Image classification

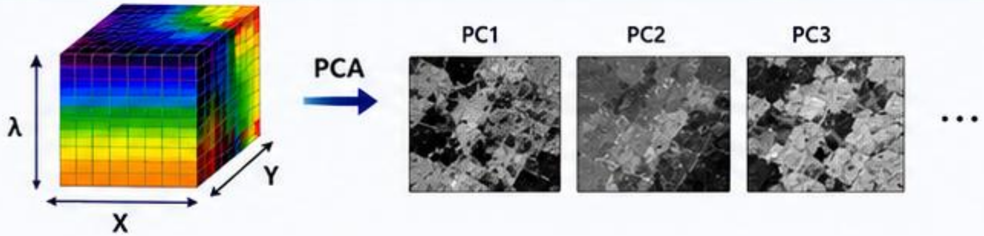
- Perform image classification using UAV hyperspectral data
- Perform image classification using fusion with **LiDAR-derived Canopy Height Model (CHM)**
- Compare and interpret classification results



3

Principal Component Analysis (PCA)

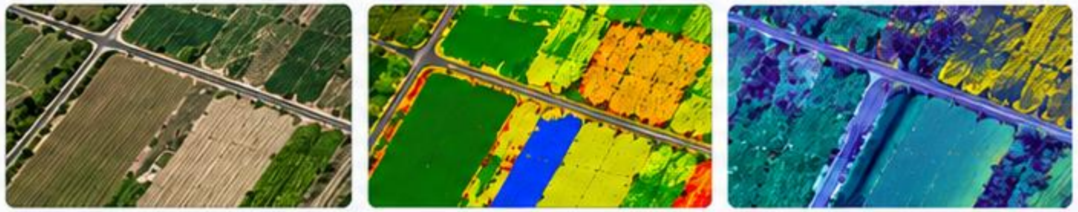
- Apply PCA to hyperspectral data
- Explore and interpret principal components
- Use PCA for data exploration and dimensionality reduction



4

Results and interpretation

- Evaluate and interpret results from all analyses
- Discuss findings, limitations and potential applications



INPUT UAV DATA

AISA Kestrel 10 hyperspectral data

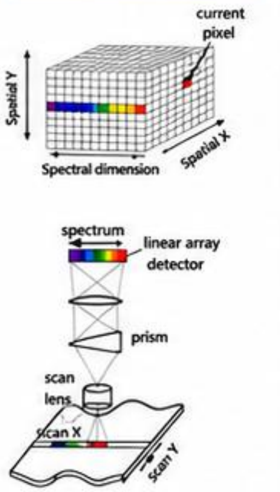
- Push-broom camera, 4.75 kg
- Spatial resolution: 1024 or 2048 pix.
- Spectral range: 400 – 1000 nm
- Max. number of spectral bands: 342

+ INPUT LASER SCANNING DATA (LiDAR)

- CHM (Canopy Height Model)

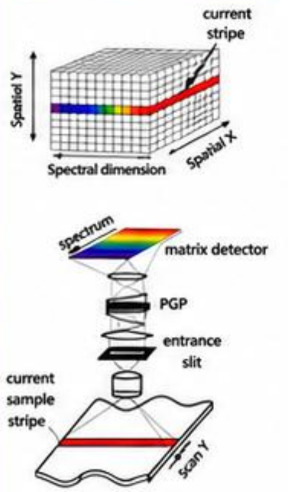
COMPARISON OF SPECTRAL IMAGING APPROACHES

WHISKBROOM



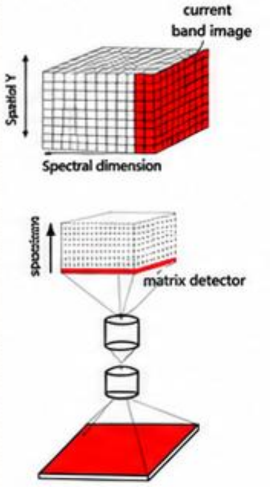
Captures one pixel at a time.
Full spectrum measured for each pixel sequentially.

PUSH-BROOM



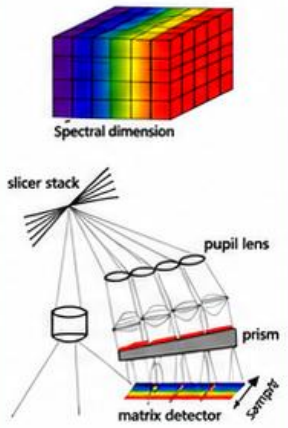
Captures one line at a time.
Full spectrum for all pixels in the line is recorded simultaneously.

STARING

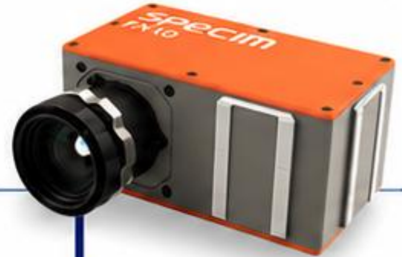


Captures one spectral band image (2D) at a time.
All pixels for that band measured simultaneously.

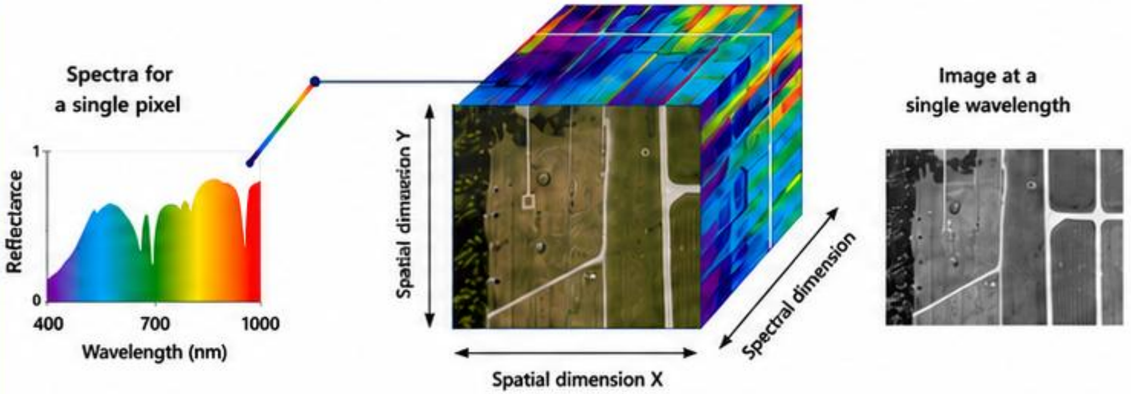
SNAPSHOT



Captures a 2D frame of the scene at one or a few wavelengths at a time.



SPECIM SPECTRAL IMAGING



Capture reflected electromagnetic energy in hundreds of contiguous narrow spectral bands

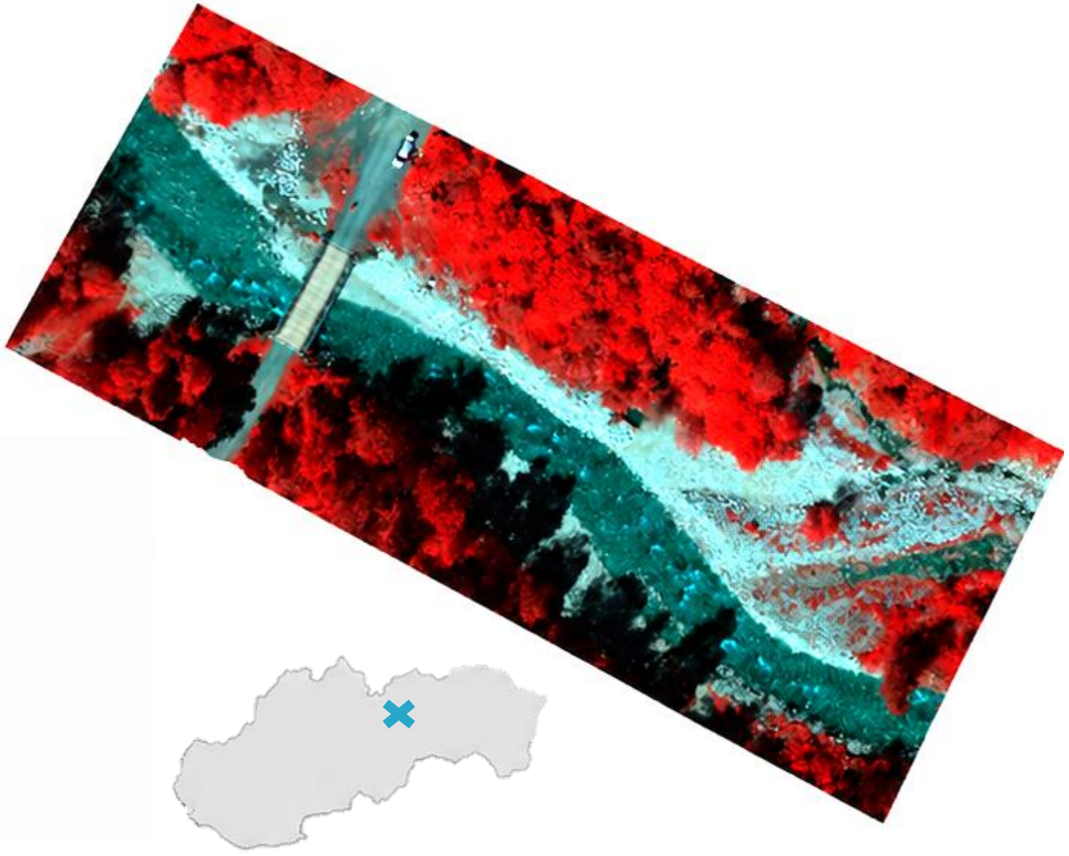
Combined with UAS:
- fast, flexible and non-destructive detection of subtle spectral features

- High spatial resolution
- Continuous spectral information
- Precise and detailed information about the target

High-quality hyperspectral input data is the foundation for accurate analysis and reliable results.

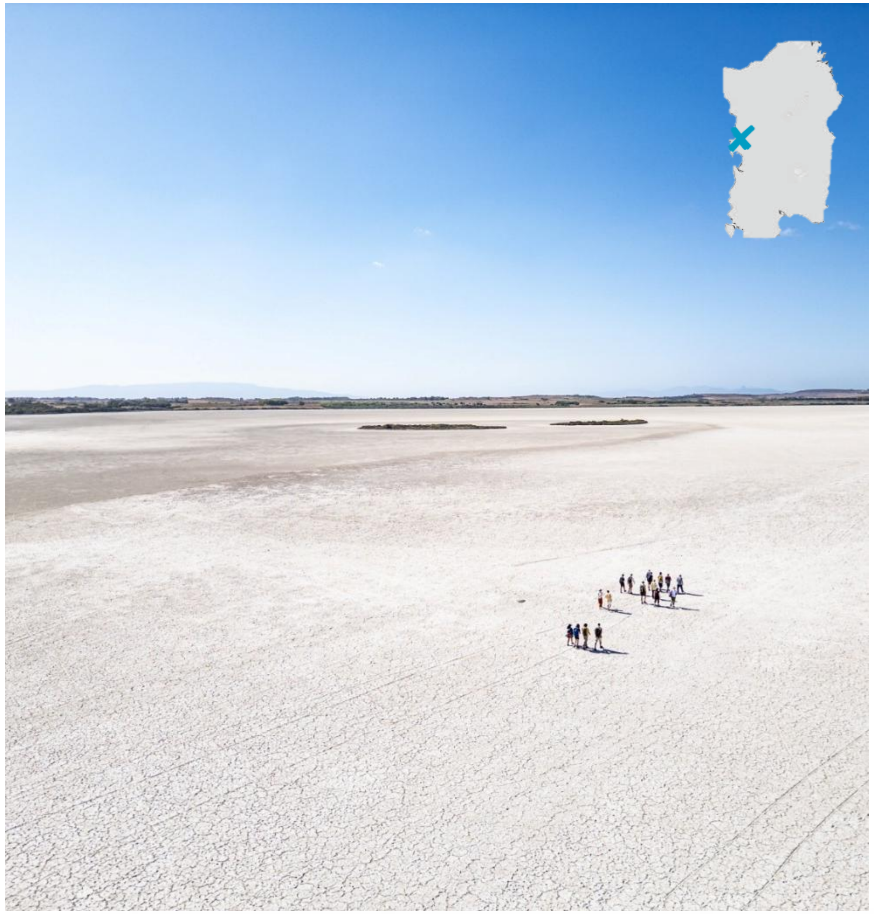
SAMPLE DATA

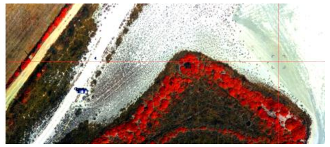
1. Stará Lesná (Slovakia)

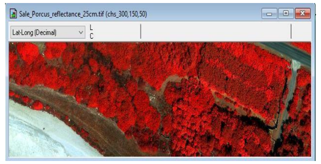


- UAV hyperspectral dataset acquired over Stará Lesná, Slovakia.

2. Sal'e Porcus (Sardinia)







- UAV hyperspectral dataset acquired over Sal'e Porcus, Sardinia, Italy.

DATA COLLECTION METHODOLOGY

UAV hyperspectral data were acquired using the **AISA Kestrel 10** hyperspectral camera mounted on a multi-rotor UAV platform.

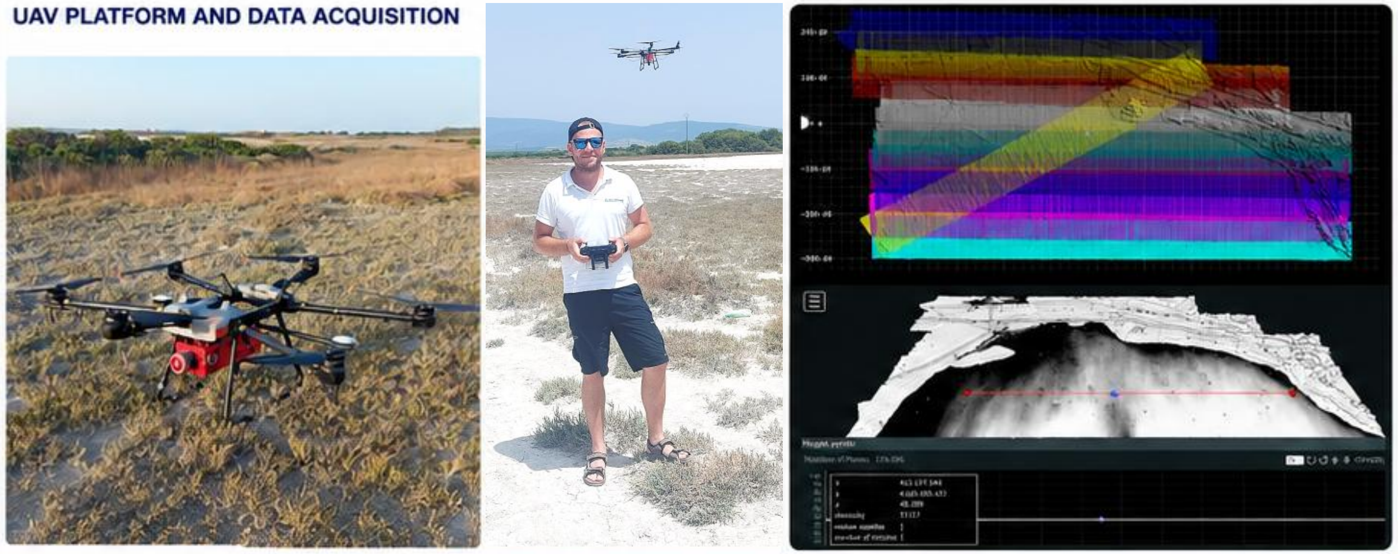
1 **FLIGHT PLANNING**
- Flight area definition and mission planning
- Appropriate flight altitude and overlap

2 **DATA ACQUISITION**
- UAV flight and hyperspectral image recording
- Real-time monitoring of flight and data quality

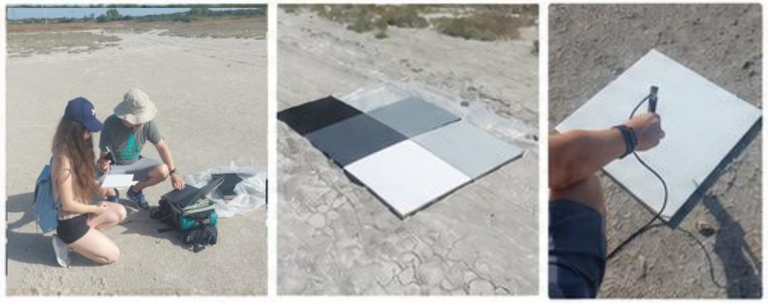
3 **CALIBRATION TARGETS**
- Collection of reflectance data using calibration panels (white, gray, black)
- Spectral calibration for radiometric accuracy

4 **GROUND MEASUREMENTS**
- In-situ spectral measurements using a field spectroradiometer
- Supporting data for data interpretation

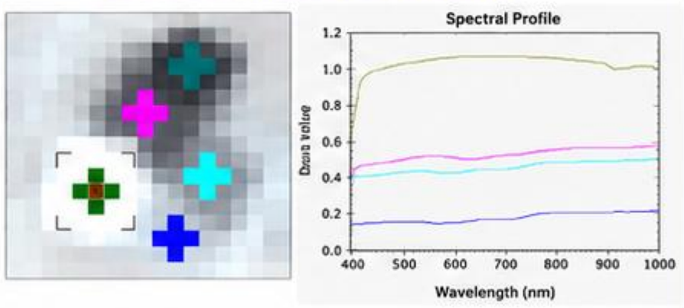
UAV PLATFORM AND DATA ACQUISITION

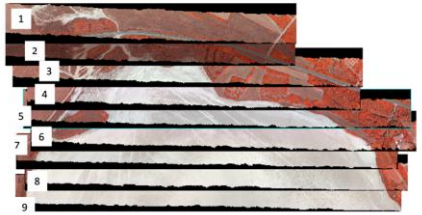


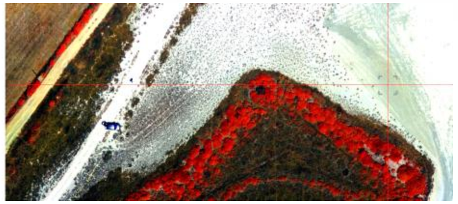
CALIBRATION PANELS



GROUND SPECTRAL MEASUREMENTS







Post-processed georectified atmospherically corrected HS data. Radiance (mW.cm^{-2} . sr $^{-1}$.µm $^{-1}$)*1000.00

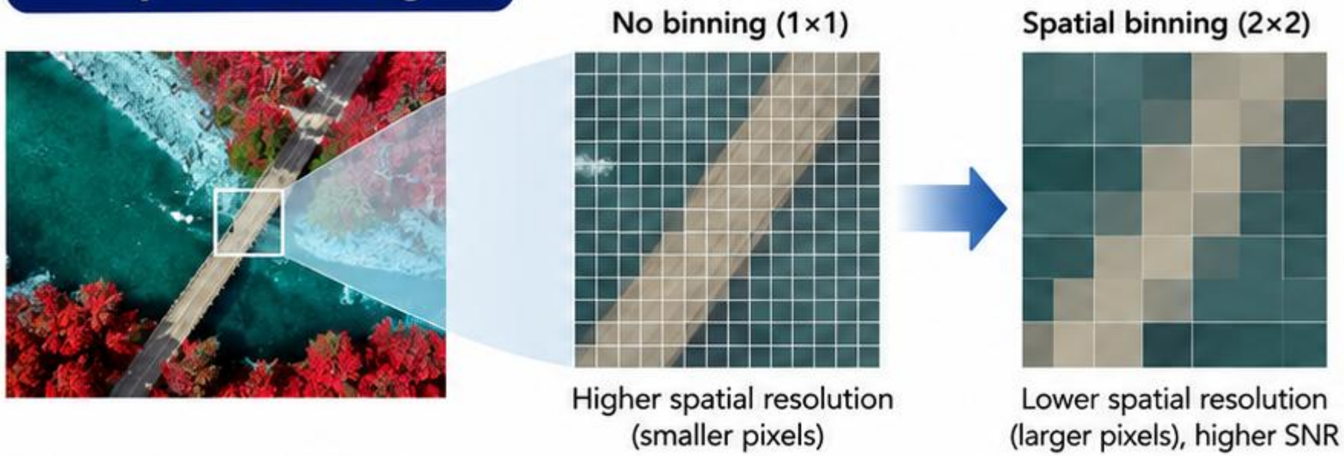
Binning

Binning: The process by which multiple pixels are lumped together into a single spatial or spectral channel to increase signal, and signal-to-noise ratio.

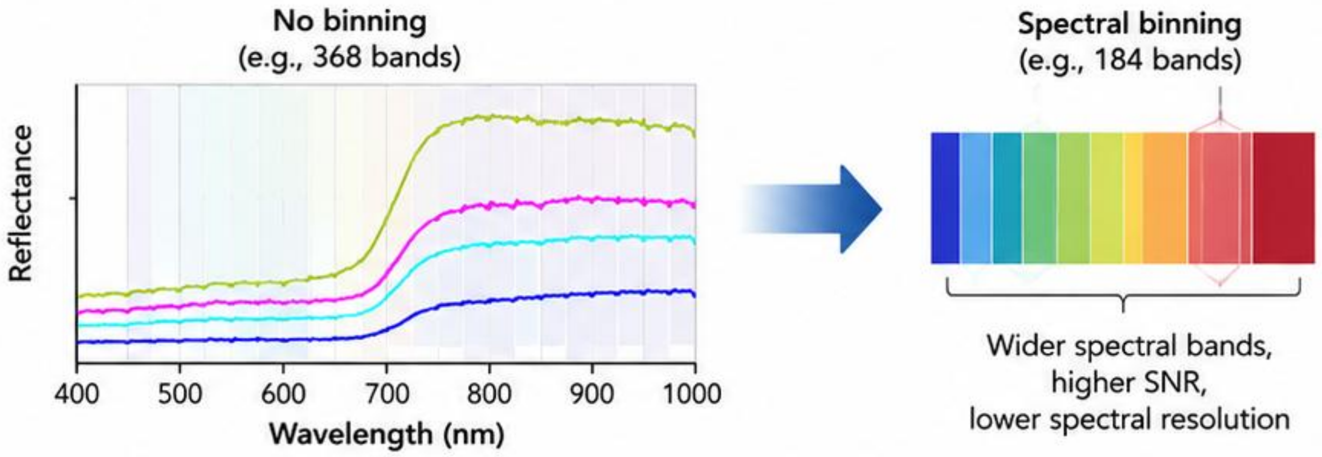
The tradeoff is a loss in spatial or spectral resolution.

- Higher signal strength
- Improved signal-to-noise ratio (SNR)
- Reduced data volume

Spatial binning



Spectral binning



MULTISPEC

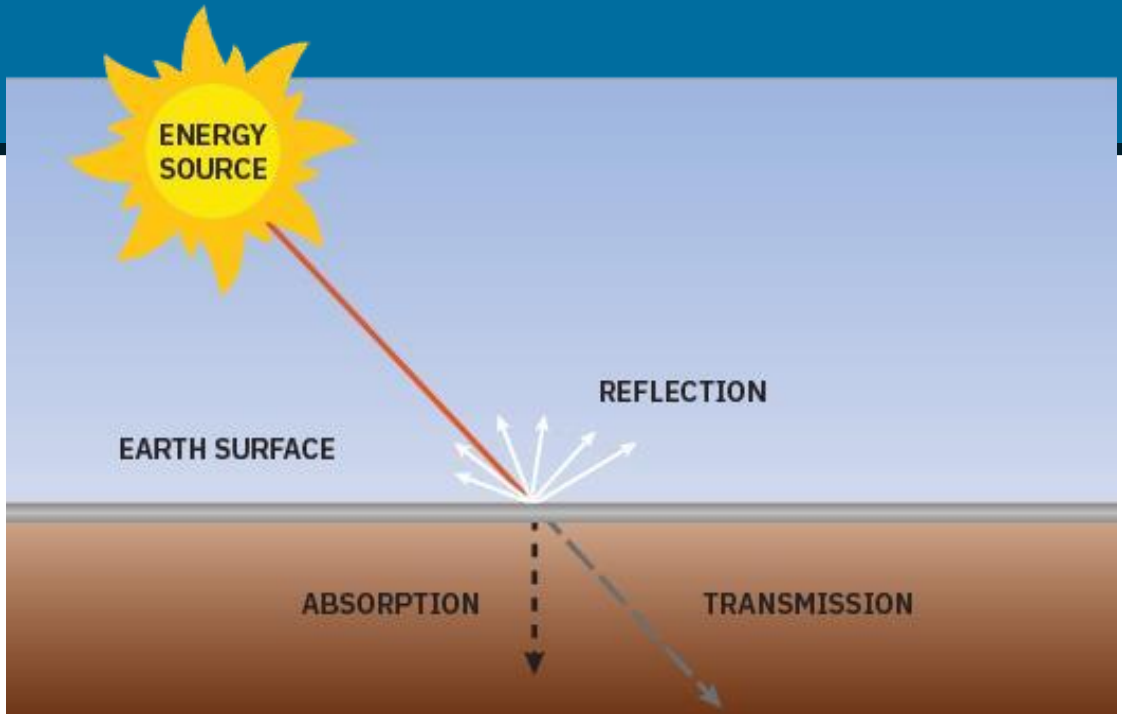
I. SPECTRAL SIGNATURES

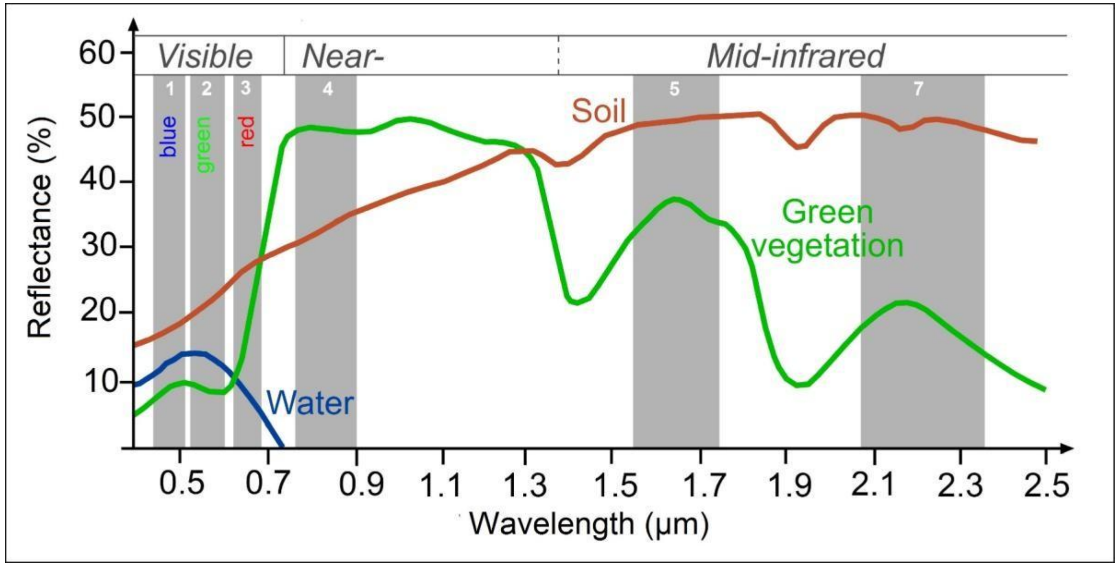
STATE-OF-THE-ART

Spectral signatures and their interpretation

- When EMR from the sun reaches the earth surface, it is:
  - transmitted
  - absorbed
  - reflected

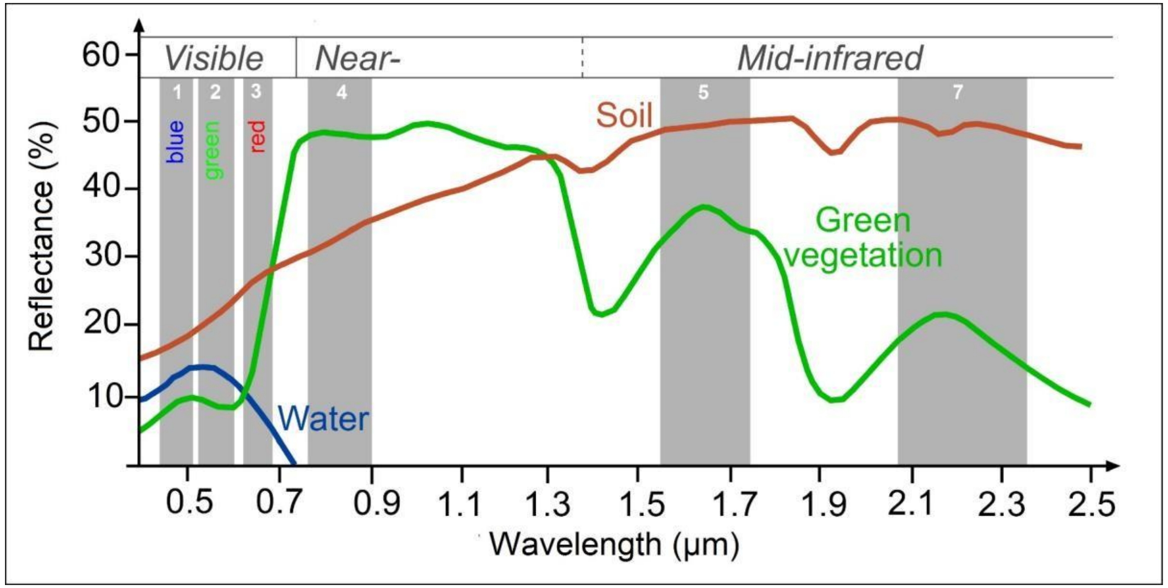
- The nature of how the earth materials transmit, absorb or reflect the solar EMR is called spectral signature of an object





SPECTRA OF EARTH MATERIALS

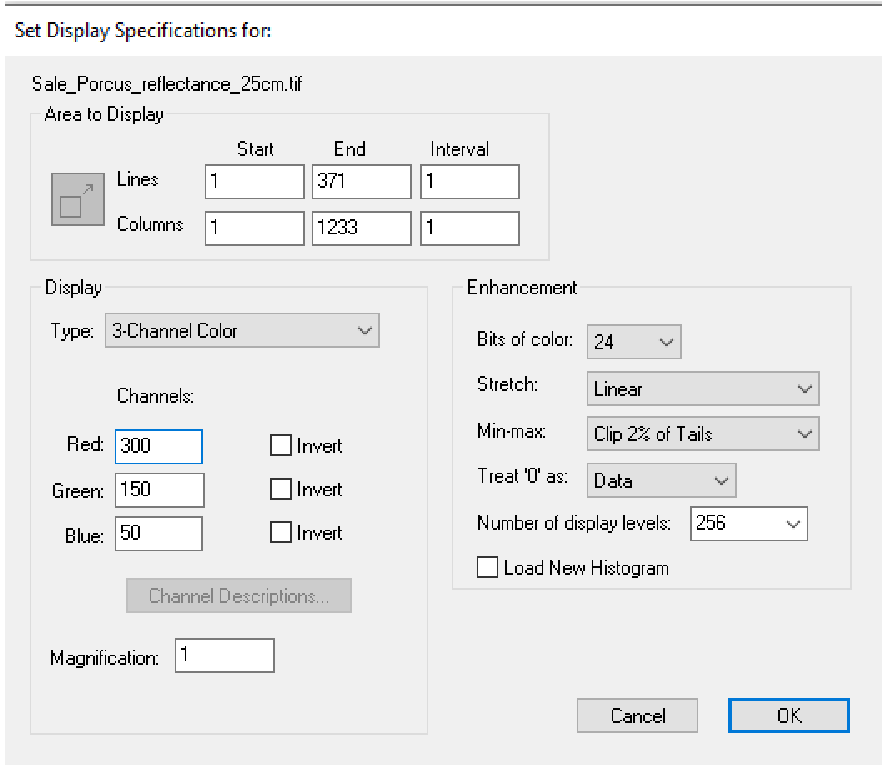
- Objects/surfaces have different combination of transmittance, absorbtion and reflectance in different bands of the spectrum

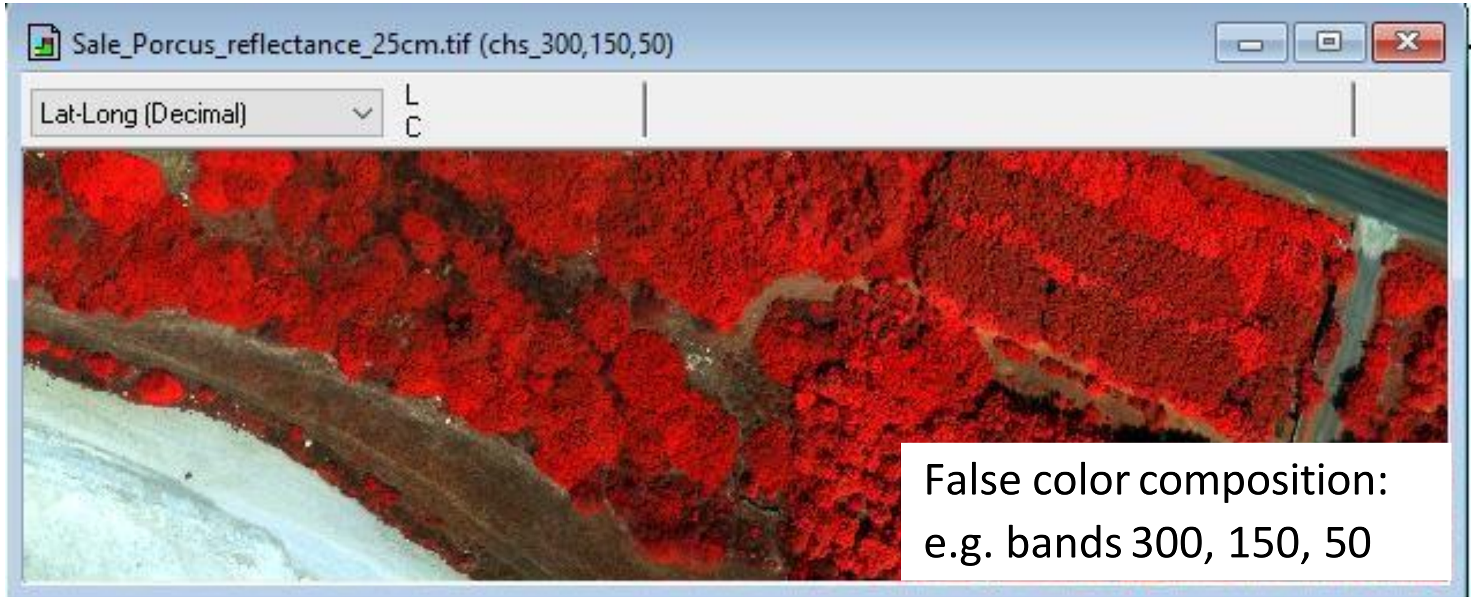


SPECTRA OF EARTH MATERIALS

1.) Data review:

File - Open Image - after selecting the file, a window called Set display specifications opens, which is used to set the visualization parameters of the selected file. In the Channels item, three bands can be selected, which will then be displayed in the form of a color composition (synthesis). It is also possible to edit the image by changing the settings in the Enhancement item.

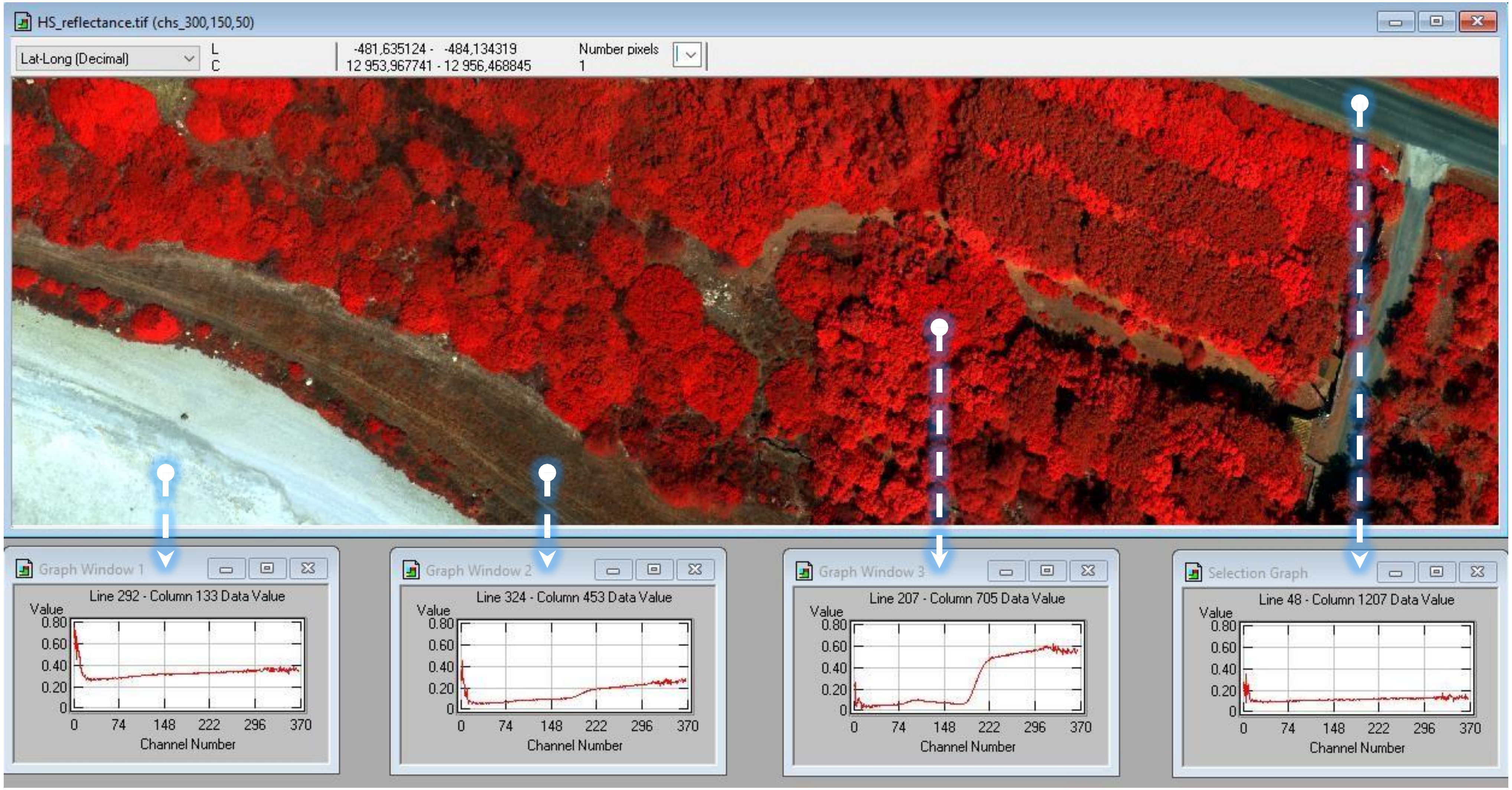




An example of displaying the false color composition using data from the HS scanner AISA KESTREL and the corresponding RGB bands of the scanner.

2.) Display of the spectral curves:

Window – New selection graph



MULTISPEC

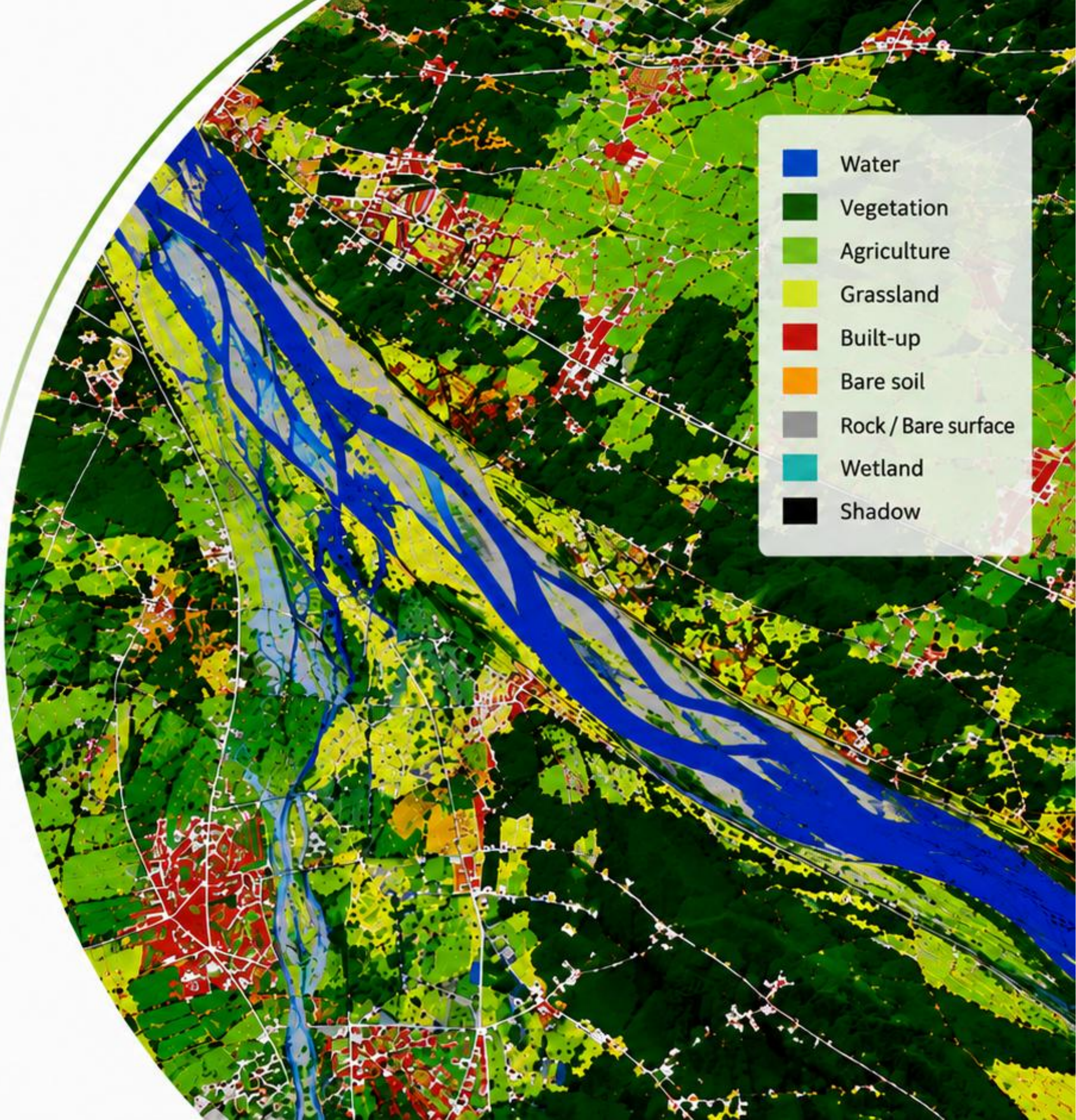
II. IMAGE CLASSIFICATION

Image classification

The process of sorting pixels into a certain number of classes based on their data values.

Finding meaningful patterns in the data (spectral and spatial).

Simplify and obtain the interpretation of the RS record



Two approaches

PIXEL-BASED (per-pixel)

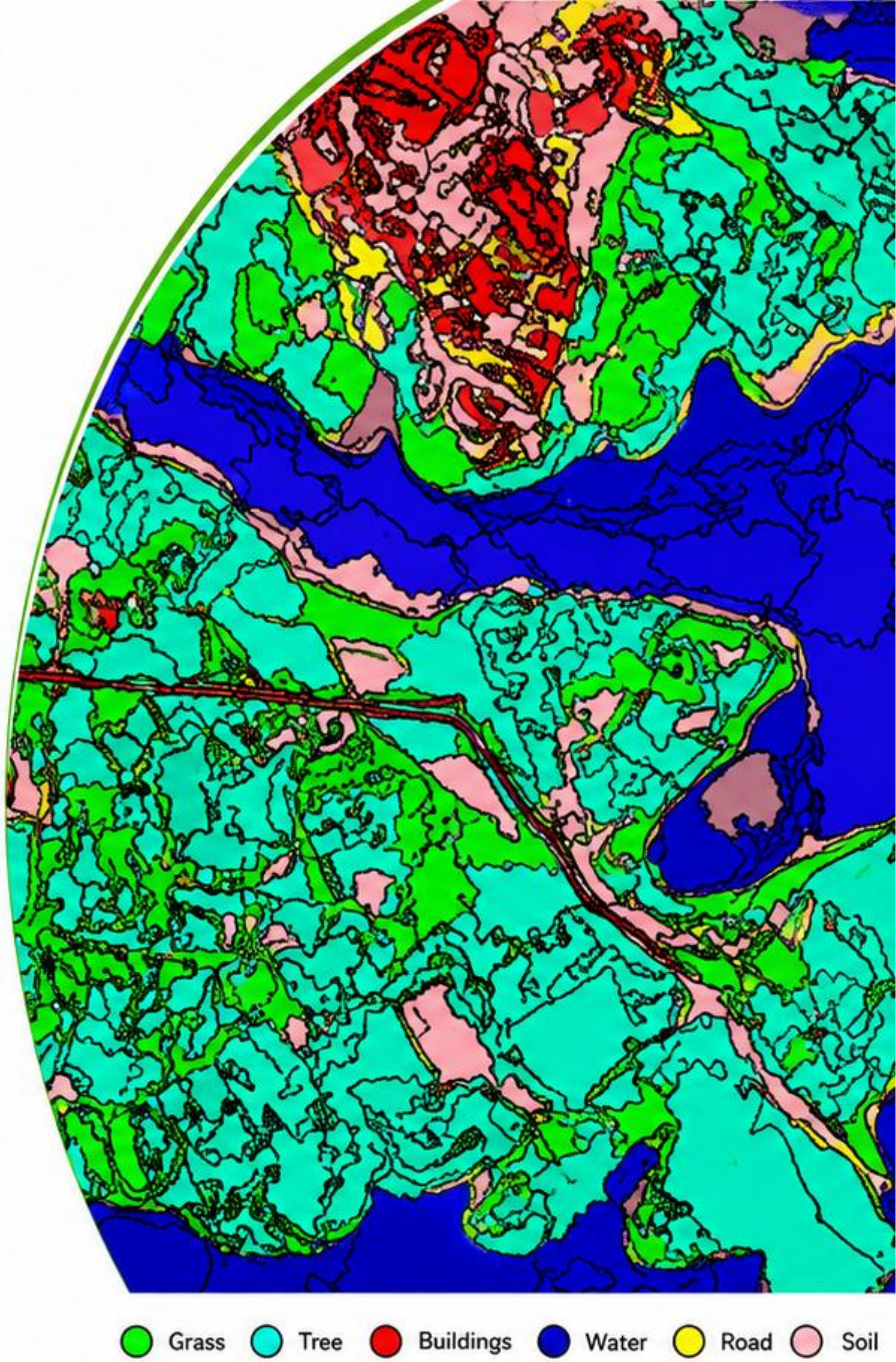
Uses only spectral information. Does not use spatial distribution or neighborhood relations.

Types:

- Supervised classification
- Unsupervised classification
- Based on a different rule

OBJECT-ORIENTED (OBIA)

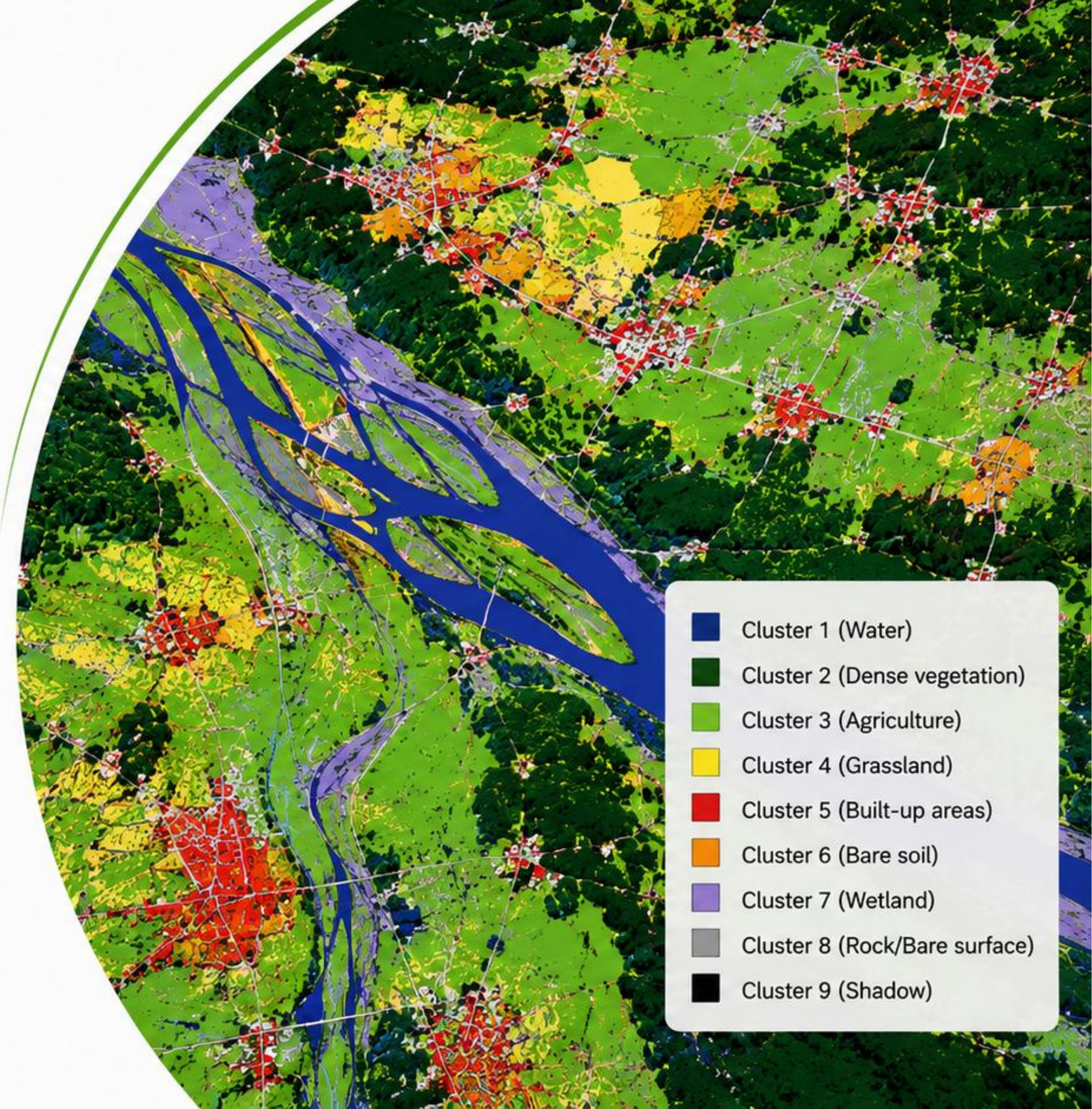
Uses both spectral information and its spatial distribution.



Unsupervised classification

The raw spectral data are grouped based on the statistical structure of the data only.

Then the computer assigns each statistical cluster into the appropriate class (if possible).

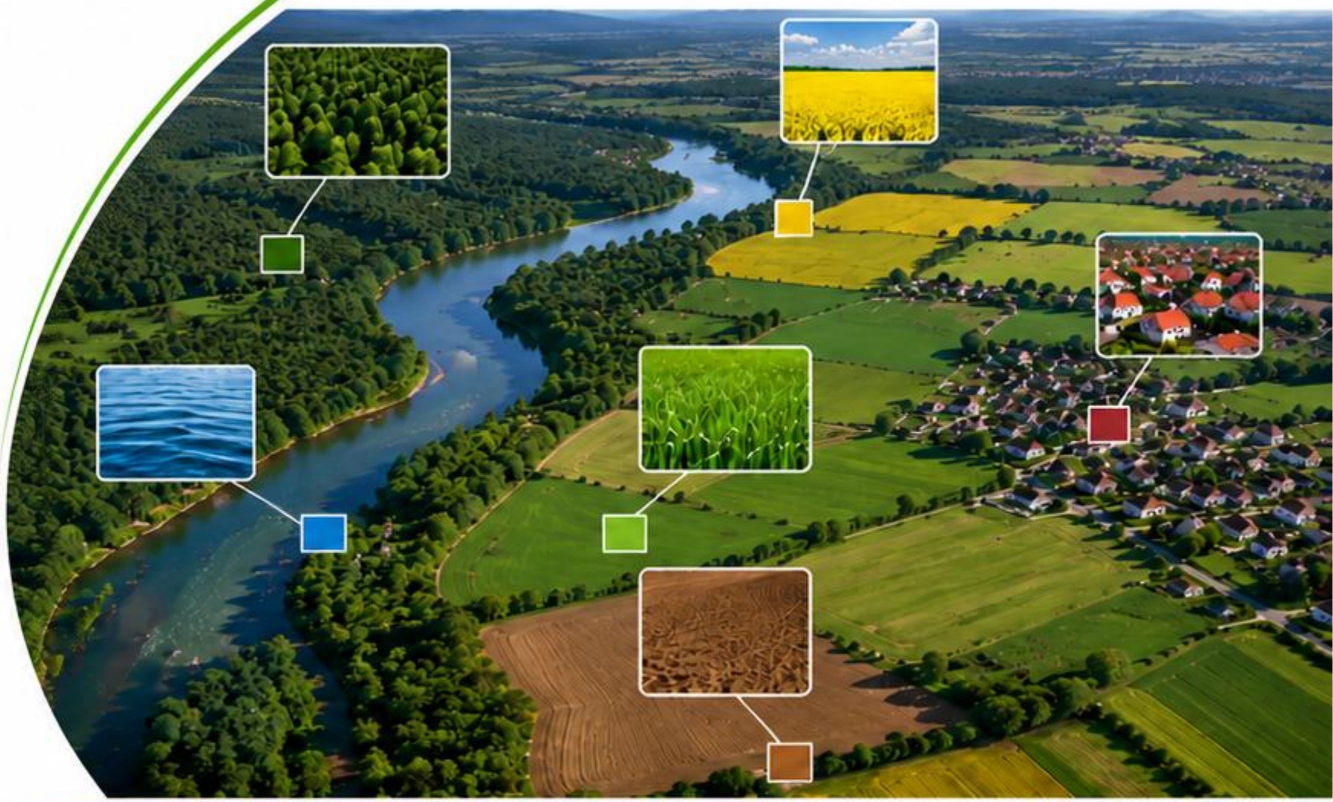


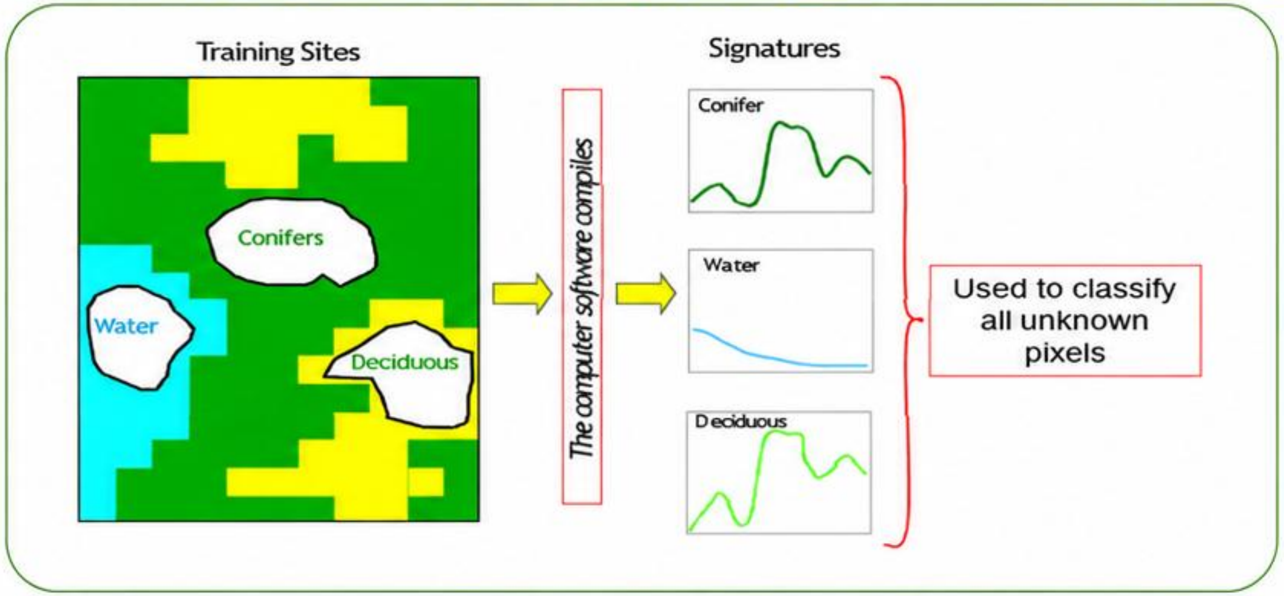
Supervised classification

The user defines homogeneous, representative samples, so-called **training samples (areas)** of different types of land cover

Based on the selected algorithm, the computer assigns the pixels to the **visually closest class** based on the training areas

Good knowledge of the classified area and good **visual interpretation** are ideal





Supervised classification – types

Minimum Distance-to-Means

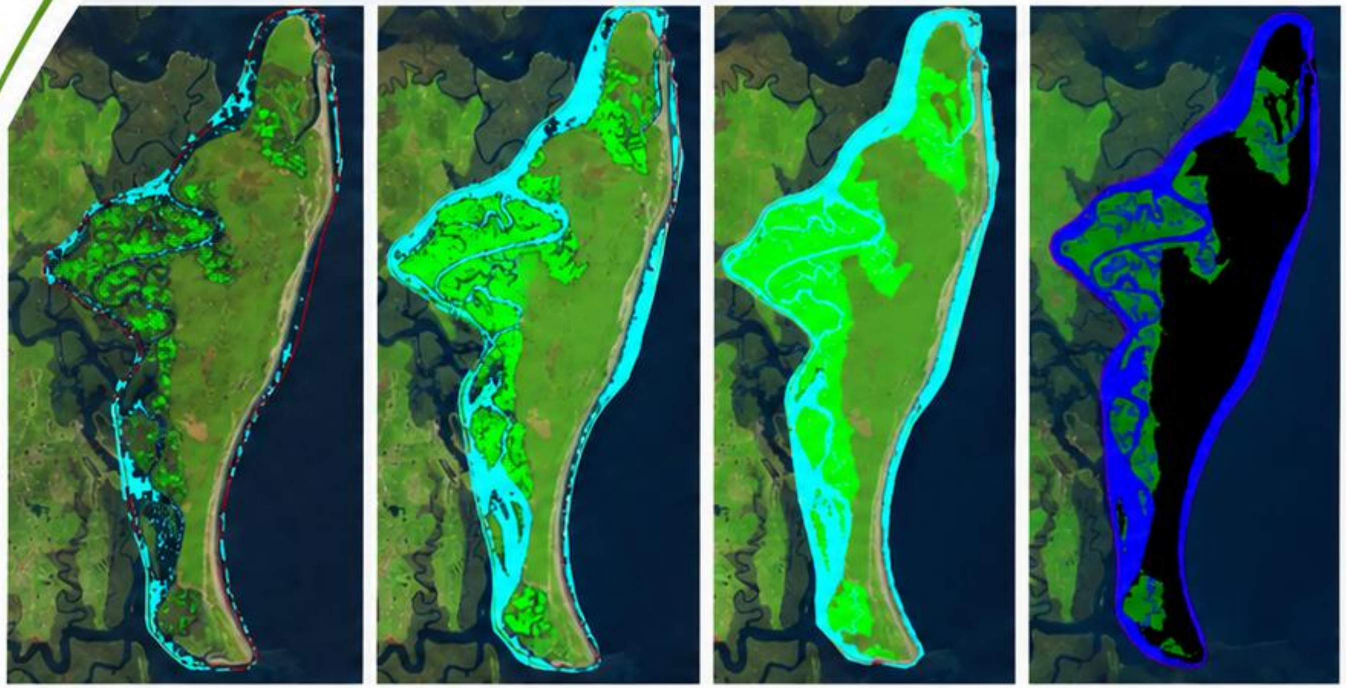
– average DN values

Maximum Likelihood

probability of class membership

Spectral Angle Mapper

the minimum angle from the n-dimensional spectral vector of the class



(a) (b) (c) (d)

Supervised classification schemes: Mahalanobis distance (a), spectral angle mapper (b), minimum distance (c), and maximum likelihood classification (d).

II.I

UNSUPERVISED CLASSIFICATION

MultiSpec

1. **Open image**

   File - Open Image

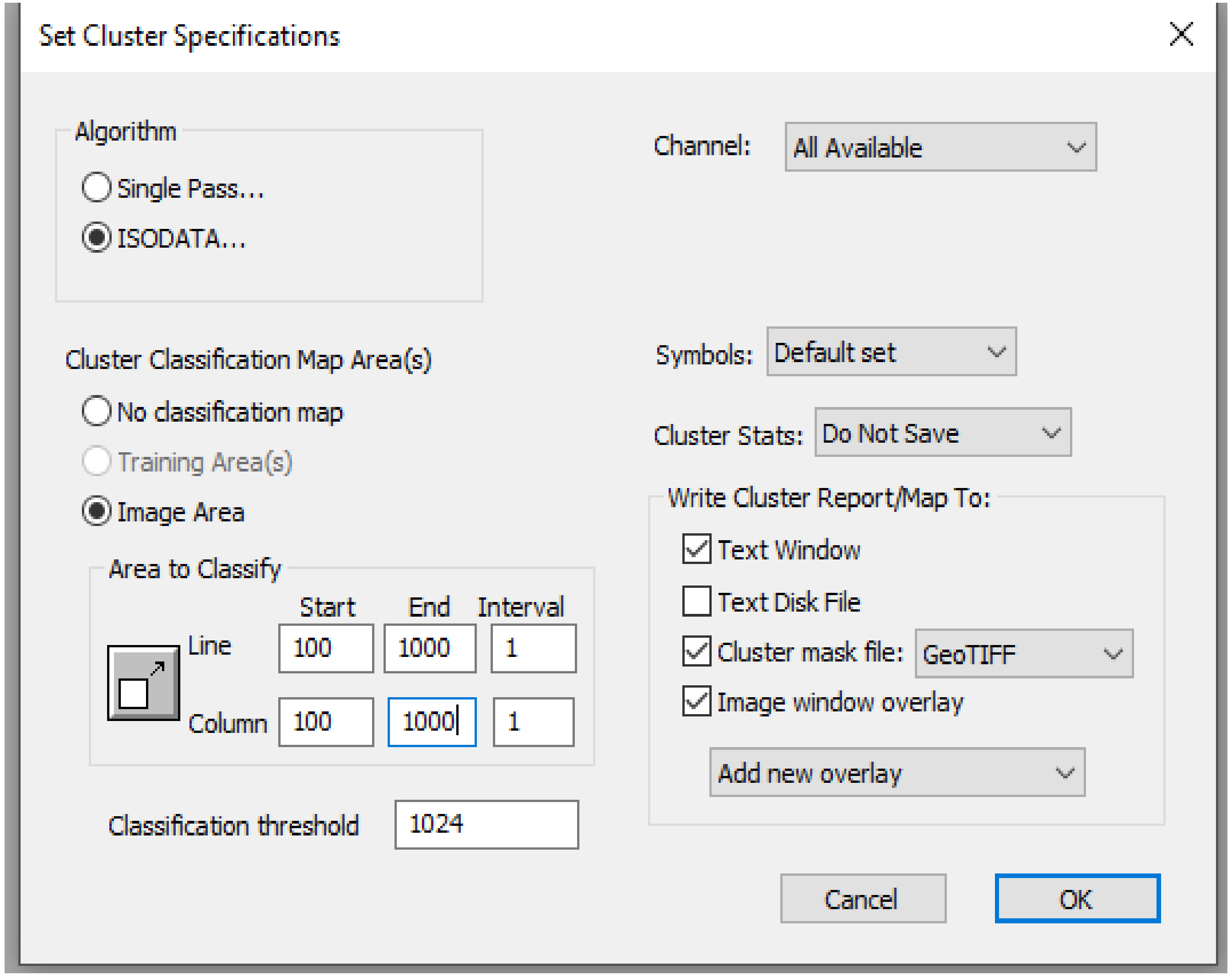
2. **Write Cluster Report/Map to**

   - *Cluster mask file*
   - *Image Window Overlay*

3. **Choose ussupervised classification algorithm:**

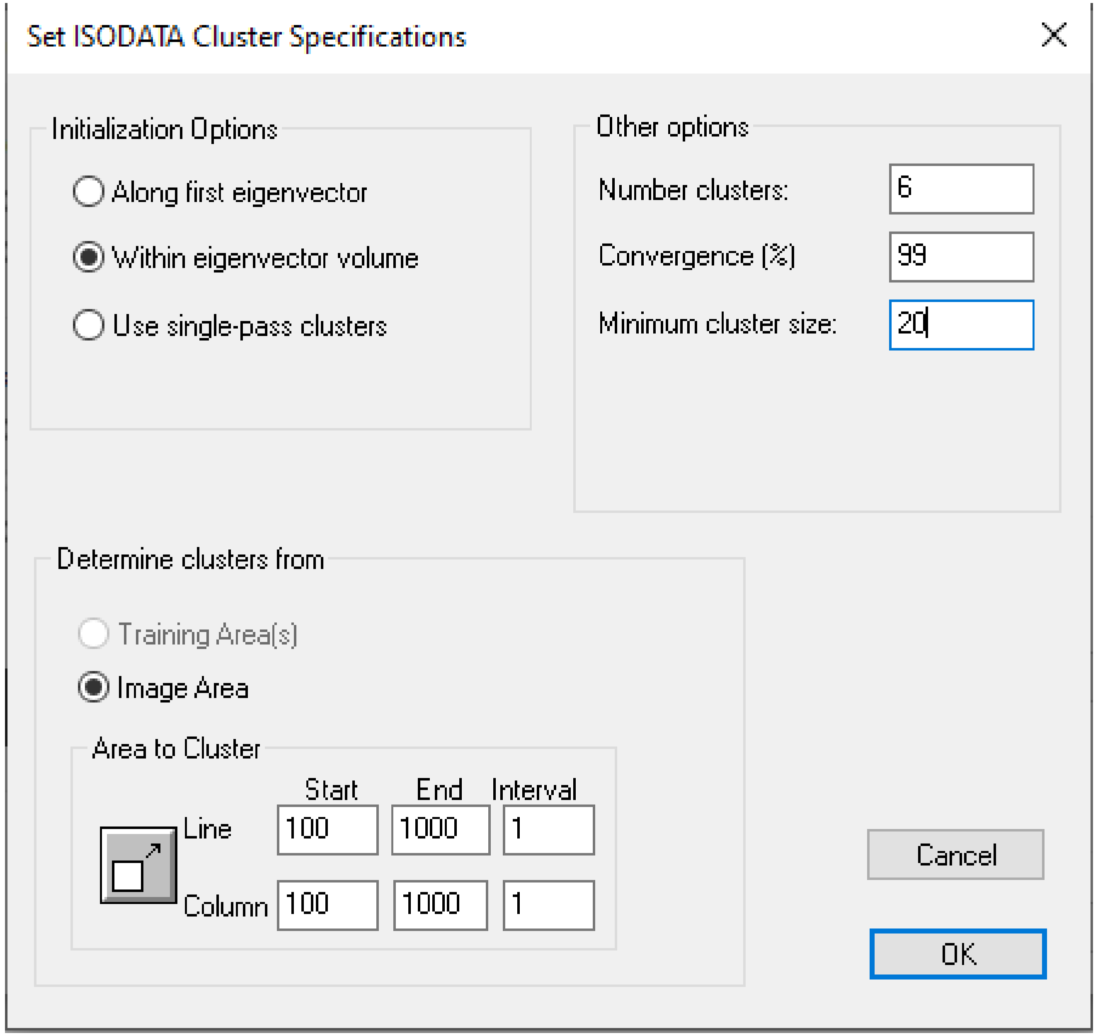
   Processor – Cluster – choose algoritm

   - ISODATA or Single pass



4. Set ISODATA Cluster specifications:

Compared to the Single pass algorithm, you can set the number of clusters (Number clusters) and, similarly to the previous case, the value of the minimum number of pixels forming a cluster (Minimum cluster size). The Convergence (%) parameter affects the number of successive repeated calculations of new cluster centers - iterations. If the number of pixels that do not change their belonging to a certain cluster during the iteration exceeds the specified value, then so-called clusters are created. stable and the calculation is finished.



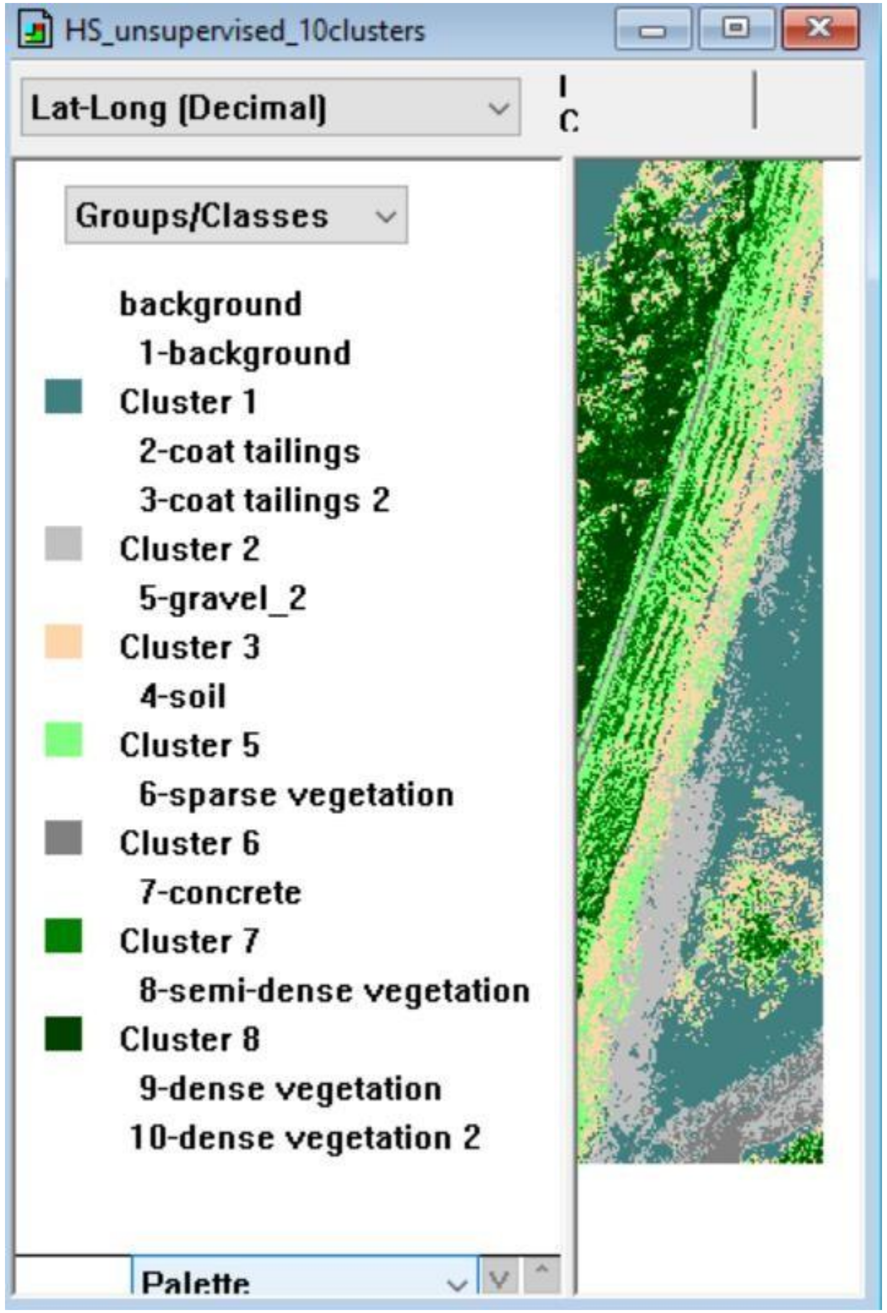
The method of cluster initialization, which you set in the upper left part of the window (Initialization options), is also important for the classification result. Here you determine how the initial positions of the clusters are to be established in the multidimensional space defined by the individual input bands. The first two options mean that the initial position of the clusters is determined by the principal component analysis method, the third option takes over the result of the single-pass algorithm

5. Editing the result of unsupervised classification

The clustering result is a thematic map stored in the ***.clu file**. In the text window of the Multispec program, you will also see the results of the classification in a clear tabular form. Above all, you will find here the resulting number of clusters and the number of pixels included in each of them. Open the saved classification file using the **File – Open Image menu.**

With a larger number of clusters and thus resulting spectral classes, the classified image is difficult to interpret. The colors of individual clusters in the image can be changed by double-clicking on the color icon next to the cluster so that they simulate the color presentation of the selected synthesis. This will make it much easier for you to interpret individual classes, recognize them, or eventually combine (aggregate) several spectral classes (clusters) into categories of basic types of surfaces.

Analogously, you change the name of individual classes by double clicking on the text next to the colored square of the legend.

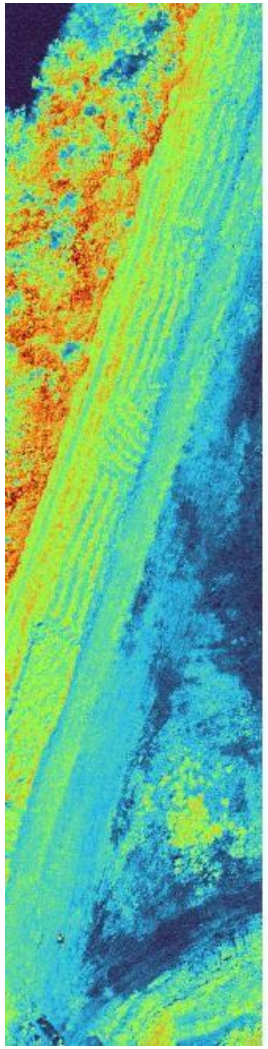


6. Repeat the process of unsupervised classification with stacked data – HS + CHM

HS data

+

LS data – CHM model



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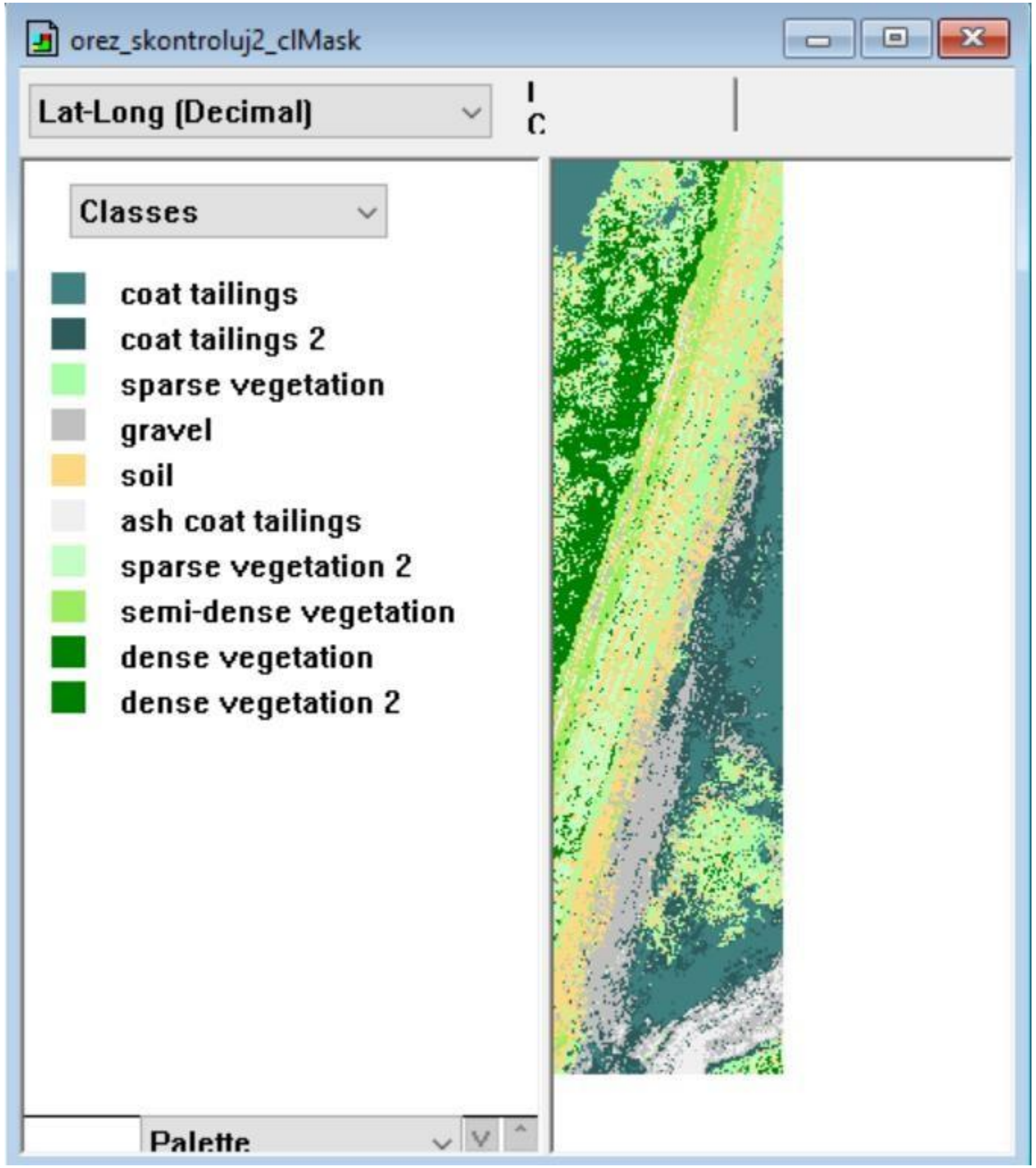


II.II

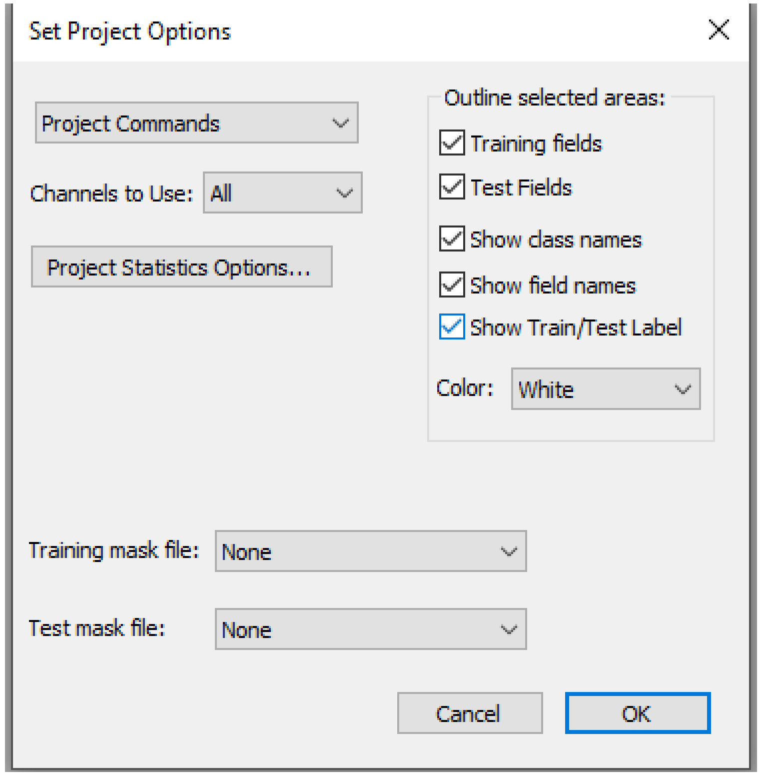
MultiSpec

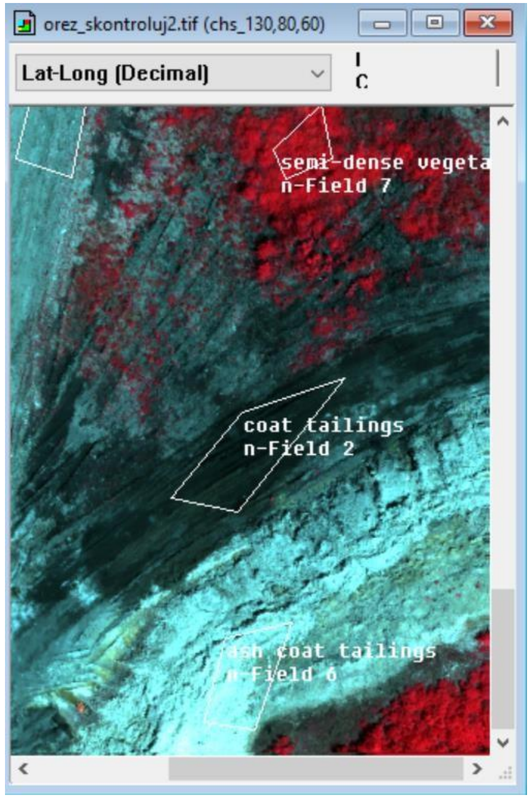
SUPERVISED CLASSIFICATION

1. File - Open Image

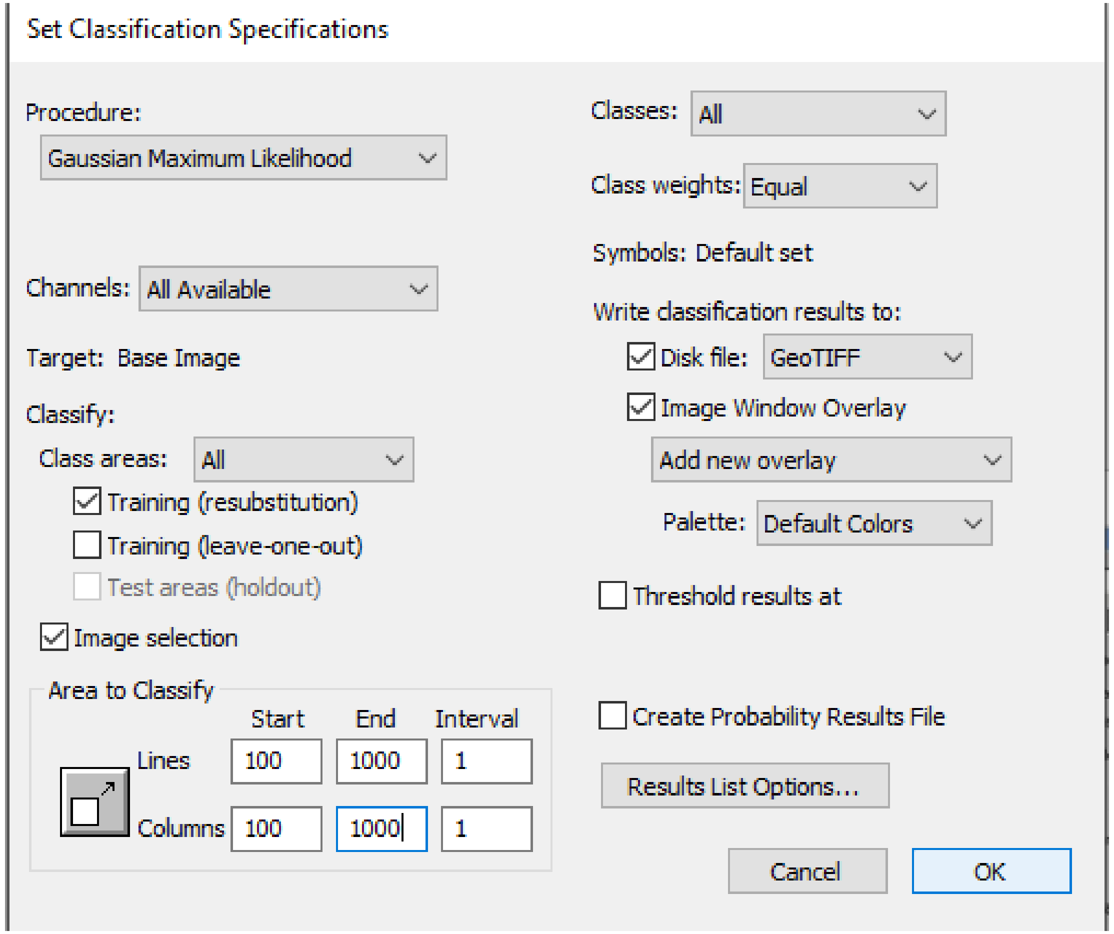
2. Create training samples (polygons) - ***Processor – Statistics ...*** Set Project Options.

In this window, check the item **Show Train/Test Label** and confirm the choice. A new window will open where you can check the **Polygon Enter** option to start creating a training sample for the corresponding land cover type. After creating a training sample (polygon), it is necessary to add the sample to the list via the Add To List option... Via the "New" Class option, we enter the name of the new class, into which other clicked training samples for the same type of land cover will be gradually included. If we want to add a polygon to an already existing class, from the Class drop-down menu we choose the corresponding, already created class, in which we want to include the sample.





- **3. Processor – Classify** opens a window called Set Classification Specifications. In this window, you can choose both the qualifier type (Procedure menu) and the selected input parameters of the selected procedure. Leave the default values of the parameters, but check the Disk file box, which will allow you to save the classification results in a new file of the type e.g. GeoTIFF to disk. You can also check the Image Window Overlay option to directly display the classification result in the MultiSpec window. Confirm the Update projectstatistics windowand save the output.

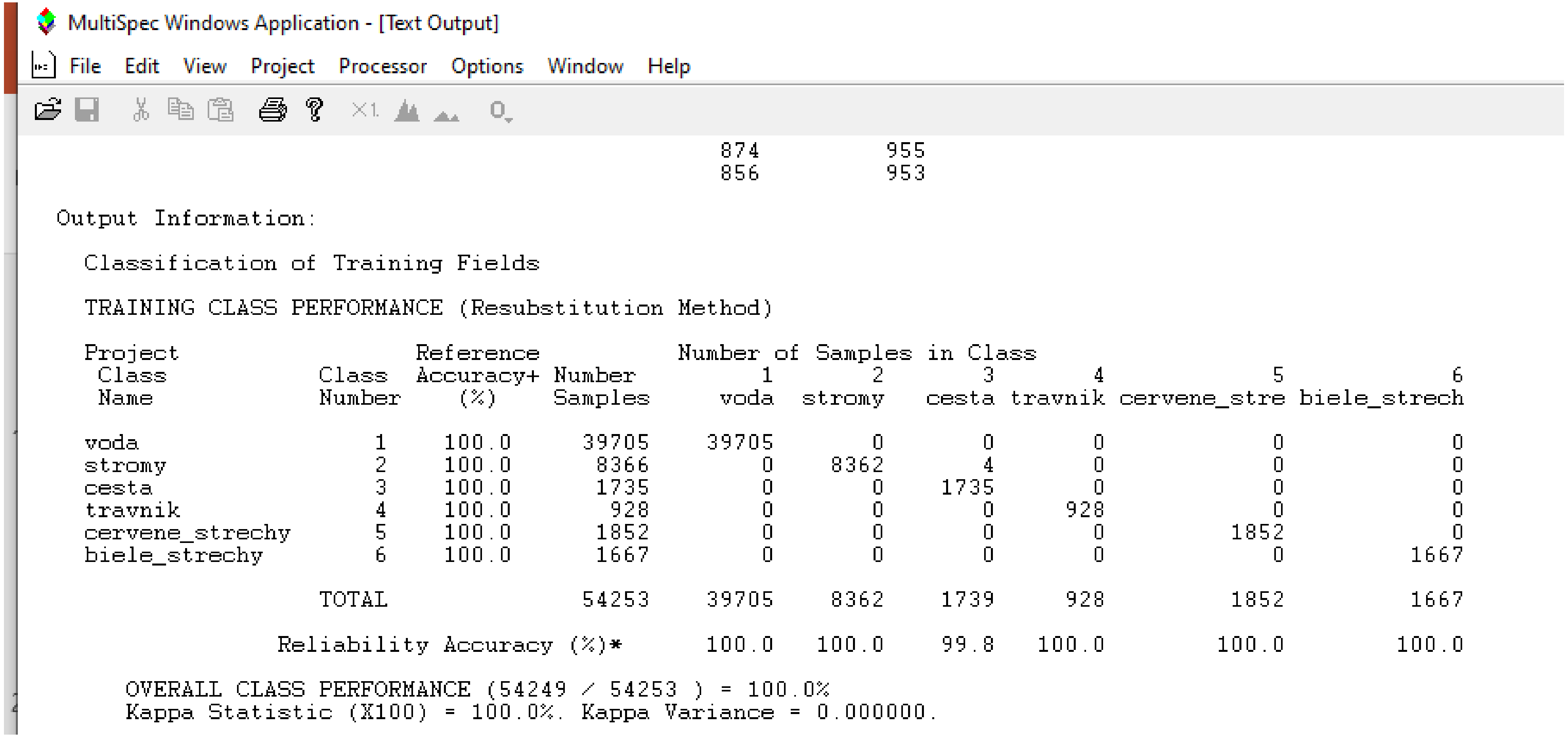


Classifiers that can be used for classification:

- *Maximum likelihood (maximum likelihood classifier - belongs to the most frequently used decision rules in controlled classification of satellite images and gives good results with suitable training areas*
- *Correlation (SAM) – classification of the so-called spectral angle, a decision rule originally used for hyperspectral image data...*

4. Evaluation of the result of supervised classification

-In addition to the file with classified data, the output of individual algorithms is also directed to the **text window** of the Multispec program. This window can be saved as a text file using the menu File - Save text output as...


MultiSpec Windows Application - [Text Output]

File Edit View Project Processor Options Window Help

874 955
856 953

Output Information:

Classification of Training Fields

TRAINING CLASS PERFORMANCE (Resubstitution Method)

Project Class Name	Class Number	Reference Accuracy+ (%)	Number Samples	Number of Samples in Class 1 voda	2 stromy	3 cesta	4 travnik	5 cervene_stre	6 biele_strech
voda	1	100.0	39705	39705	0	0	0	0	0
stromy	2	100.0	8366	0	8362	4	0	0	0
cesta	3	100.0	1735	0	0	1735	0	0	0
travnik	4	100.0	928	0	0	0	928	0	0
cervene_strechy	5	100.0	1852	0	0	0	0	1852	0
biele_strechy	6	100.0	1667	0	0	0	0	0	1667
	TOTAL		54253	39705	8362	1739	928	1852	1667
	Reliability Accuracy (%)*			100.0	100.0	99.8	100.0	100.0	100.0

OVERALL CLASS PERFORMANCE (54249 / 54253) = 100.0%
Kappa Statistic (X100) = 100.0%. Kappa Variance = 0.000000.

III

MultiSpec

PCA - Principal Component Analysis

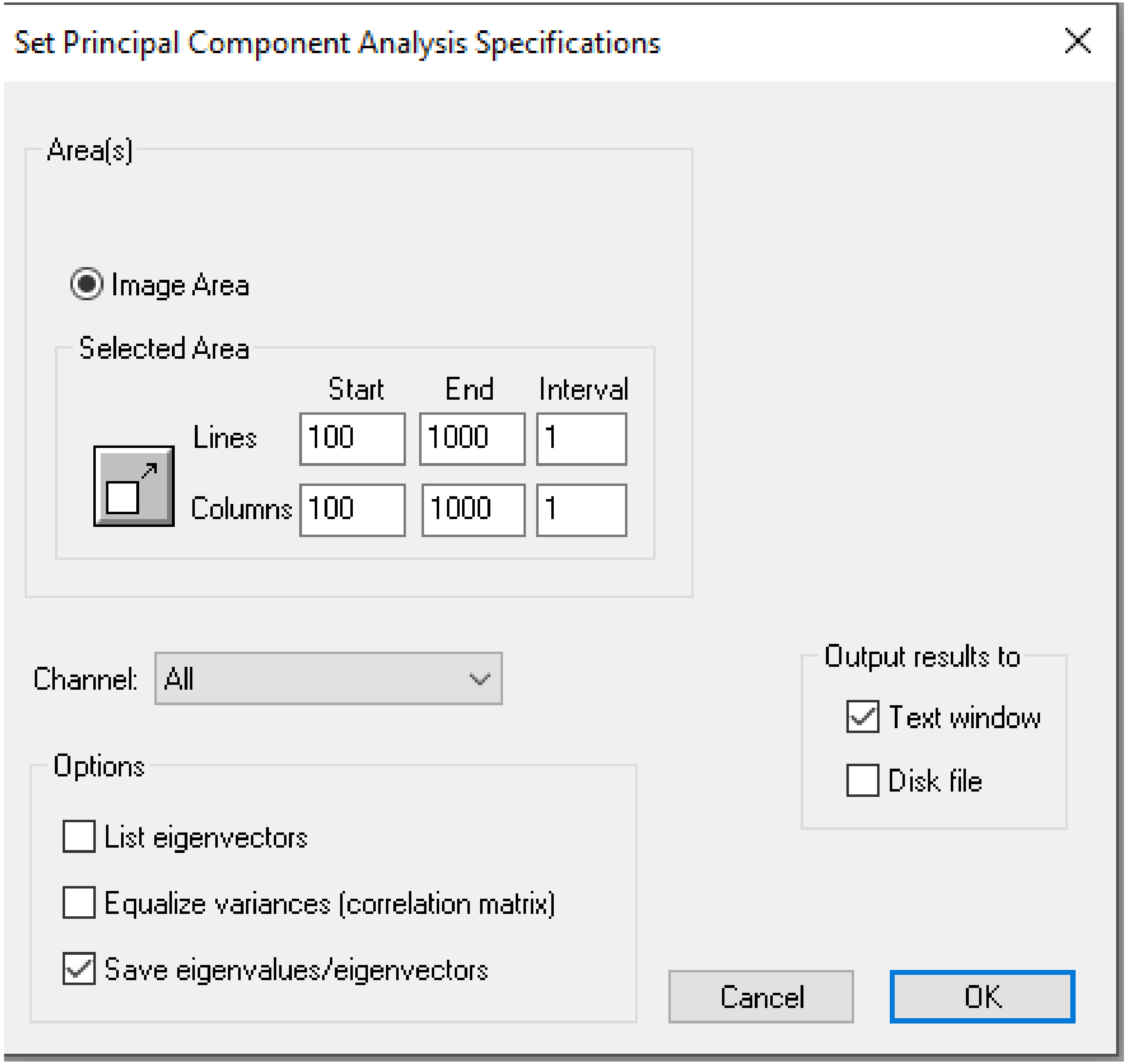
- Creating new variables/components that are a linear combination of the original variables without substantial loss of information

1.) Open image

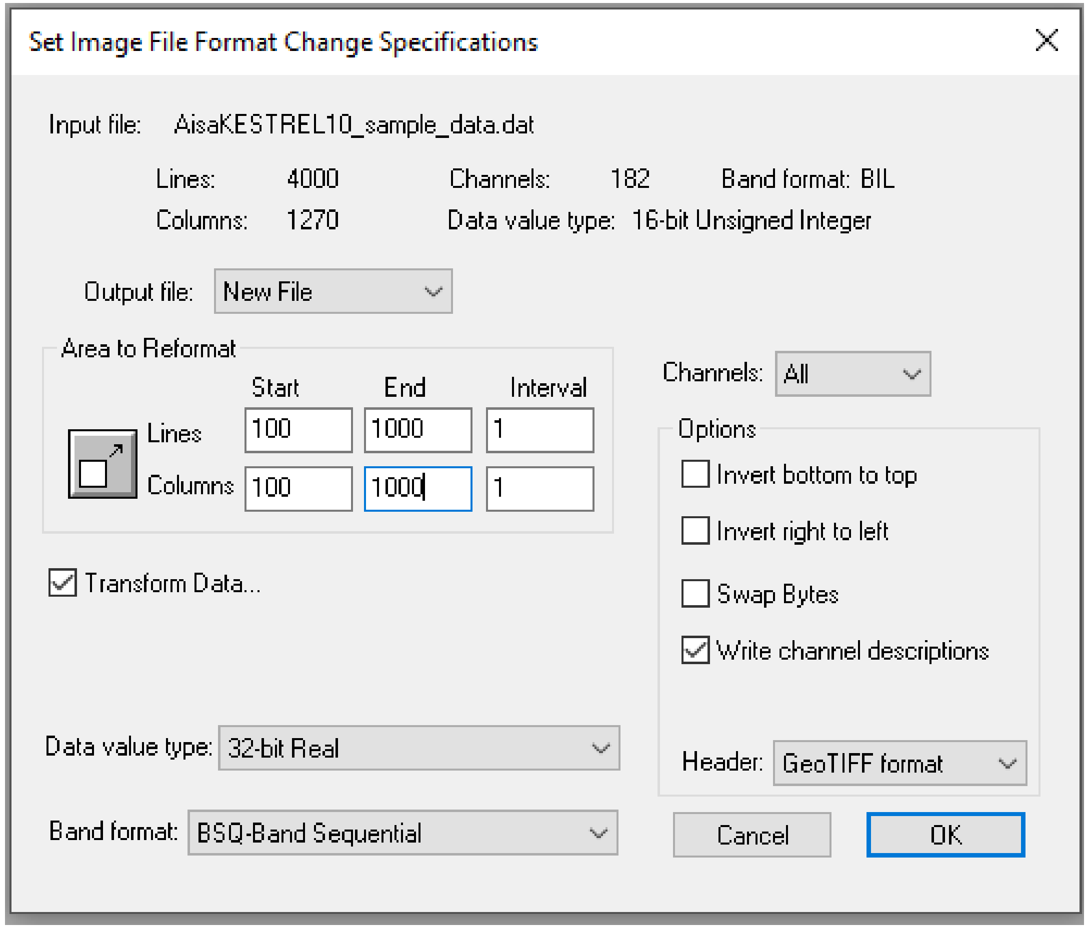
File - Open Image

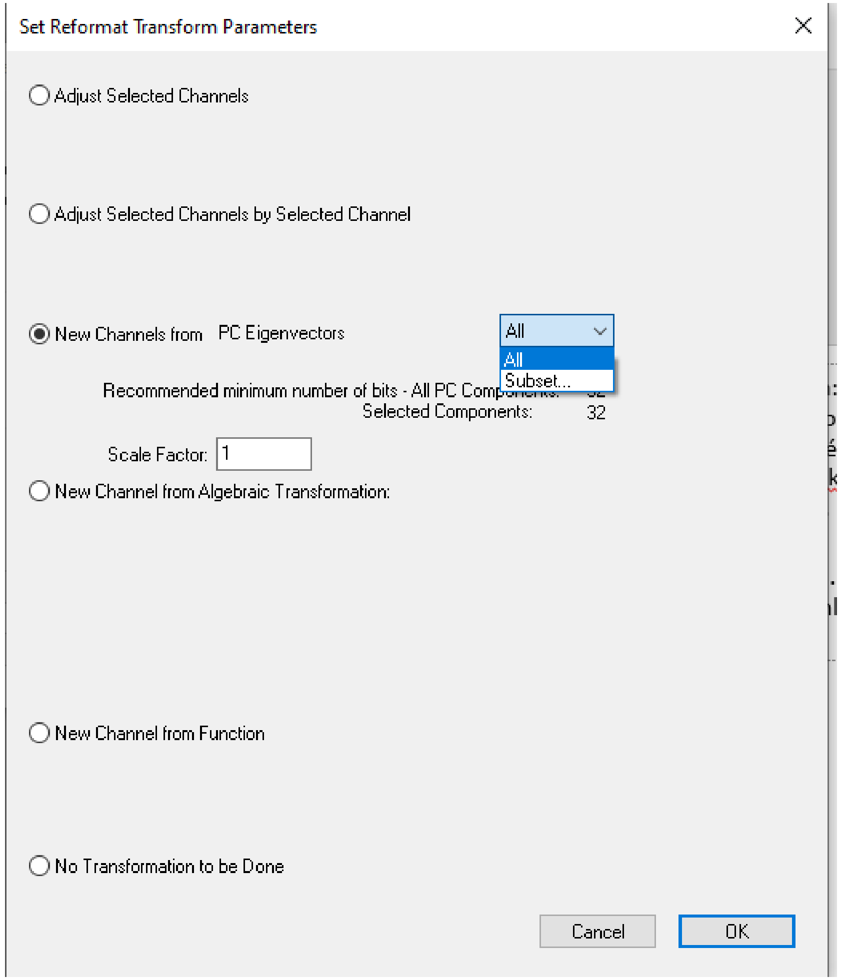
2. Transform the image using the method of principal components by selecting **Processor – Utilities – Principal Component Analysis**. In the window that opens, you can set parameters that define the range of input data. The analysis can include all or only some of the bands of the hyperspectral image (Subset), the entire range of rows and columns or only a part of them

3**. Save eigenvalues/eigenvectors** - that are used to calculate the so-called main components – mutually uncorrelated data transformed into a new space. Also check the option to save as text output (Note: do not check the option to save to Disk file!). The transformation matrix can also be saved to a file on disk by selecting File – Save Transformation Matrix. It is saved in the directory where the original data is located as a file with the same name as the original data with the ending *.TRA. The results of all calculations are also displayed in the text window of the program.

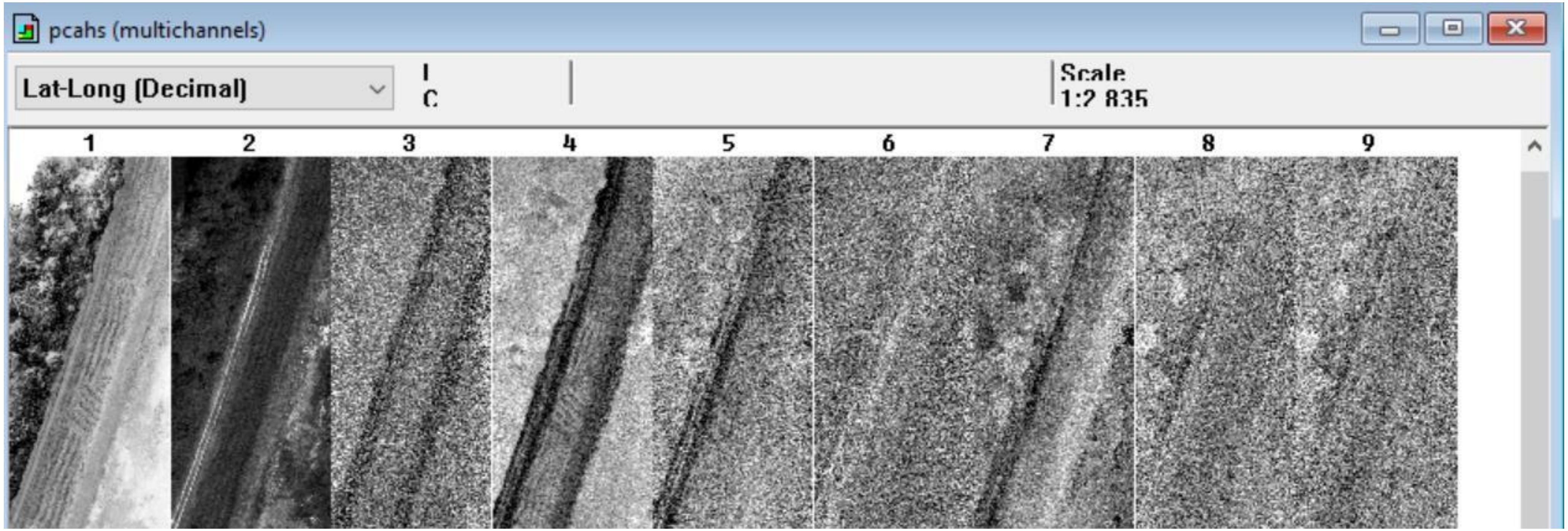


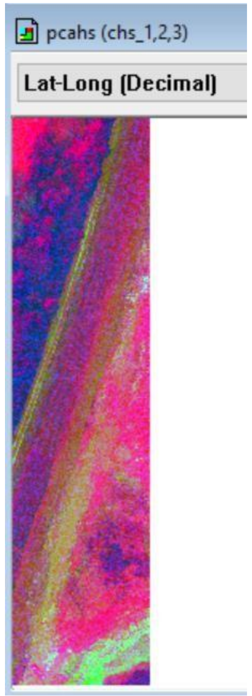
4. **Processor – Reformat – Change Image File Format**. In the window that appears, check Transform data and in the new window choose New Channels from PC Eigenvectors. You can select only a subset (if you want to use only certain/significant principal components that e.g. comprise more than 3% - you can find them in the text window) or all bands. Confirm the following two requests with the OK button. Subsequently, you are invited to save the image created by the analysisof the main components in a ***.LAN file**. Enter a file name and save it.





5. Next, you can view the transformed image. Choose File - Open Image. Select the resulting file of type *.LAN. In the Set Display Specifications for ... window, select Side by Side Channels as the Display type. This allows you to view the individual main components side by side in the form of grayscale images, as in the images below.





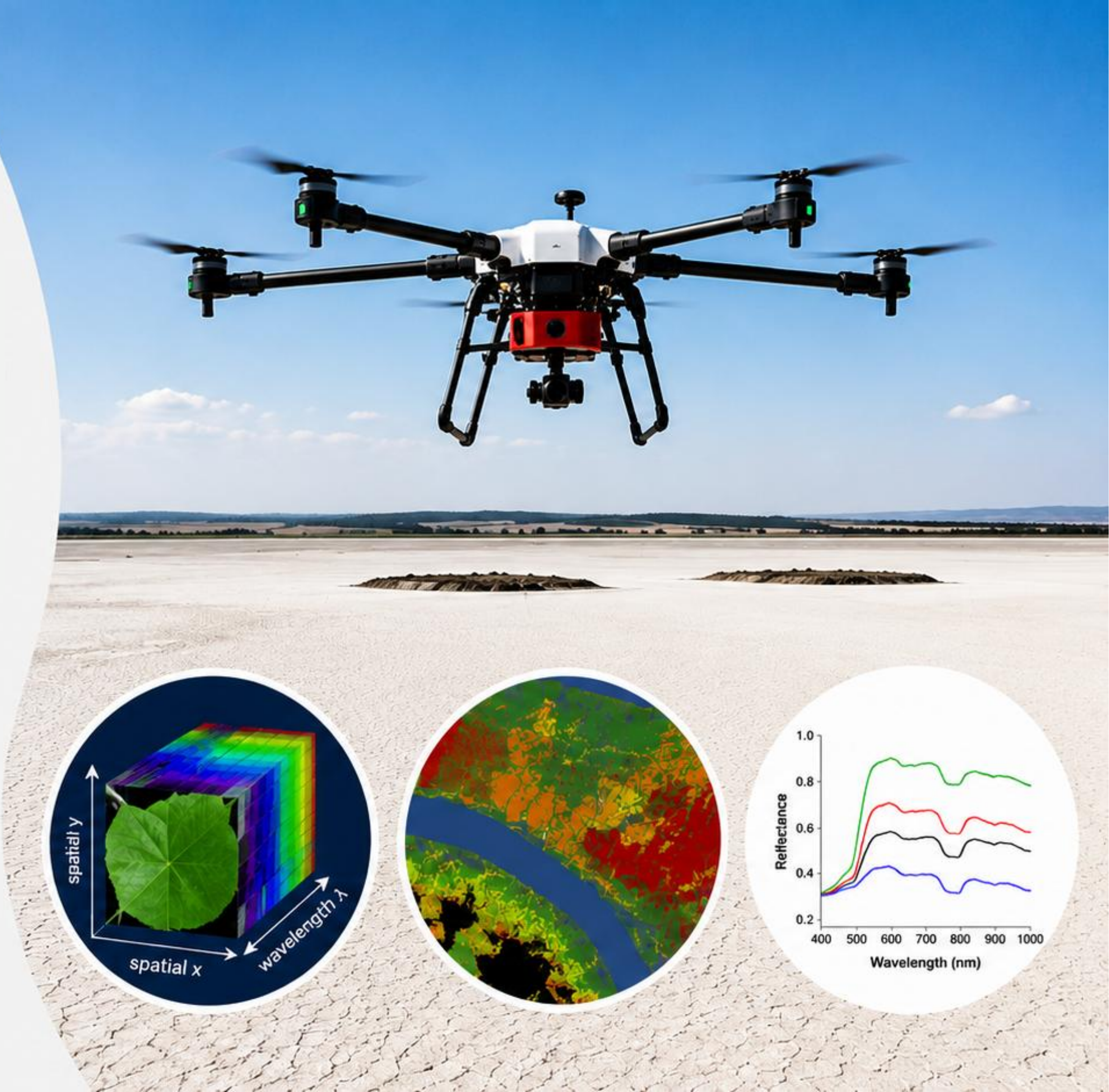
A sample of nine images transformed by the principal component analysis method from the AISA KESTREL bands. Notice the gradual loss of useful information, or noise increase in major components with higher numbers. PCA will therefore allow us to use instead of all bands after transformation for further work, such as to create a color composition, only a subset - the first e.g. three components that capture the largest part of the information, and we can neglect the remaining bands, as they include only a negligible part of the information. This will speed up e.g. subsequent creation of image classification.

CONCLUSION

- UAV hyperspectral remote sensing provides **detailed spectral and spatial information** for a wide range of applications.
- **Proper processing** of hyperspectral data – from acquisition to analysis – is essential to obtain reliable results.
- **Spectral signatures analysis** helps to understand the spectral behavior of different materials and their variability.
- Image classification using HS data and its **fusion with LiDAR CHM** improves the ability to discriminate and map land cover / vegetation.
- **PCA** is a powerful tool for data exploration, interpretation and dimensionality reduction.

THANK YOU

for your attention !



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